

The general equilibrium effects of fiscal policy: estimates for the euro area

Lorenzo Forni Libero Monteforte Luca Sessa

BANCA D'ITALIA, RESEARCH DEPARTMENT*

First version: January 2006

This version: April 11, 2007

Abstract

This paper lays down a dynamic stochastic general equilibrium model with a fraction of non-Ricardian agents with the aim of estimating with Bayesian techniques the effects of fiscal policy in the euro area. A newly computed quarterly data set for fiscal variables is used. Our results show that innovations in fiscal policy variables tend to be very persistent. Despite this persistence, government spending in goods and services and in compensation for public employees have rather small and short lived expansionary effects on private consumption; slightly more sizable and lasting is the effect of innovations to transfers to households. Among revenues, decreases in labor income and consumption taxes have a sizable effect on consumption and output, while reductions in capital income taxes favor 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.

*lorenzo.forni@bancaditalia.it; libero.monteforte@bancaditalia.it; luca.sessa@bancaditalia.it. We benefited from comments by Alberto Alesina, Silvia Ardagna, Susanto Basu, Fabio Canova, Marco Del Negro, Rochelle Edge, Nicola Fuchs-Schündeln, Jordi Galí, Teresa Garcia-Milá, Peter Ireland, Greg Mankiw, Domenico J. Marchetti, Roberto Perotti, Pedro Teles and seminar participants at Harvard, Banca d'Italia, Bocconi, University of Bologna, CEF 2006 in Cyprus, EEA-ESEM 2006 in Vienna, Central Bank Workshop on Macroeconomic Modeling 2006 in Santiago de Chile, and Fiscal Stabilization Policies in a Monetary Union Conference at DG-Ecfin in Brussels. We thank all members of the Banca d'Italia Research Dept. DSGE working group: in particular, for their help with techniques and codes we specially thank Andrea Gerali, Claudia Miani, and Stefano Neri. A previous version of this paper was circulated under the title: "The estimated general equilibrium effects of fiscal policy: the case of the euro area". The usual disclaimers apply.

1 Introduction

This paper reconsiders the economic effects of fiscal policy using an estimated new-keynesian dynamic stochastic general equilibrium model for the euro area. We try to better understand how these effects depend on the composition of expenditures and on how taxes are levied, 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 government 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 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 wages tend to grow, while the response of private investment is generally negative.²

The new-keynesian paradigm, which adds frictions and price stickiness to an intertemporal optimizing framework, displays the same wealth-effect mechanism that

¹Among the others, Perotti (2005) supports this view. His sample is based on 5 OECD countries (USA, Germany, UK, Canada and Australia) and covers the period 1960-2000. Moreover, Galí *et al.* (2007) provide an extensive review of the literature on the topic.

²On the response of employment and real wages, see for an analysis on US data Pappa (2005). 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, in Germany.

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 schedule 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 rational and rule-of-thumb agents (who 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 *et al.* (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}

In this paper we take this idea to the data and contribute to the debate on the macroeconomic effects of fiscal policy using an estimated general equilibrium model.

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

⁴As 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."

⁵GLSV pg. 260.

⁶As another alternative to a model with a representative infinitely-lived rational agent, Romanov (2003), Sala (2004) and Cavallo (2005), among others, consider agents with a finite horizon by introducing a constant probability of dying *à la* Blanchard (1985). The idea is that, although government expenditure increases will increase the level of expected future taxes, agents - while fully benefiting from the expansion in expenditure - will not likely live long enough to pay their entire share of the financing. Since the keynesian effect of expenditure shocks depend essentially on the probability of dying before paying taxes and this probability (or share of the population) is reasonably small over the short to medium term, these models cannot match the positive response of private consumption after a government spending shock.

In order to do so, we take the model considered by Christiano *et al.* (2005) that Smets-Wouters (2003, henceforth SW) proved to match euro area data in a satisfactory way, and add to it rule-of-thumb agents and a relatively rich framework for fiscal policy.

As 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 have computed average effective tax rates on labor income, capital income and consumption on a quarterly basis for the euro area following the methodology of Mendoza *et al.* (1994).⁷

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 (NA) data, includes both purchases and compensations for government employees, as early recognized by Rotemberg-Woodford (1992) and more recently by Finn (1998). Actually, 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 is around 60% on average. While government purchases of goods and services is a component of aggregate demand, compensations for government employees affect the economy mainly through their effects 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 starting from 1980.⁸

Our results show that innovations in fiscal policy variables tend to be very persistent. Notwithstanding this persistence, government spending in goods and services and in compensation for public employees have rather small and short lived expansionary effects on private consumption; slightly more sizable and lasting is the effect of innovations to transfers to households. Among revenues, decreases in labor income and consumption taxes have a sizable effect on consumption and output, while reductions in capital income taxes favor investment and output in the medium run. Finally, with the exception of transfers to households and labor income tax rates, most fiscal policy

⁷Appendix 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.

⁸CS have performed a similar exercise using data for the euro area from the Area Wide Model of the ECB, but they do not include fiscal variables other than government consumption (the only variable available from official sources at a quarterly frequency). Their main result is that the estimated mean share of rule-of-thumb consumers is small (around 1/4) and unable to deliver a positive response of private consumption to a government expenditure shock.

variables contribute little to the cyclical variability of the main macro variables.

The paper is organized as follows. Section 2 describes in detail the model and our assumptions regarding fiscal and monetary policies. Section 3 sketches the techniques we use to solve and to estimate the model, describing in particular the data and the assumptions regarding priors 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 policy, 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, who do not have access to financial or capital markets. Asset markets (not modelled) are assumed to be complete. Ricardian households are the only asset-owners, including capital, which is rented to firms. Households have separable preferences over consumption and leisure, with external habit formation in consumption.

Non-Ricardian households have been modelled in various ways in the literature, leading to different responses of their consumption to 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.⁹ Other authors have made assumptions implying stronger responses of non-Ricardian agents' consumption to variations in disposable income. In particular, GLSV - following Campbell-Mankiw (1989) - assume that 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 they are wage setters for their own type of labor 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 the

⁹However, 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.

labor of the two groups is perfectly substitutable and therefore that both types of agents receive the same wage and work the same amount of hours.

In this paper we will follow this latter approach. In particular we assume that Ricardian households have a monopoly power in the labor market, supplying a differentiated labor service that is sold to a competitive firm (a labor packer). In setting their wage households face a quadratic adjustment cost as in Kim (2000). Non-Ricardian households simply set their wage rate equal to the average wage of Ricardian ones. Since all households face the same labor demand, each non-Ricardian household will work the same number of hours as the average Ricardian one.¹⁰

A perfectly competitive firm transforms differentiated labor into an homogeneous labor input. This is sold to the final sector firms that combine it with capital rented from Ricardian households to produce the final good. Firms are monopolistically competitive and produce differentiated goods. In setting their prices they also face a quadratic adjustment cost. All firms share the same Cobb-Douglas technology. In the following we present the details of the model. The first order conditions and the corresponding log-linearizations that we use to solve the model are reported in Appendixes A and C.

2.1 Consumers Problem

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

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

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

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

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

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

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.

¹⁰Erceg *et al.* (2005), in an analysis of US external balance, make the same assumption.

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 $\tilde{P}_t = P_t/(1 + \tau^c)$.

2.1.1 Ricardian households

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

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

Ricardian households have group-specific external habits in consumption with parameter $h \in [0, 1]$: c^R is 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:

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

where $(1 - \tau_t^w) w_t(i) l_t^R(i)$ is his net labor income, $(1 - \tau_t^k) R_t^k \bar{k}_t^R(i) u_t(i)$ is net nominal income from renting capital services $k_t^R = \bar{k}_t^R u_t$ (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 $\tilde{P}_t$ and the consumers one $P_t = (1 + \tau_t^c) \tilde{P}_t$. 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 $\tilde{P}_t$. 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 $P_t I_t^R$ and compensate it with a rebate equal to $\frac{\tau_t^c}{1 + \tau_t^c} P_t I_t^R$, so that the difference between the two is equal to the actual expenditure on investment goods $\tilde{P}_t I_t^R$. 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 $\psi(u_t)\bar{k}_t^R$ denotes the cost (in terms of consumption units) associated with the utilization level u_t .

The physical capital accumulation law is

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

where not all new investment gets transformed into capital and the term $s \left(\frac{\varepsilon_t^i I_t^R(i)}{I_{t-1}^R(i)} \right) I_t^R(i)$ 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 .¹¹ Investment and capital are expressed in units of the consumption good.

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:

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

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:

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

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

¹¹As in Christiano *et al.* (2005), $s(\cdot)$ has the general properties $s(1) = s'(1) = 0$ and $s''(1) > 0$

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

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

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

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

$$MC_t = \zeta W_t^{1-\alpha} R_t^k \alpha \varepsilon_t^z \alpha^{-1} . \quad (11)$$

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

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

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

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

We assume that the wage rate in the public sector is equal to the one prevailing in the private sector.¹² In fact, in our setup, hours can be moved costlessly across the two

¹²This 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.

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 (2005), 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:

$$\begin{aligned} \max_{l_t^p(i)} l_t^p &= \left[\int_0^1 l_t^p(i)^{\frac{\theta_L-1}{\theta_L}} di \right]^{\frac{\theta_L}{\theta_L-1}} \\ \text{s.t.} \quad &\int_0^1 w_t(i) l_t^p(i) di = \bar{E}_t \end{aligned} \quad (14)$$

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

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

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

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

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 they cover the period starting from 1999, 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. As we have computed quarterly data for government purchases of good and services, employment, transfer to families, total revenues and tax rates, we are

able to model with more detail than previous work the role of the fiscal policy. In particular, we consider the following budget constraint:

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

where B_{t+1} indicates one period nominal bonds, C_t^g is nominal government purchases of goods and services, $W_t l_t^g$ 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:

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

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

$$\tau_t^w = \rho_{\tau^w} \tau_{t-1}^w + (1 - \rho_{\tau^w}) [\tau^w + \eta_{\tau^w} (b_t - b)] + \varepsilon_t^{\tau^w} \quad (18)$$

$$\tau_t^c = \rho_{\tau^c} \tau_{t-1}^c + (1 - \rho_{\tau^c}) [\tau^c + \eta_{\tau^c} (b_t - b)] + \varepsilon_t^{\tau^c} \quad (19)$$

$$\tau_t^k = \rho_{\tau^k} \tau_{t-1}^k + (1 - \rho_{\tau^k}) [\tau^k + \eta_{\tau^k} (b_t - b)] + \varepsilon_t^{\tau^k} \quad (20)$$

where $b_t = \log(B_t/P_t)$, τ_t are log tax rates, b and τ are steady state values and $\varepsilon_t^{\tau^w}$, $\varepsilon_t^{\tau^c}$ and $\varepsilon_t^{\tau^k}$ are i.i.d..

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 :

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

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

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, we assume $C^g = 10\%$ of output and $B = 60\%$ 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 values, the steady state value for transfers is set in order 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 model we assume that taxes are set in order to keep real debt dynamics under control. This is consistent with the general consensus that debt stabilization is an important motive in the conduct of fiscal policy. Moreover, our results do not depend in any significant way on whether or not we use as a measure of debt the real debt or to the debt/output ratio. However, debt stabilization 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 run some experiments augmenting our policies with the gap of output from its steady state value. The estimates show that the coefficients relating tax rates to the output gap are hardly identified and in general too small to affect significantly the results.¹³ We have also experimented adding measures of expenditures (transfers, government consumption of good and services, government wage bill) in the tax rates equations and found that the corresponding coefficients in the tax rules 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. As a matter of fact, these latter expenditures are generally referred to as automatic stabilizers. The inclusion of measures of economic activity in the process describing expenditure 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 the deviation of output and of private employment from their own steady state values. Our results are hardly changed by this extension. In particular, the estimated response of transfers to both measures of gap is relatively minor 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

¹³There 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. 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).

innovations, that is 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, one may argue 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.

2.5 Monetary policy

The monetary policy specification follows SW and assumes that the central bank follows an interest rate feedback rule *à la* Taylor characterized by a response of the nominal rate R_t to deviations from steady state values of lagged inflation π_{t-1} , contemporaneous output, y_t , changes in inflation, $\Delta\pi_t = (\pi_t - \pi_{t-1})$, and output growth, $\Delta y_t = (y_t - y_{t-1})$:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R) [\pi + \rho_\pi (\pi_{t-1} - \pi) + \rho_y (y_t - \bar{y})] + \rho_{\Delta\pi} \Delta\pi_t + \rho_{\Delta y} \Delta y_t + \varepsilon_t^m \quad (23)$$

The parameter ρ_R captures the degree of interest rate smoothing. The monetary policy shock ε_t^m is assumed to be i.i.d. with standard deviation σ_{ε^m} .¹⁴

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:

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

¹⁴In new-keynesian models with non Ricardian agents the *Taylor principle* (that prescribes $\rho_\pi > 1$ in order to have determinacy) might not hold. For example, Bilbiie (2005) argues 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 Galì *et al.* (2004, 2007) show that, when both the 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 (2005) and Galì *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.

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

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

Equilibrium in the goods market requires:

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

where ADJ stands for adjustment costs which, in real terms, are given by

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

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

$$\begin{aligned} k_t &= \left(\frac{W_t}{R_t^k} \frac{\alpha}{1 - \alpha} \right)^{1-\alpha} \varepsilon_t^z \alpha^{-1} y_t \\ l_t^p &= \left(\frac{W_t}{R_t^k} \frac{\alpha}{1 - \alpha} \right)^{-\alpha} \varepsilon_t^z \alpha^{-1} y_t \end{aligned} \quad (26)$$

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

$$AE_t(x_{t+1}) = Bx_t + Cz_t \quad (27)$$

$$E_t(z_{t+1}) = Sz_t \quad (28)$$

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 solution takes the following state-space representation:

$$\begin{aligned} K_{t+1} &= MK_t + Nz_t \\ Y_t &= PK_t + Qz_t \end{aligned}$$

where K_t and Y_t contain the predetermined and non-predetermined variables in the model, respectively.

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-Hasting algorithm.¹⁵

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,

¹⁵The mode and the Hessian of the posterior distribution, the latter evaluated at the mode, are used to initialize the Metropolis-Hasting algorithm. The mode is computed using both a simplex algorithm (fminsearch in Matlab) and the csmmwel function proposed by Sims. The latter function computes also an estimate of the Hessian.

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 the sample mean. As for the inflation rate we fit a linear spline for inflation until 1999:Q1 and assume a 2% target for annual inflation thereafter. The trend for the interest rate is assumed to be equal to the trend 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 1.

As for the prior distributions, 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. 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 approximately from 10% to 50%.

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 a very robust, although counter intuitive, result of their estimated model 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 , equal to 100. Given mean values for the other parameters, this assumption corresponds approximately to an adjustment frequency of five quarters for both wages and prices¹⁶ (approximately the frequency at

¹⁶The mapping between cost of adjustment parameters and adjustment frequency can be obtained

which the median firm changes its prices in the euro area according to the evidence on firms pricing behavior 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 is chosen so to span approximately from less than one fifth to more than double the mean frequency of adjustment. 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

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

with steady state value ε and i.i.d. error term η . 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

The estimates are obtained from the Metropolis-Hastings algorithm with one million iterations and prior distributions as described in table 1. The number of iterations seems to be sufficient to achieve convergence (as measured by the cumulated mean and

comparing coefficients in the respective expectational Phillips curves, as sketched in Corsetti *et al.* (2005).

standard deviation of the parameters). Figure 4 plots prior and posterior distributions for a selection of parameters.¹⁷

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 the investment adjustment cost, s'' , for the monetary response to inflation, ρ_π , and to a certain degree for 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 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 an 8 quarters price duration, i.e. lower than in the other two 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. On the fiscal side, tax rate processes appear to be very highly persistent, although the reaction to debt

¹⁷The percentage of accepted draws is 26%. Since we initialize the MH with the mode and the 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 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, does not imply any correlation among parameters higher than 0.8 and the likelihood at the mode shows a significant curvature for all parameters. This latter result, in particular, is evidence of the fact that the data contain useful information to identify the parameters.

is quite sizeable and large enough to be stabilizing. The autoregressive parameter for government purchases, public employment and transfers to households are estimated at around 0.96, a level similar to the one estimated for government consumption by SW and CS.

5 General equilibrium effects of fiscal policy

5.1 Government spending shocks

We now discuss the implications of our estimates on the effects of government spending shocks on the economy. Figure 5 shows impulse responses with respect to a shock to real government purchases c_t^g , figure 6 with respect to a shock to government employment l_t^g , while figure 7 with respect to real transfers tr_t . 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).¹⁸ 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 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 taxes minus the response of output is approximately equal to the response of total tax revenues/output ratio). The bottom right panel of each picture reports the path of the shock.

We can immediately observe that all three shocks increase private consumption and employment. The shock to spending does that by increasing the demand for goods and services which, in turn, brings about an increase in employment, labor income and consumption. The shock to transfers directly increases disposable income and consumption of non-Ricardians and therefore total consumption and output, which translates into an increase in employment. The shock to government employment increases labor demand and determines an increase in both total employment and real wages, and thus in labor income of both Ricardian and non-Ricardian households. With respect to a c_t^g shock, the l_t^g shock has a greater effect on impact on private consumption but lower on output, as the hiring from the government crowds out employment in the

¹⁸In 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.

private sector (in figure 6 we show the responses of both total and private sector employment). Finally, the shock to transfers to households has the biggest impact on consumption as it translates one to one into an increase in disposable income of non-Ricardians.

These estimated responses are consistent with a new-keynesian framework but not with a RBC style model. Not only the positive response of private consumption following an expenditure shock is inconsistent with the RBC framework, but also the (mild) increase in real wages after a shocks to c_t^g , as the wealth effect should bring about an increase in employment that in turn should imply a decrease in the marginal productivity of labor and in real wages. An increase in real wage is therefore possible only if there is an increase in labor demand. Finally, private employment increases on impact after a government employment shock, although mildly, reflecting the keynesian effect on labor demand via 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 government expenditures cannot compensate for the increase in public employment, so that private sector employment decreases on impact. The increase in private sector employment is due to a contemporaneous increase in labor demand. 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 8-10 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, together with the decrease in labor taxes, brings about an increase in non-Ricardian disposable income and consumption, which further reinforces the increase in output. The positive effect on employment and output of a decrease in labor income taxes is greater the higher is the share of non-Ricardian households.

The decrease in capital income taxes (slightly less than 3 percentage points) leads on impact to a reallocation from labor to capital. The initial decrease in employment reduces non-Ricardian labor income and therefore aggregate consumption (and inflation). Over time, however, the capital stock builds up, leading also employment back towards its steady state value. In the case of changes in capital income taxes, there-

fore, the presence of non-Ricardian consumers has a stabilizing effect on output. In fact, the expansive effect (on 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 an annual terms) that brings about an increase in real interest rate. As regards real variables, as expected, private consumption, in particular non-Ricardians' one, increases. Agents face a less expensive consumption right after the decrease in the tax, while as the tax rate comes back to its steady state level, it becomes progressively more expensive. Therefore they front load consumption decisions, shifting away resources also from investment (that is, from future consumption).

5.3 Fiscal multipliers

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

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 smaller. 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 consumption or labor taxes.

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

The effects on prices are generally mild, with the notable exception of changes to consumption taxes (as the change translates almost one to one to prices).

These results are broadly in line with available empirical evidence, coming from

both standard macroeconomic models and VAR analysis. Both these classes of models are not microfounded at all (VAR) or not in the same way as in the DSGE literature. In addition simulation exercises run with macroeconomic models usually assume as exogenous the path of certain variables, as the interest rates or the fiscal variables itself. This obviously complicates the comparison with our results. Moreover, analysis with both econometric models and VAR focus on a small set of variables. For example Henry *et al.* (2004) compare the responses in terms of output and inflation obtained from a selection of 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. 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 (that is, taxes net of transfers to households). These definitions are different from ours, therefore any quantitative comparison with his work would not be appropriate.

As reported by Henry *et al.* (2004), the effect of an increase of purchases of good and services equal to 1% of GDP in the first year 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 year obtained from the AWM are 1.04 and 1.53. As for prices, the effect on inflation in the first year for the Deutsche 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 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 shock to indirect tax rates.¹⁹ 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 are these quantitative effects to the specific parameters values, in figures 11-16 we plot the average response in the first year of output, consumption and investment to each of our six fiscal shocks, moving one important

¹⁹Personal income taxes, in fact, include both taxes on 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 look at the cost of labor (w , that includes all social security contributions) while workers at the take home pay ($w(1 - \tau^w)$, that is net of all social security contributions and labor income taxes).

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_g , ρ_{tr} and ρ_{lg} depending on the shock), the debt coefficient in the labor income tax rule ($\eta_{\tau w}$) and the inflation coefficient in the Taylor rule (ρ_π). For example, in figure 11 top left panel we plot the average first year response of output, consumption and private investment to a government purchases shock equal to 1% of output allowing the parameter γ to move between 0 and 1, while leaving the other parameters unchanged.

Regarding the expenditures shocks we note that the results are most sensitive to γ and the autoregressive coefficients. A positive response of private consumption obtains only for shares of non-Ricardian higher than about 20% following shocks to purchases and government employment. On the other hand, as expected, the responses are heavily affected by the value of the persistence parameter of the expenditures shock, in particular for high values of these parameters. The decrease in consumption for very high values of this parameter reflects the sizable negative wealth effect due to the very high persistence on Ricardian agents' consumption.

As for taxes, labor income tax shocks seems to be 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). In interpreting the results of this robustness exercise, however, we should keep in mind that some parameters, like h , have a relevant effect on the steady state. Thus, since we calibrate our shocks with respect to the steady state levels of the variables, different steady states may correspond to different absolute sizes of the changes in tax rates.

Finally, we briefly comment on the contribution of each of the structural fiscal shocks to the forecast error variance decomposition of the endogenous variables at various horizon (at the first, fourth quarter and asymptotically; see table 3). Focusing on the long term horizon we see that government purchases and employment shocks do not explain a significant fraction of the variance of any of the macro variables considered. Among expenditures, only transfers do have a role 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 the fiscal shocks - in partially driving some macro variables (in particular private consumption) is mainly related with their effects on disposable income of non-Ricardian consumers

and the role of the latter in affecting the variability of total consumption and inflation.

6 Interaction of fiscal and monetary policy

Perotti (2005), in the context of VAR analysis, has argued that controlling for monetary policy is not very important when estimating the effects of fiscal policy on output. In our estimated model 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.²⁰ However, since our parameter estimates imply that a 1% increase in the short-term real rate has an impact on the consumption of Ricardians of 0.1% and the size of the responses of the real rate of interest is in the range from -0.3 to 0.6 (with the exception of consumption taxes), our estimates suggest that 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 in order to see whether or not our results change. In our baseline model we maintained the Taylor rule with interest rate smoothing used by SW, specified in terms of (deviations from their steady state values of) lagged inflation and contemporaneous output and their contemporaneous first differences: monetary policy reacts to the output gap, defined as a statistically computed measure 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 when experimenting with the indicated alternative Taylor rule specifications, 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.

²⁰On this issue, see for example Canova-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 shocks. 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 with 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 show that innovations in fiscal policy variables tend to be very persistent. Despite this persistence, government spending in goods and services and in compensation for public employees have rather small and short lived expansionary effects on private consumption; slightly more sizable and lasting is the effect of innovations to transfers to households. Among revenues, decreases in labor income and consumption taxes have a sizable effect on consumption and output, while reductions in capital income taxes favor 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 be missing some effects coming from the external channel. Coenen *et al.* (2007) have shown - in a calibrated two country model with non-Ricardian households, but with lump sum taxes and no government employment - that the negative wealth effect of Ricardian households due to a government spending shock might be dampened, although not eliminated, by the possibility for these households to borrow abroad. Therefore, it could well be the case that our results in favor of (moderate) keynesian effects would be strengthened in an open economy setting. This, however, is a topic for future research.

References

- [1] Barbone, L., G. Bodo and I. Visco (1981), Costi e profitti nell'industria in senso stretto: un'analisi su serie trimestrali, 1970-1980, *Bank of Italy Economic Bulletin*, No. 36.
- [2] Baxter M. and R.G. King (1993), Fiscal Policy in General Equilibrium, *American Economic Review*, Vol. 83 No. 3, 315-334.
- [3] Benigno P. and M. Woodford (2006), Optimal Inflation Targeting Under Alternative Fiscal Regimes, NBER Working Paper No. 12158.
- [4] Blanchard O. (1985), Debt, Deficits, and Finite Horizons, *Journal of Political Economy*, Vol. 93 No. 2.
- [5] Blanchard O. and R. Perotti (2002), An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output, *Quarterly Journal of Economics*, November.
- [6] Campbell J.Y. and G. Mankiw (1989), Consumption, Income and Interest Rate: Reinterpreting the Time Series Evidence, in O.J. Blanchard and S. Fisher eds., *NBER Macroeconomics Annual* 1989, MIT Press.
- [7] Canova F. (2005), Monetary Policy and the Evolution of US Economy, mimeo.
- [8] Canova F. and E. Pappa (2005), Price Dispersions in Monetary Unions: The Role of Fiscal Shocks, *Economic Journal*, forthcoming.
- [9] Carey D. and J. Rabesona (2002), Tax Ratios on Labour and Capital Income and Consumption, *OECD Economic Studies*, Vol. 35 No. 2, pp. 129-174.
- [10] Cavallo M. (2005), Government Consumption Expenditures and the Current Account, Federal Reserve of San Francisco Working Paper 2005-03.
- [11] Chow G.C. and A.L. Lin (1971), Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series, *The Review of Economics and Statistics*, Vol. 53.
- [12] Christiano, L.J., M. Eichenbaum and L.E. Evans (2005), Nominal Rigidities and the Dynamic Effect of a Shock to Monetary Policy, *Journal of Political Economy*, Vol. 113, No. 1.

- [13] Coenen G. and R. Straub (2005), Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area, *International Finance*, Vol. 8.
- [14] Coenen, G., P. McAdam and R. Straub (2007), Tax Reform and Labour-Market Performance in the Euro Area: A Simulation-Based Analysis Using the New Area-Wide Model, *Journal of Economic Dynamics and Control*, forthcoming.
- [15] Corsetti, G., L. Dedola and S. Leduc (2005), Inflation and Exchange Rate Pass-Through: a Quantitative Assessment of Theoretical and Empirical Models, mimeo.
- [16] Erceg, C.J., L. Guerrieri and C. Gust (2005), Expansionary Fiscal Shocks and the Trade Deficit, Board of Governors of the Federal Reserve System International Finance Discussion Paper 2005-825.
- [17] EUROSTAT (2006), Structures of the Taxation Systems in the European Union.
- [18] Fabiani, S., M. Druant, I. Hernando, C. Kwapil, B. Landau, C. Loupias, F. Martins, T.Y. Matha, R. Sabbatini, H. Stahl and C.J. Stockman (2006), What Firms Surveys Tell Us about Price-Setting Behavior in the Euro Area, *International Journal of Central Banking*, Vol. 2, No. 3.
- [19] Finn M.G. (1998), Cyclical Effects of Government Employment and Goods Purchases, *International Economic Review*, Vol. 39 No. 3.
- [20] Galí J. (1999), Technology, Employment and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?, *American Economic Review*, Vol. 89 No. 1.
- [21] Galí J., M. Gertler and J.D. López-Salido (2001), European Inflation Dynamics, *European Economic Review*, Vol. 45, pp. 1237-1270.
- [22] Galí J., J.D. López-Salido and J. Vallés (2007), Understanding the Effects of Government Spending on Consumption, *Journal of the European Economic Association*, Vol. 5, No. 1, pp. 227-270.
- [23] Goodfriend M. and R.J. King (1997), The New Neoclassical Synthesis and the Role of Monetary Policy, NBER Macroeconomics Annual.
- [24] Henry J., P. Hernandez de Cos and S. Momigliano (2004), The Short Term Impact of Government Budgets on Prices: Evidence from Macroeconomic Models, ECB Working Paper No. 396.

- [25] Kim J. (2000), Constructing and Estimating a Realistic Optimizing Model of Monetary Policy, *Journal of Monetary Economics* 45, 329-359.
- [26] Klein P. (2000), Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model, *Journal of Economic Dynamics and Control* 24.
- [27] Linnemann L. and A. Schabert (2003), Fiscal Policy in the New Neoclassical Synthesis, *Journal of Money, Credit, and Banking*, Vol. 35, No. 6, pp. 911-929.
- [28] Mankiw N.G. (2000), The Savers-Spenders Theory of Fiscal Policy, *American Economic Review*, Vol. 90 No. 2.
- [29] Mendoza, E.G., A. Razin and L.L. Tesar (1994), Effective Tax Rates in Macroeconomics: Cross-country Estimates of Tax Rates on Factor Incomes and Consumption, *Journal of Monetary Economics*, Vol. 34 No. 3.
- [30] Pappa E. (2005), New-keynesian or RCB Transmission? The Effects of Fiscal Shocks in Labor Markets, CEPR Discussion Paper n. 5313.
- [31] Perotti R. (2005), Estimating the Effects of Fiscal Policy in OECD Countries, CEPR Discussion Paper n. 4842.
- [32] Romanov A. (2003), International Effects of Fiscal Policies, mimeo IMF.
- [33] Rotemberg J.J. and M. Woodford (1992): Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity, *Journal of Political Economy*, Vol. 100 No. 6.
- [34] Sala L. (2004), The Fiscal Theory of the Price Level: Identifying Restrictions and Empirical Evidence, IGER Working Paper No. 257.
- [35] Smets F. and R. Wouters (2003), An estimated Dynamic Stochastic General Equilibrium Model of the Euro area, *Journal of the European Economic Association*, Vol. 1 No. 5.
- [36] Smets F. and R. Wouters (2007), Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach, *American Economic Review*, forthcoming.

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

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

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

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

$$\lambda_t \frac{P_t}{(1 + \tau_t^c)} = \mu_t \left\{ [1 - s_t(\cdot)] - s'_t(\cdot) \frac{\varepsilon_t^i I_t}{I_{t-1}} \right\} + \beta E_t \left[\mu_{t+1} s'_{t+1}(\cdot) \varepsilon_{t+1}^i \left(\frac{I_{t+1}}{I_t} \right)^2 \right] \quad (33)$$

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

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

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

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

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:

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

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

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

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 $tr = tr^R = tr^{NR}$)]:

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

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

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

Moreover, using also

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

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

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

where $D = \omega + \frac{b}{y} \frac{\pi - R}{R} A^\alpha + \tau^k (r^k A + \frac{A^\alpha}{(1 + \tau^c) \theta_c}) - \frac{A^\alpha}{1 + \tau^c} \frac{c^g}{y}$ 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

$$c = E \cdot l^p + F \cdot c^R \quad (42)$$

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

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

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 :

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

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

$$c^R = H \cdot l^p \quad (45)$$

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 $l_{ss}^g = (\frac{l^g}{l}) = 0.2$. Hence

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

and therefore

$$c^R = H \cdot (1 - l_{ss}^g) \cdot l \quad (46)$$

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:

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

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

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

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

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

C Log-linearizations

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

$$\hat{\chi}_t = -\frac{\sigma_c}{1-h} (\hat{c}_t^R - h \hat{c}_{t-1}^R) + \hat{\varepsilon}_t^b \quad (48)$$

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

$$\hat{\chi}_t = \hat{R}_t + E_t[\hat{\chi}_{t+1}] - E_t[\hat{\pi}_{t+1}]. \quad (49)$$

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

$$\hat{\pi}_t^W = \hat{\omega}_t - \hat{\omega}_{t-1} + \hat{\pi}_t \quad (50)$$

and also, log-linearizing (32),

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

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

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

and

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

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

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

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

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

where

$$\widehat{k}_t = \widehat{u}_t + \widehat{k}_t, \quad (56)$$

and, from the capital market equilibrium (26),

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

As for budget constraints, it is enough to log-linearize that of non-Ricardian households (7)

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

and the aggregate resource constraint (25)

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

where

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

and

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

with

$$l \widehat{l}_t = l^p \widehat{l}_t^p + l^g \widehat{l}_t^g. \quad (62)$$

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

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

where from (11)

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

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

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

As for log-linearized version of the government budget constraint, recalling that $R = \pi/\beta$, it is

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

where

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

$$+ \frac{\tau^c}{1 + \tau^c} c \widehat{c}_t + \frac{\tau^c}{1 + \tau^c} c^g \widehat{c}^g + \tau^k r^k k \left[\widehat{r}_t^k + \widehat{k}_t \right] + \widehat{\tau}_t^k \left[\tau^k r^k k + d\tau^k \right] + d^2 \tau^k \widehat{y}_t - d\tau^k y mc \widehat{mc}_t \quad (68)$$

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 and the government sector series are seasonally adjusted and, when available, working day adjusted.

Data for national accounts variables (households' consumption and capital accumulation) are taken from the EUROSTAT ESA95 data base. The euro area national accounts have a break in 1991 because of the German unification, therefore for previous years we used the series reconstructed by the ECB for the Area Wide Model (ECB-AWM data base, available on the web site of the EABCN, updated at the 2005:4).

Some effort has been devoted to the construction of the quarterly fiscal policy series, as a large part of the euro area information for the government sector is available only on annual basis.²¹ We then obtained quarterly series from the annuals, applying standard techniques commonly adopted by national statistical offices to estimate high frequency series using proxy indicators (in the following section we indicate the quarterly indicator for each of the series).²² Annual data are mainly extracted from the AMECO data base of the European Commission. To construct series from 1980 we had to join three different subsets of the database because of discontinuities. The governments statistics based on the current system of accounts ESA95 start in 1995. For the earlier years there are only data of the former standard (ESA79). In addition, the aggregate of the euro area countries has been reconstructed from 1991, since previously there is a lack of statistics for East Germany. For the earlier years we aggregated ESA79 country data. In each of these joins, we removed discontinuities of the levels by applying the growth rates of the old series to the levels of the new series, as done by most of the data providers.

Concerning implicit tax rates, official EUROSTAT data start in 1995. The OECD series are constructed by Carey-Rabesona (2002) refining the methodology of Mendoza *et al.* (1994). They obtain long time series but refer to countries, not covering the whole euro area. Then we had to compute our tax rates for the euro area. We followed the Mendoza *et al.* methodology, as all the other reconstruction are refinements of this starting point.

²¹Recently a number of quarterly series for the principal items of the Government accounts have been released, but they are available for a short time span (start in the first quarter of 1999) and are unadjusted neither for the seasonality nor for the working days.

²²In particular, we followed the Chow-Lin (1971) method, as modified by Barbone *et al.* (1981). This methodology provides an efficient way to estimate the linear relationship between the annual data and the annual values of a quarterly indicator (with an AR(1) structure for the error term). Once this linear estimate is obtained, the quarterly data results as the prediction of the estimated annual model at quarterly frequency.

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

Households' consumption (c) = real private consumption; source: National Accounts ESA95 after 1991 and AWM-ECB data set before.

Investment (I) = real investments; source: National Accounts ESA95 after 1991 and AWM-ECB data set before.

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

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

Private per-capita compensation (w) = private sector per-capita compensation, computed as the ratio between private total economy compensations and private employees (private variables are computed as difference between whole economy and public sector values); source for the total: National Accounts ESA95 after 1991 and AWM-ECB data set before; source for the public sector series: ECOUT after 1991 and AWM-ECB data set before.

Government consumption (G) = real government consumption; source: National Accounts ESA95 after 1991 and AWM-ECB data set before. The source for the government consumption deflator is National Accounts ESA95 after 1991 and AWM-ECB before.

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: National Accounts ESA95 after 1991 and AWM-ECB data set before. HICP-deflated.

Government transfers (Tr) = real government transfers to households; source for annual series: AMECO. The quarterly indicator is a linear trend. HICP-deflated.

Total revenues (T) = real government total revenues; source for annual nominal 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 National Accounts 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 National Accounts 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 National Accounts data for social contributions. HICP-deflated.

Government employment (L^g) = Public employees; source: ECOUT after 1991 and AWM-ECB data set before.

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 :

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

2) the labor tax rate is given by:

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

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's Revenue Statistics and AMECO. The quarterly indicator is a linear trend.

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

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

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 share of taxes on private and public consumption. Sources for annual series: OECD's Revenue Statistics, AMECO and ECOUT. The quarterly indicator is a linear trend.

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 :

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

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's Revenue Statistics and AMECO. The quarterly indicator is a linear trend.

D.3 Comparison of our quarterly fiscal series with alternative sources

Official quarterly series for euro area fiscal policy data are available starting from 1999:1. Although coverage and definitions might be different, we compare our series for total revenue T , transfers Tr and government consumption G with the official ones.²³ When available, we also compared our series with the series obtained from the ECB-AWM quarterly data set. In order to understand the size of the differences, the data are expressed as ratios over GDP.

The top panel in figure D1 shows total revenues. 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 annual profile as the official one. Starting from the late nineties there is a difference of about one percentage point of GDP with respect to the AWM series. The discrepancies in the quarterly profile between the three series seem related to the different adjustments for seasonality.

The central panel of figure D1 plots the series for government social transfers. Excluding the first three years, the differences with the ECB one are not remarkable in terms of quarterly shape. The correlation coefficient is around 80% and the larger discrepancies are before the nineties. From the nineties onwards the series look rescaled but with a similar profile. Both the series constructed by us and by the ECB show non negligible differences in magnitude and, to a lesser extent, in profile, in comparison with the official series. This is likely due to inconsistencies in series definitions and coverage.

The bottom panel of figure D1 plots series for government consumption. The differences with the AWM data are negligible and the correlation coefficient is very close to one. This is not unexpected as the government consumption is the only fiscal policy variable produced on a quarterly basis in the national accounts. The official quarterly series shows much more volatility at infra-annual frequency, probably due to differences

²³Official data are not seasonally adjusted, therefore for comparison with our series we adjusted them for seasonality using TRAMO-SEATS.

in the seasonal adjustment. As in the social transfers case, there is a difference in scale with our (and ECB) values, again, probably due to heterogeneities in the definitions.

D.4 Comparison of our implicit tax rates with alternative sources

Our implicit tax rates are basically a quarterly and updated version of the rate computed by Mendoza *et al.* (1994). On annual basis these rates can be compared with those provided by Eurostat (2005) and those in Mendoza *et al.* (1994). In addition Carey-Rabesona (2002) provide time series of the rates for most of the euro area countries. In principle, all of these rates are based on Mendoza methodology but still there are some differences in the definitions adopted. Carey-Rabesona use the same data definitions as Mendoza *et al.* with a refinement of the methodology. On the other hand EUROSTAT uses country data not always of public domain.

In terms of time coverage, among euro area countries Mendoza *et al.* computed rates, from 1965 to 1988, only for Germany, France and Italy. Carey-Rabesona have longer series but refer to the countries, thus, in order to make comparisons with our series, we aggregated these three national series using fixed GDP weights. EUROSTAT computes tax rate for each euro country since 1995 and provides three euro area series with different aggregation methods : 1) a weighted average using country GDP weights; 2) a weighted average using country tax base weights; 3) an arithmetic average. We choose GDP weights, as they are the most similar to our aggregation method.

The top panel in figure D2 shows implicit labor income tax rates. Our series is the highest but in term of magnitude is comparable with Mendoza *et al.* , our point of reference for the methodology. Adjusting for these differences in scale our series appears more volatile than the others, but with a similar trend.

The central panel of figure D2 plots implicit tax rates on consumption. Our series track closely the one of Mendoza *et al.* in the first part of eighties and thereafter almost overlaps with that of Carey-Rabesona. The constant differences in scale with the EUROSTAT series, are due to a diverse definition of the denominator, not including government consumption of goods and services among the tax base.

The bottom panel of figure D2 shows implicit capital income tax rates. Notwithstanding our series is about four points lower than the others, once adjusting for the mean seems consistent with the alternatives. In particular our series captures the slight fall in the eighties for Mendoza *et al.* and the increase from the nineties in the other two series. It is worth noting, however, that the capital income tax rate is also generally considered the hard to define, given that it requires many detailed informations to be

properly computed.²⁴

²⁴For the robustness of the methods to compute this rate see Eurostat (2005).

Table 1: Selected prior and posterior distributions

Parameter		Prior distribution			Posterior	
		Type	Mean	St.Dev.	Mean	St.Dev.
<i>Preferences and technology</i>						
inverse intertemporal subst. elasticity	σ_c	Γ	2	0.5	2.46	0.21
inverse labor supply wage elasticity	σ_l	Γ	3	0.5	1.72	0.17
fraction of non-Ricardian	γ	β	0.5	0.1	0.43	0.04
habit parameter	h	β	0.7	0.1	0.74	0.04
labor demand wage elasticity	θ_L	Γ	6.5	1	5.65	0.57
<i>Frictions</i>						
investment adjustment cost	s''	Γ	5	0.25	5.00	0.26
wage adjustment cost	ϕ	Γ	100	$1000^{\frac{1}{2}}$	93.63	12.60
price adjustment cost	κ	Γ	100	$1000^{\frac{1}{2}}$	295.30	47.34
capital utilization adjustment cost	ψ''/ψ'	Γ	0.2	0.1	0.25	0.04
<i>Monetary policy</i>						
interest rate AR coefficient	ρ_R	β	0.8	0.1	0.89	0.01
inflation coefficient	ρ_π	Γ	1.7	0.1	1.82	0.09
output coefficient	ρ_y	N	0.125	0.05	0.09	0.02
inflation change coefficient	$\rho_{\Delta\pi}$	N	0.3	0.1	0.41	0.09
output growth coefficient	$\rho_{\Delta y}$	N	0.0625	0.05	0.06	0.02
<i>Fiscal policy</i>						
labor tax rate AR coefficient	$\rho_{\tau w}$	β	0.8	0.1	0.99	0.00
labor tax rate debt coefficient	$\eta_{\tau w}$	Γ	0.5	0.1	0.46	0.07
consumption tax rate AR coeff.	ρ_{τ^c}	β	0.8	0.1	0.99	0.00
consumption tax rate debt coeff.	η_{τ^c}	Γ	0.5	0.1	0.45	0.05
capital tax rate AR coefficient	ρ_{τ^k}	β	0.8	0.1	0.98	0.01
capital tax rate debt coefficient	η_{τ^k}	Γ	0.5	0.1	0.37	0.05

Table 2: Fiscal multipliers

		Quarters	$\frac{\Delta y}{y}$	$\frac{\Delta c}{c}$	$\frac{\Delta I}{I}$	$\Delta \pi$	
Increase in	c^g	1	1.35	0.27	-0.36	0.05	
		4	0.99	0.16	-0.70	0.04	
		8	0.67	0.07	-0.90	0.03	
		12	0.48	0.02	-0.94	0.02	
	Tr	1	0.60	0.72	-0.11	-0.19	
		4	0.48	0.59	-0.17	-0.19	
		8	0.40	0.50	-0.12	-0.18	
		12	0.36	0.45	-0.02	-0.16	
	l^g	1	0.38	0.48	-0.36	0.39	
		4	0.23	0.38	-0.84	0.38	
		8	0.06	0.26	-1.35	0.34	
		12	-0.07	0.17	-1.70	0.31	
	Reduction of	τ^w	1	0.19	0.23	0.00	-0.25
			4	0.19	0.22	0.07	-0.25
			8	0.22	0.23	0.21	-0.23
			12	0.25	0.25	0.36	-0.22
τ^k		1	0.34	-0.16	0.39	-0.84	
		4	0.46	-0.13	1.02	-0.75	
		8	0.62	-0.07	1.78	-0.65	
		12	0.74	-0.01	2.36	-0.57	
τ^c		1	0.64	0.57	-0.07	-4.90	
		4	0.72	0.70	-0.36	-1.33	
		8	0.71	0.76	-0.82	-0.74	
		12	0.64	0.75	-1.23	-0.56	

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}	Tot
c	5.9	87.1	3.2	1.1	0.2	0.7	1.2	0.1	0.0	0.4	0.0	100
I	2.8	2.8	1.0	2.6	0.1	0.0	0.0	0.0	0.0	90.7	0.0	100
π	62.4	2.4	14.4	1.4	0.1	0.0	1.0	16.5	0.3	1.3	0.1	100
i	22.5	9.3	6.1	54.4	1.4	0.1	0.0	2.8	0.0	3.4	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	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	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	100
ω	0.4	20.1	76.6	1.2	0.0	0.0	0.4	1.1	0.0	0.1	0.0	100
T	32.8	31.1	17.1	1.5	3.5	0.1	9.1	0.2	2.4	2.1	0.2	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}	Tot
c	3.3	75.1	1.4	8.3	0.2	0.3	0.8	0.5	0.1	10.0	0.0	100
I	6.8	2.9	1.3	1.2	0.1	0.0	0.2	0.0	0.1	87.4	0.0	100
π	71.1	1.6	10.8	1.4	0.2	0.2	1.4	9.4	0.4	3.1	0.3	100
i	34.0	7.2	6.5	16.5	0.9	0.2	0.3	0.9	0.1	33.3	0.1	100
τ^w	0.3	0.1	0.0	0.4	0.0	0.0	99.0	0.0	0.0	0.0	0.0	100
τ^c	0.2	0.0	0.0	0.3	0.0	0.0	0.1	99.2	0.0	0.0	0.0	100
τ^k	0.2	0.0	0.0	0.3	0.0	0.0	0.1	0.0	99.3	0.0	0.0	100
ω	1.1	14.5	68.5	10.0	0.0	0.2	3.3	1.5	0.0	1.0	0.0	100
T	13.5	22.5	11.9	9.9	1.7	0.1	12.3	0.3	2.5	25.1	0.2	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}	Tot
c	20.2	27.6	1.9	15.0	2.2	11.3	4.2	1.0	2.1	12.7	1.8	100
I	10.7	1.9	0.9	1.5	0.2	0.9	0.8	0.1	0.2	82.5	0.2	100
π	42.1	1.1	6.0	11.1	2.0	13.5	7.4	3.3	2.7	8.9	1.9	100
i	21.6	3.4	3.2	14.0	1.8	9.6	4.7	1.0	1.8	37.6	1.3	100
τ^w	6.8	0.2	0.6	20.6	3.5	23.9	24.3	1.0	6.1	10.7	2.3	100
τ^c	5.6	0.2	0.5	17.1	2.9	20.0	13.7	24.2	5.1	8.8	1.9	100
τ^k	6.1	0.2	0.6	18.6	3.2	22.0	15.0	0.9	21.8	9.5	2.1	100
ω	20.1	9.5	44.4	10.1	0.6	3.7	4.9	1.7	0.3	4.4	0.4	100
T	20.0	15.5	9.8	10.5	1.7	5.6	10.9	0.4	2.6	22.2	0.6	100

Figure D1

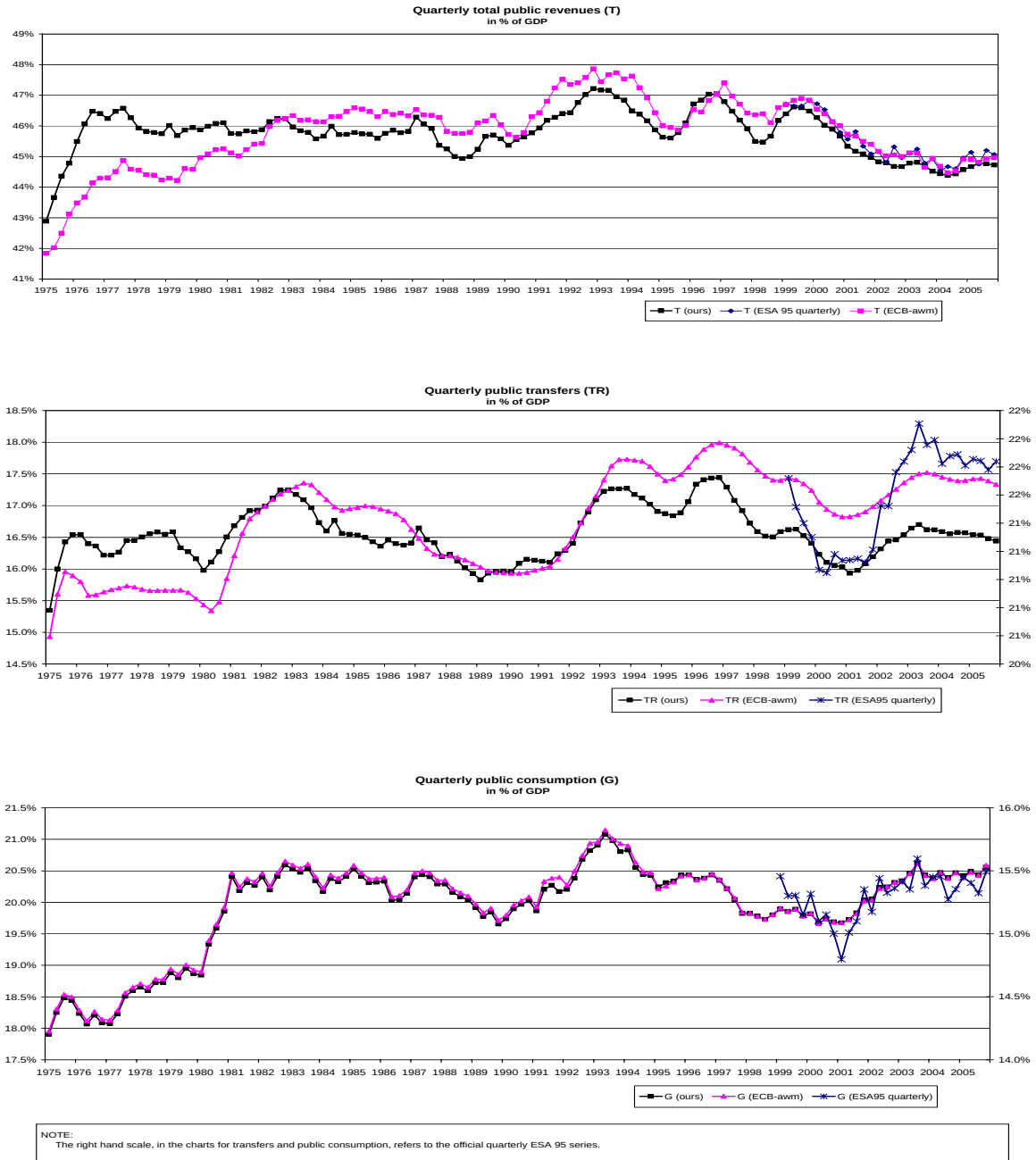


Fig. 1: Quarterly fiscal policy series

Figure D2

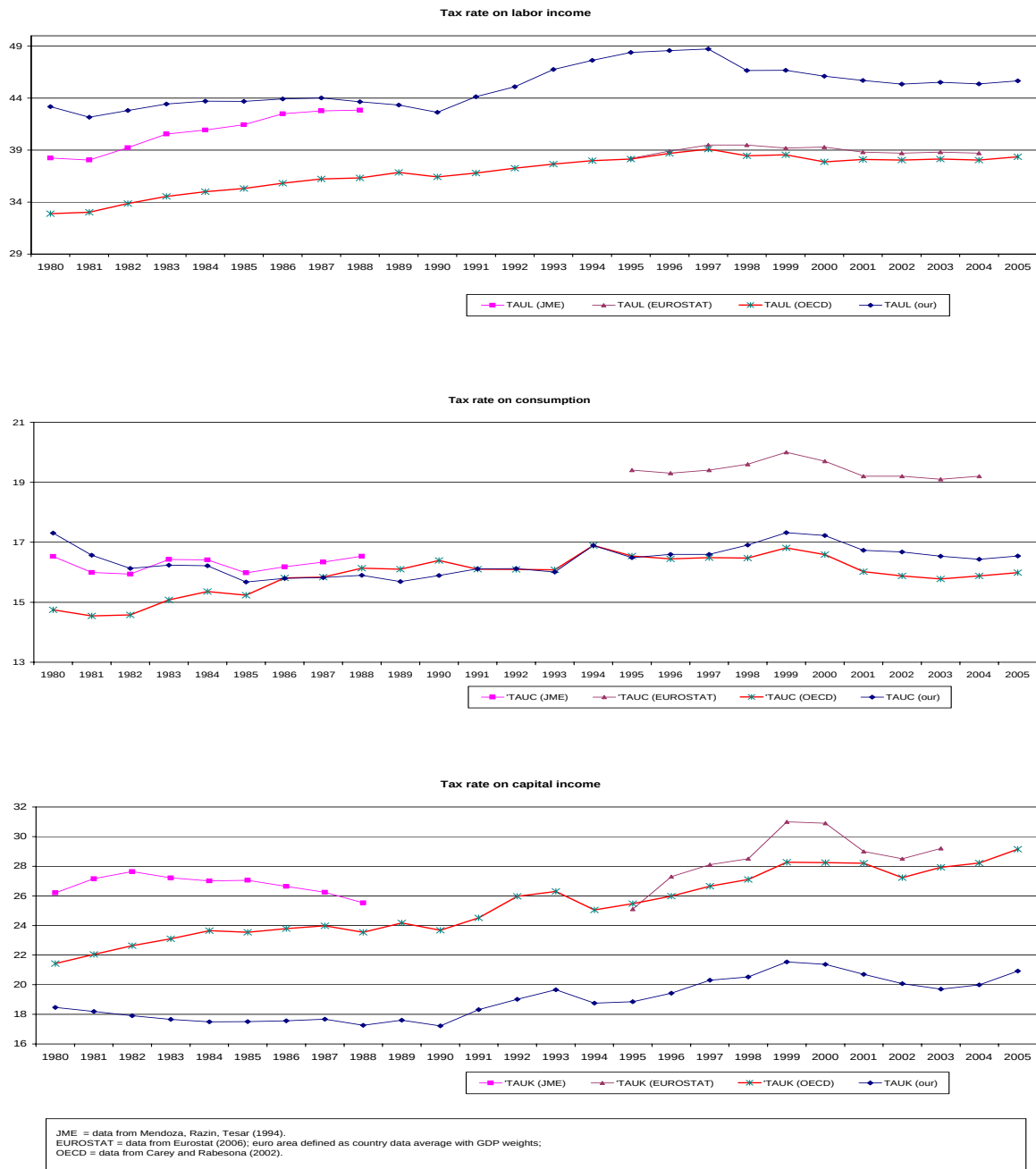


Fig. 2: Quarterly implicit tax rates

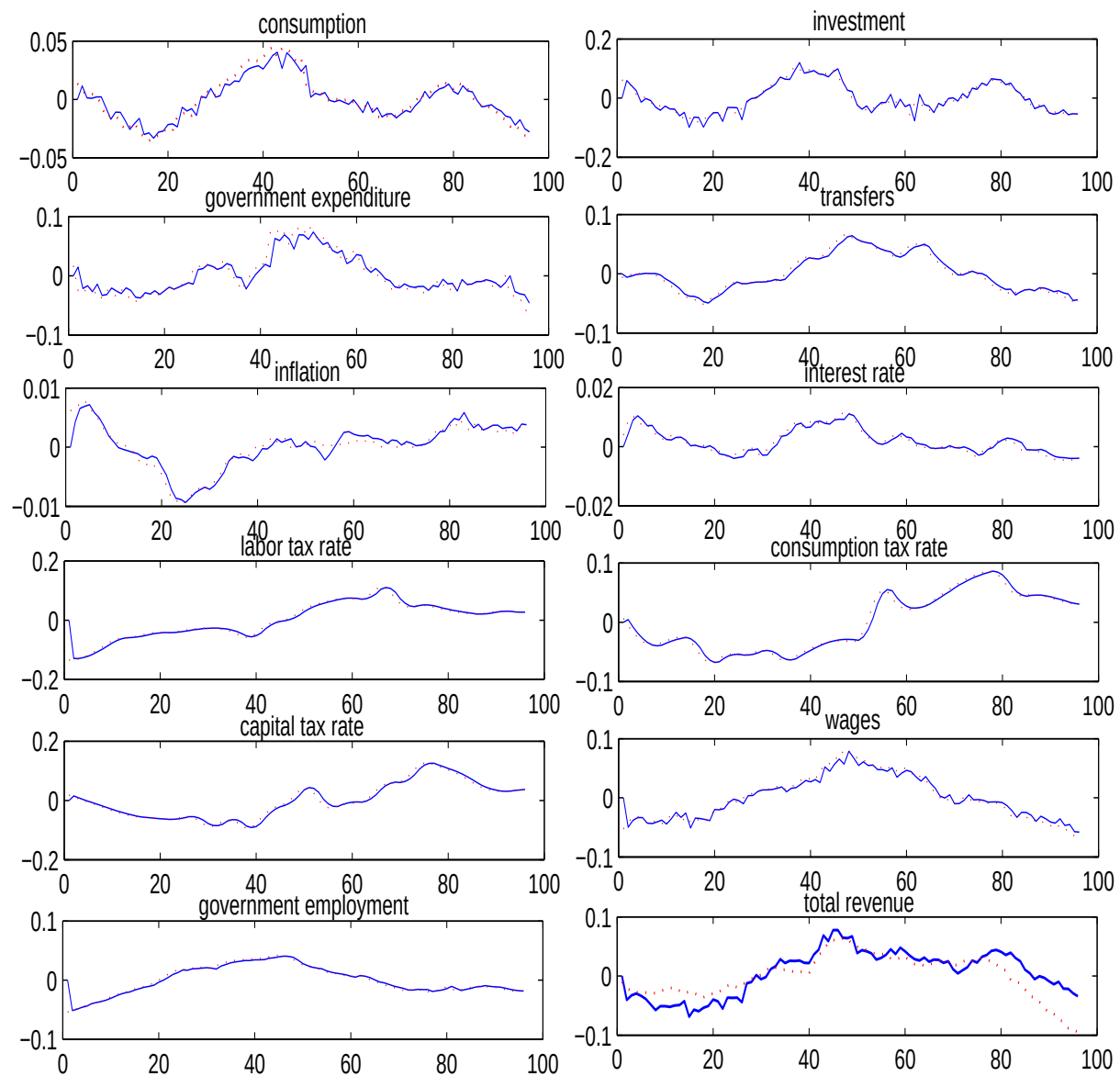


Fig. 3: Model fit after MH procedure: data (blue/solid) vs. model (red/dotted)

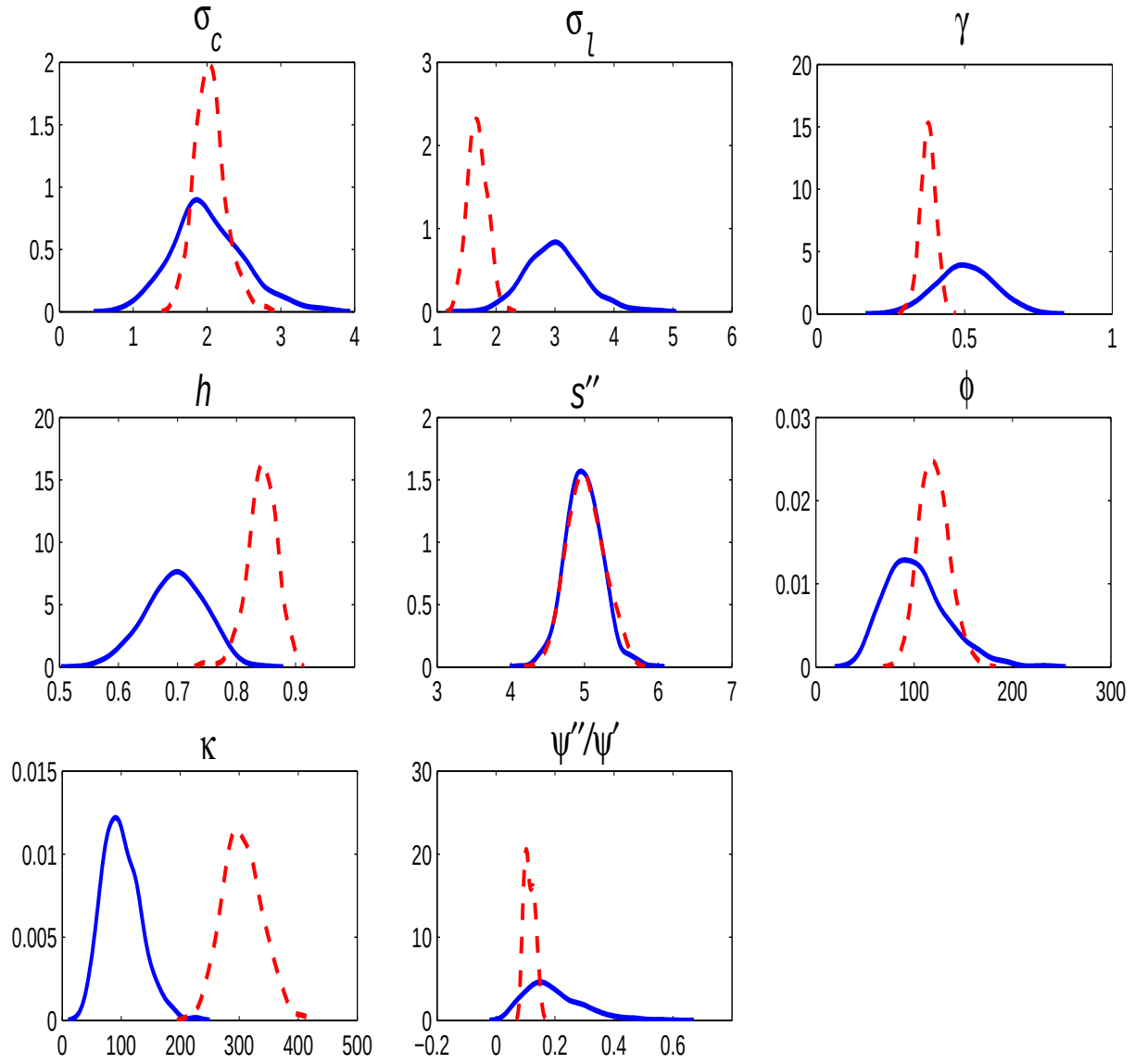


Fig.4.1: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

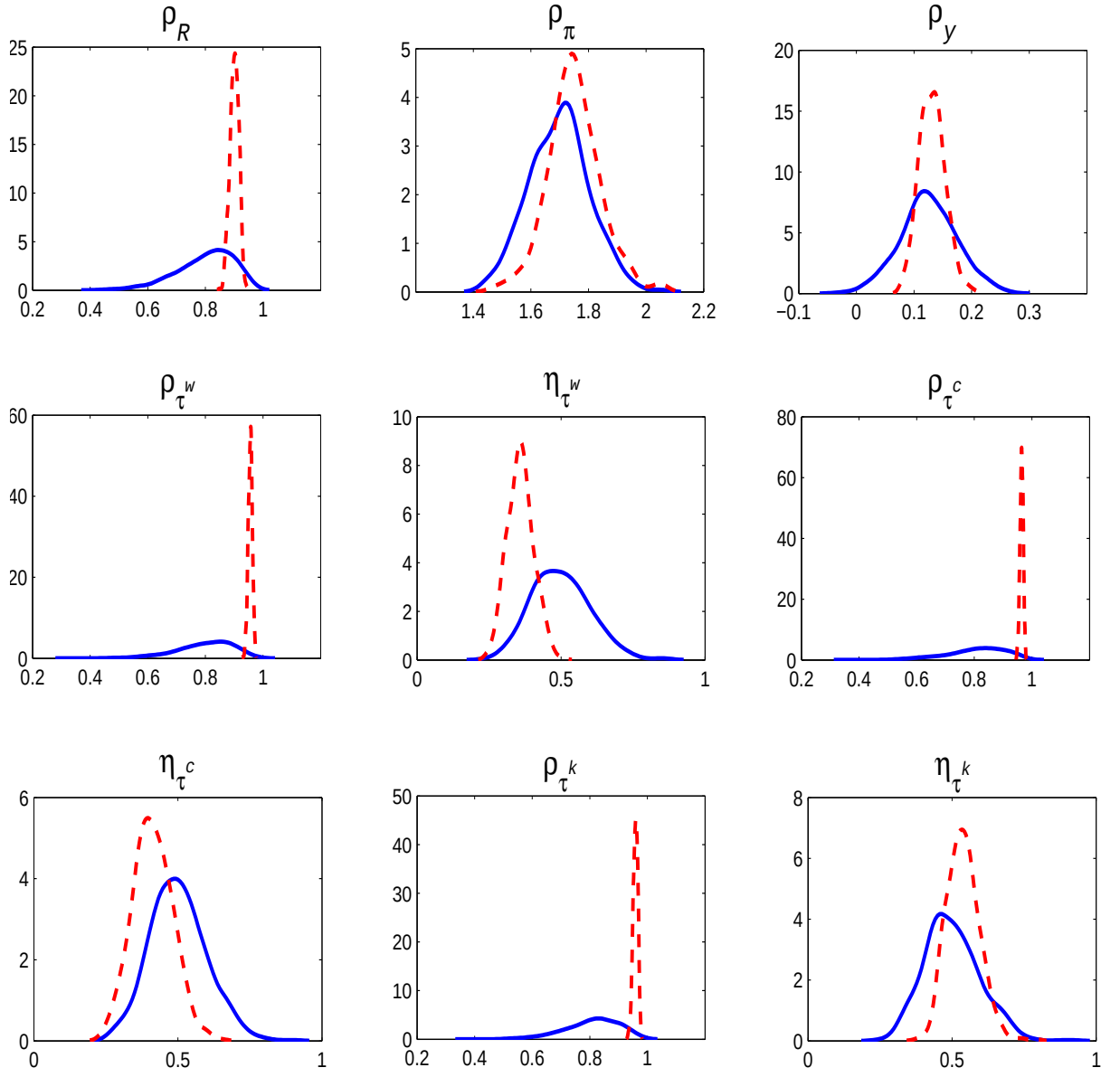


Fig.4.2: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

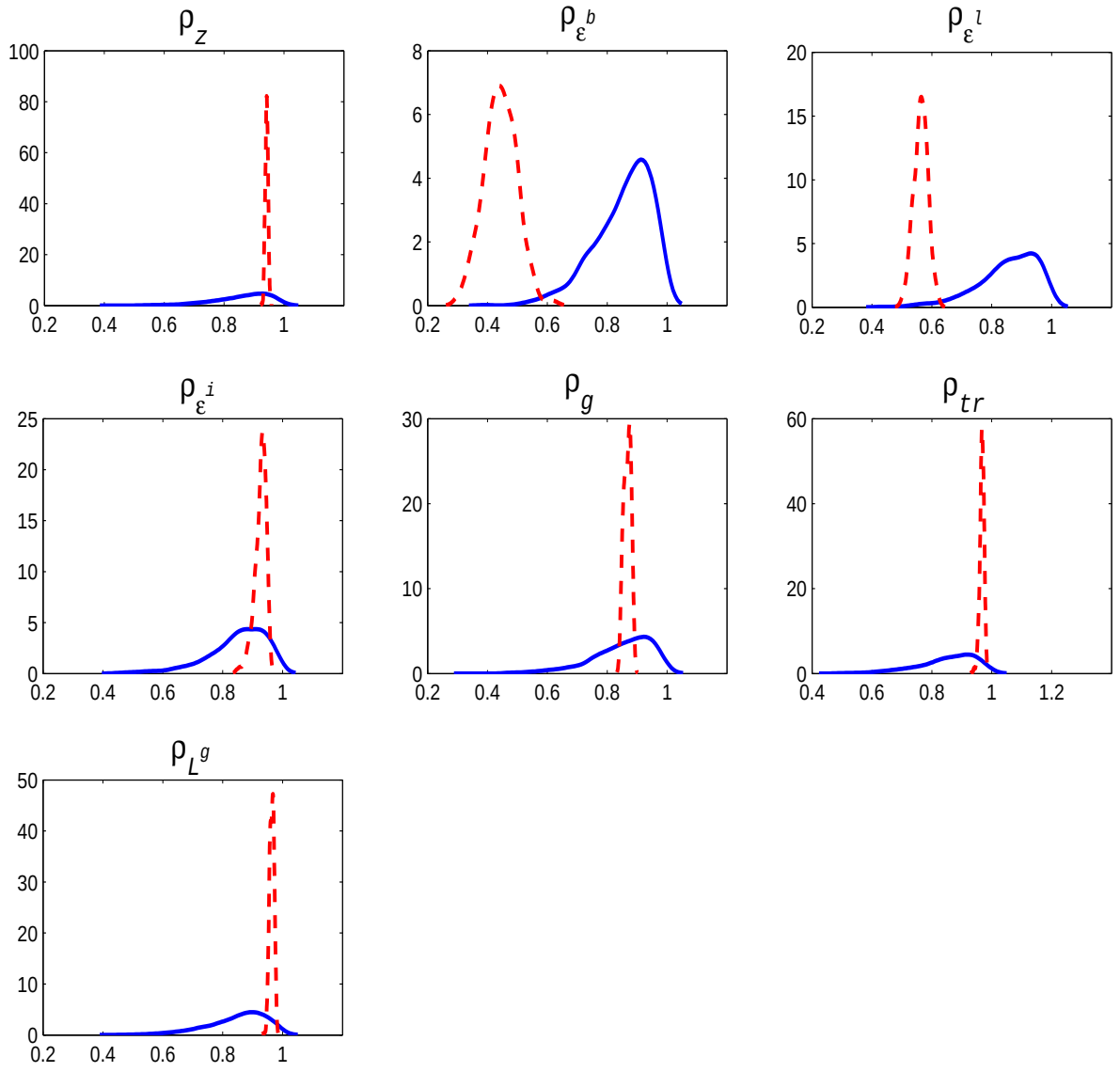


Fig.4.3: Prior (blue/solid) vs. posterior (red/dashed) distributions in MH procedure

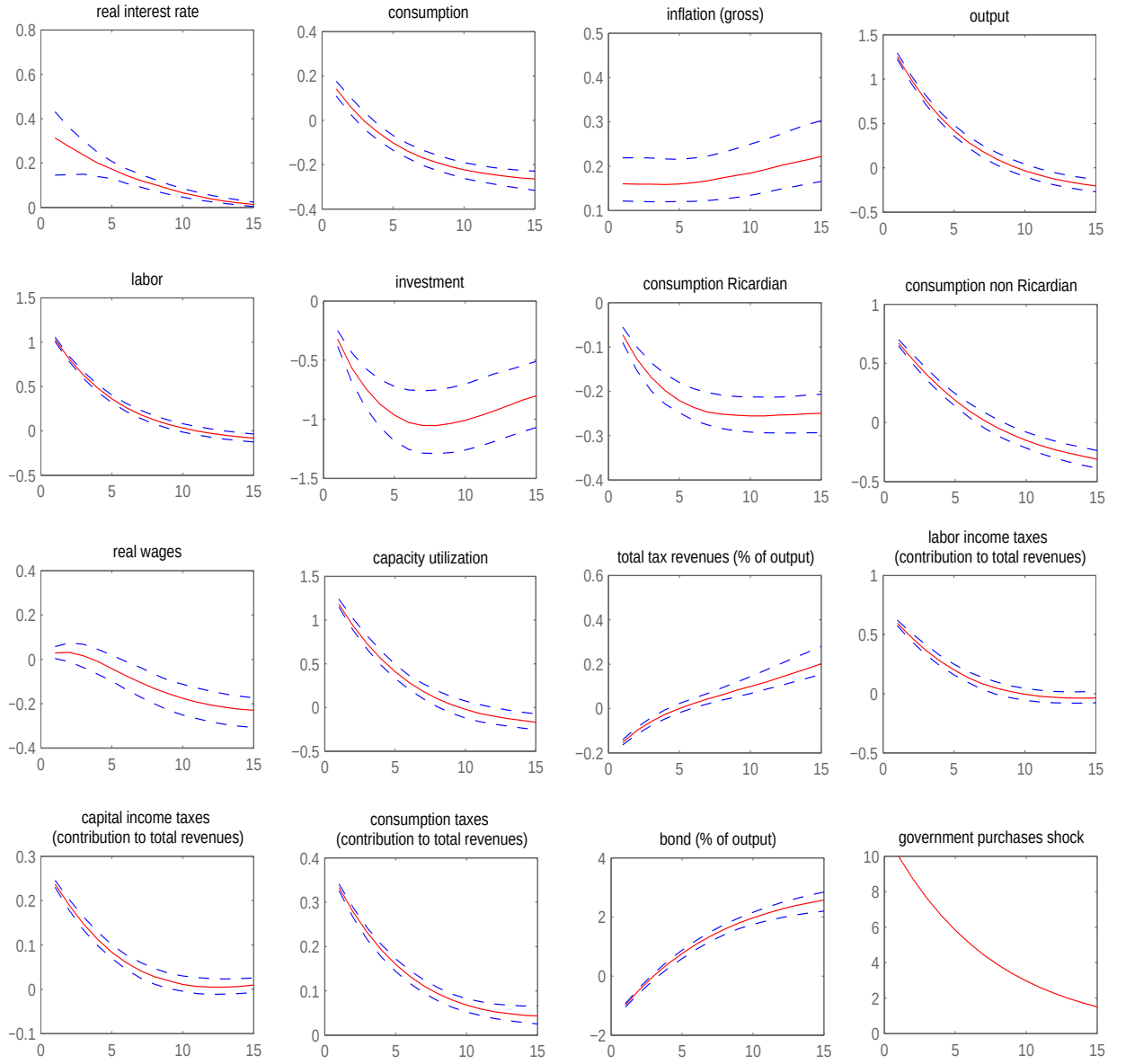


Fig. 5: Impulse responses after a government purchases shock

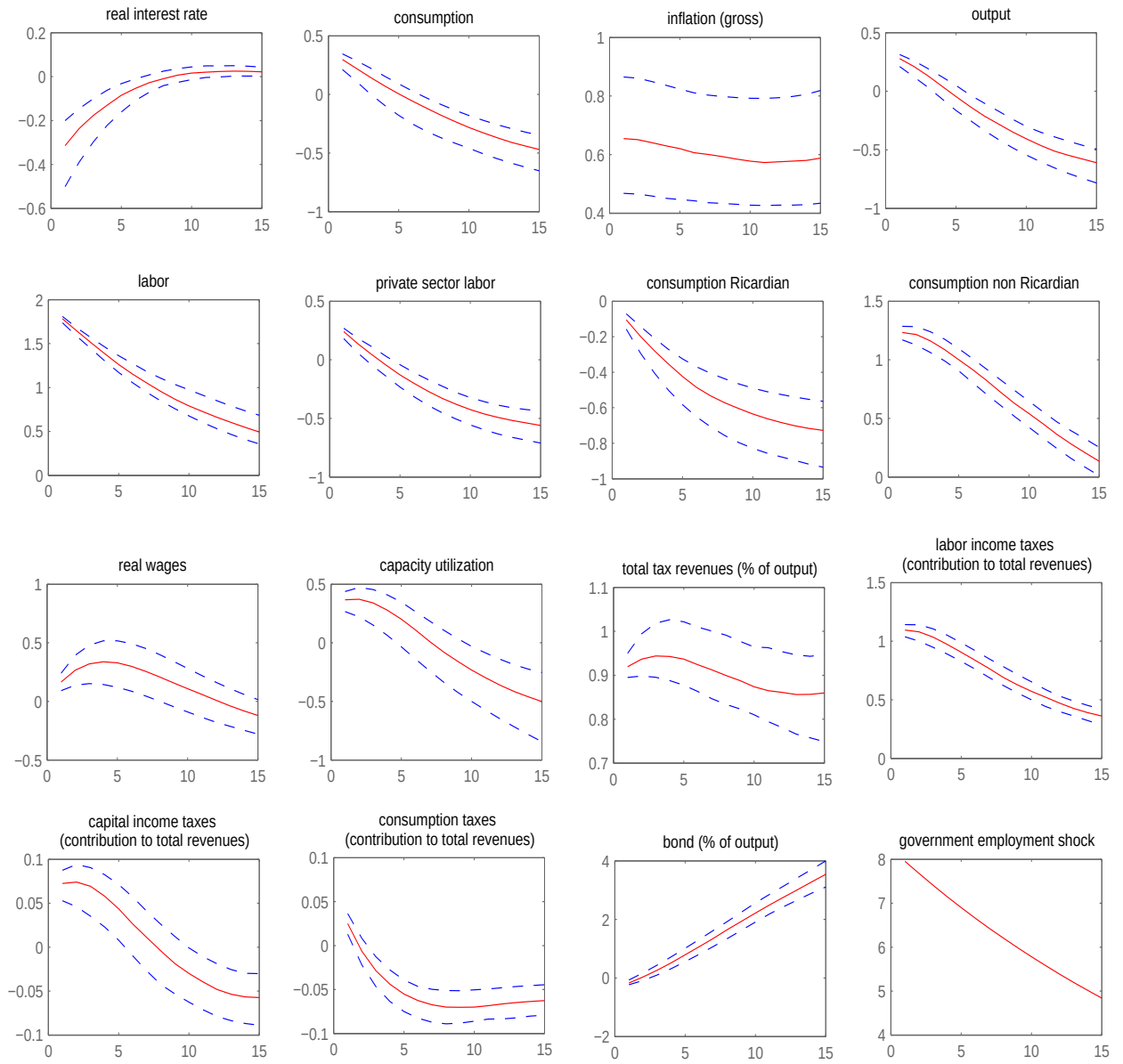


Fig. 6: Impulse responses after a government employment shock

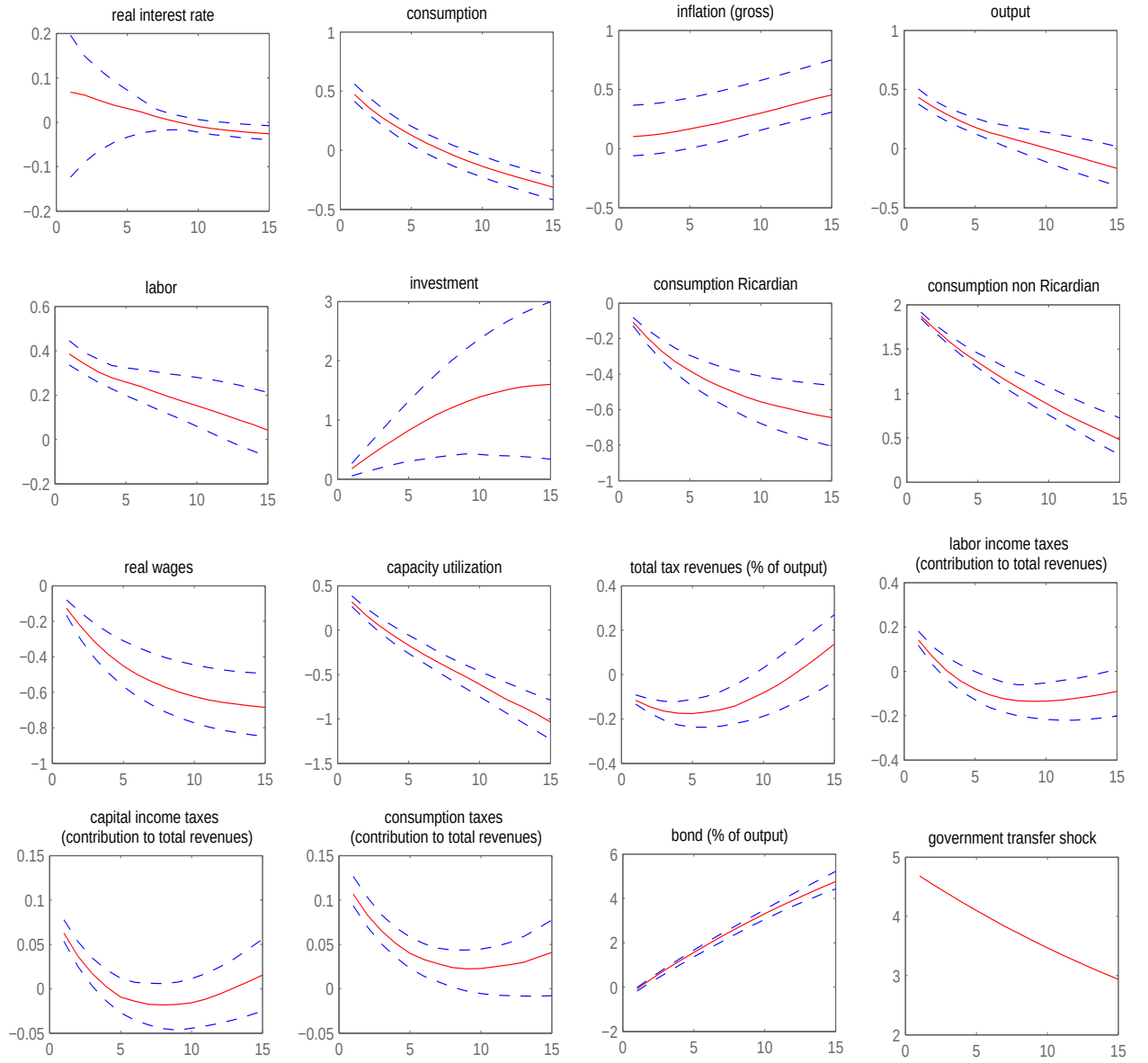


Fig. 7: Impulse responses after a transfers shock

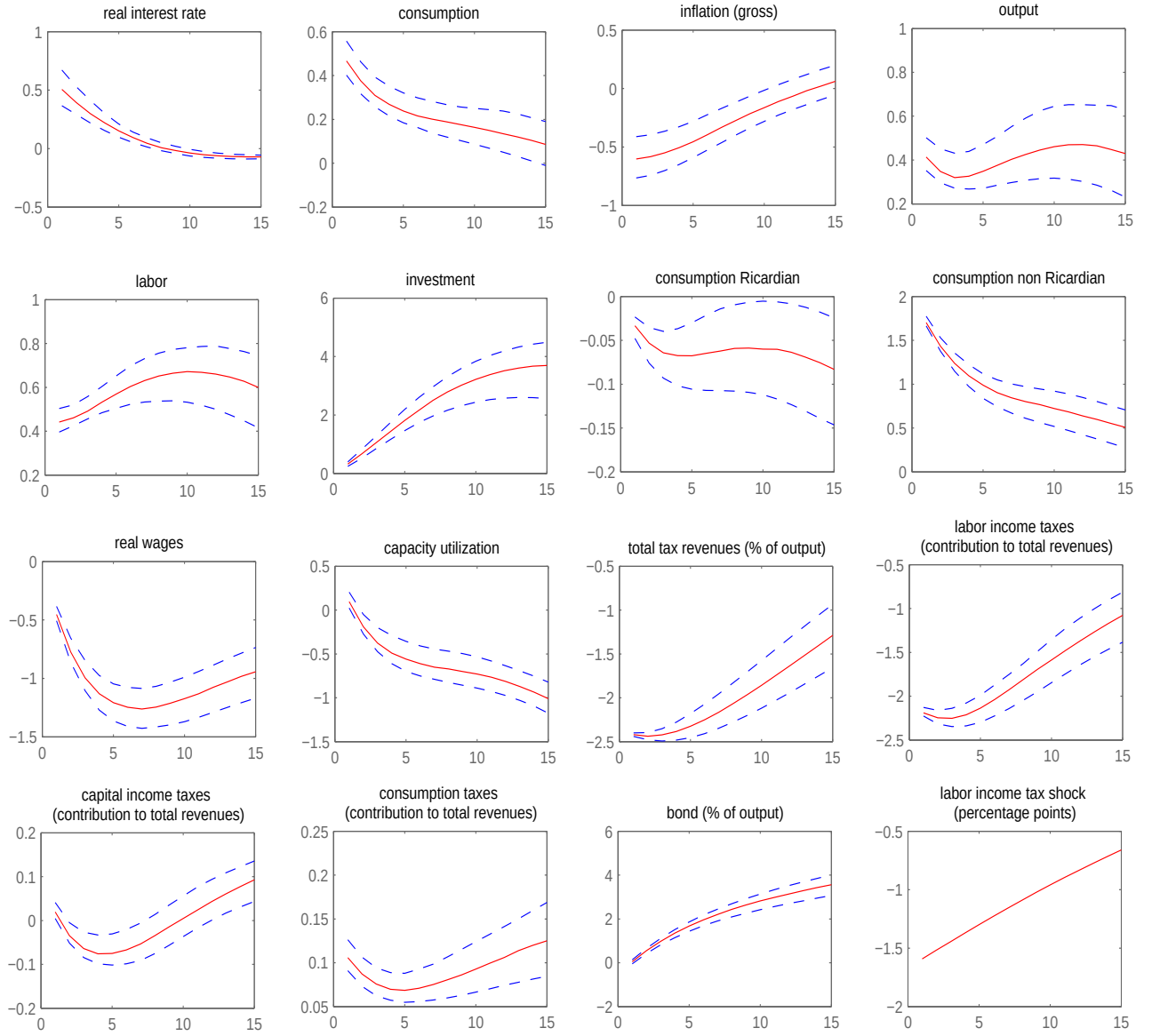


Fig. 8: Impulse responses after a labor income tax shock

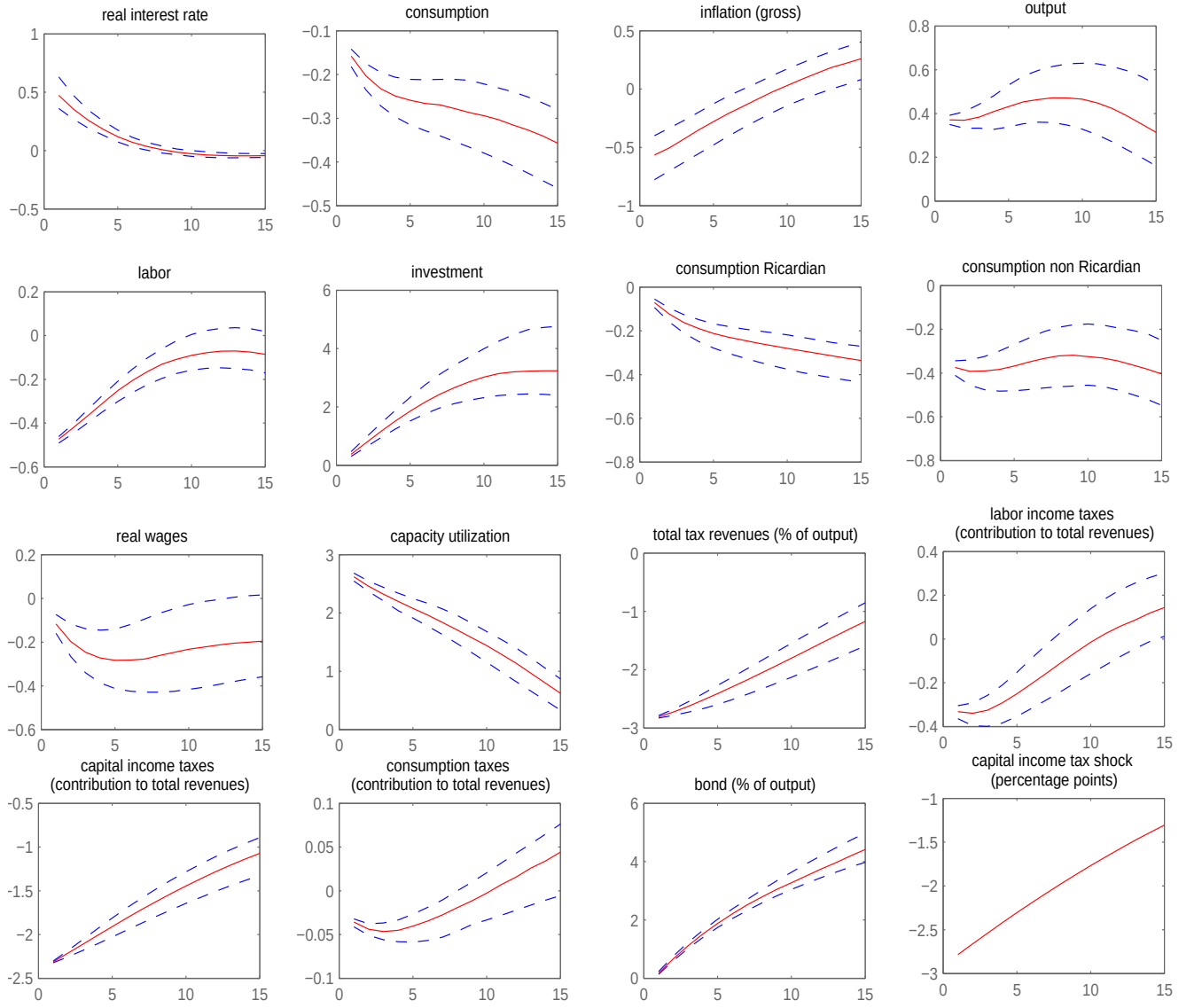


Fig. 9: Impulse responses after a capital income tax shock

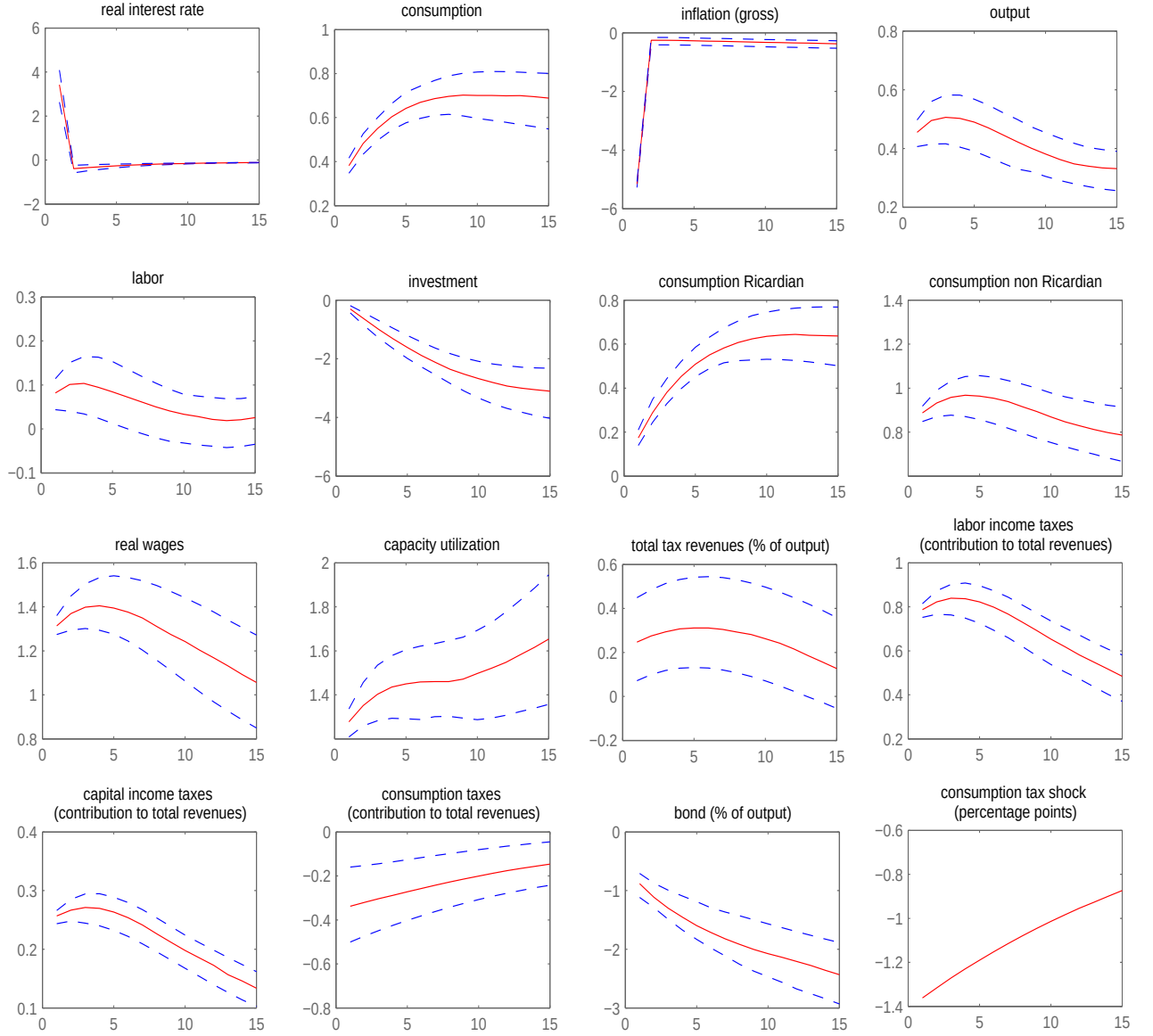


Fig. 10: Impulse responses after a consumption tax shock

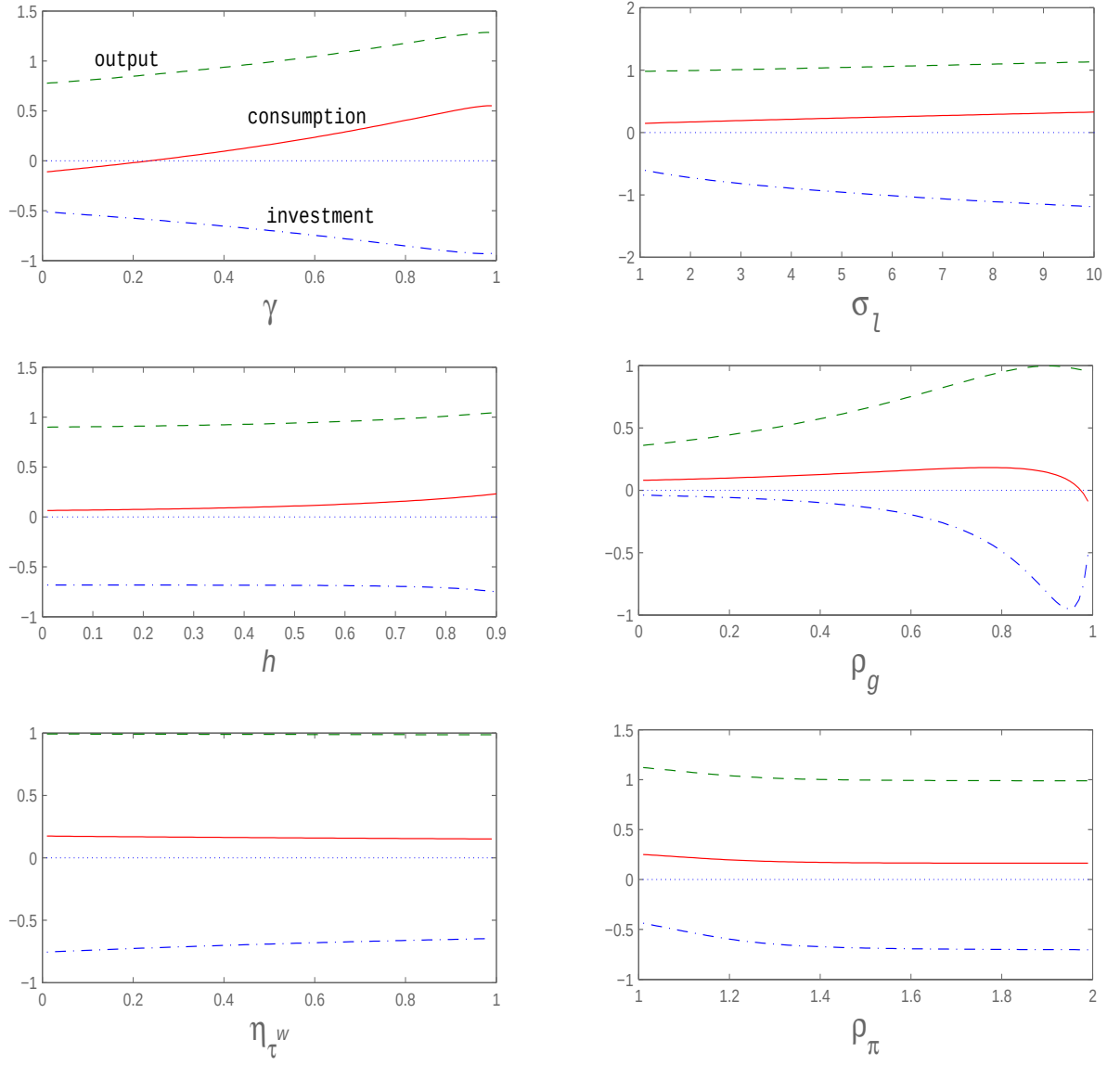


Fig. 11: Robustness - First year average responses to a government purchases shock of output, consumption and investment for parameters ranges

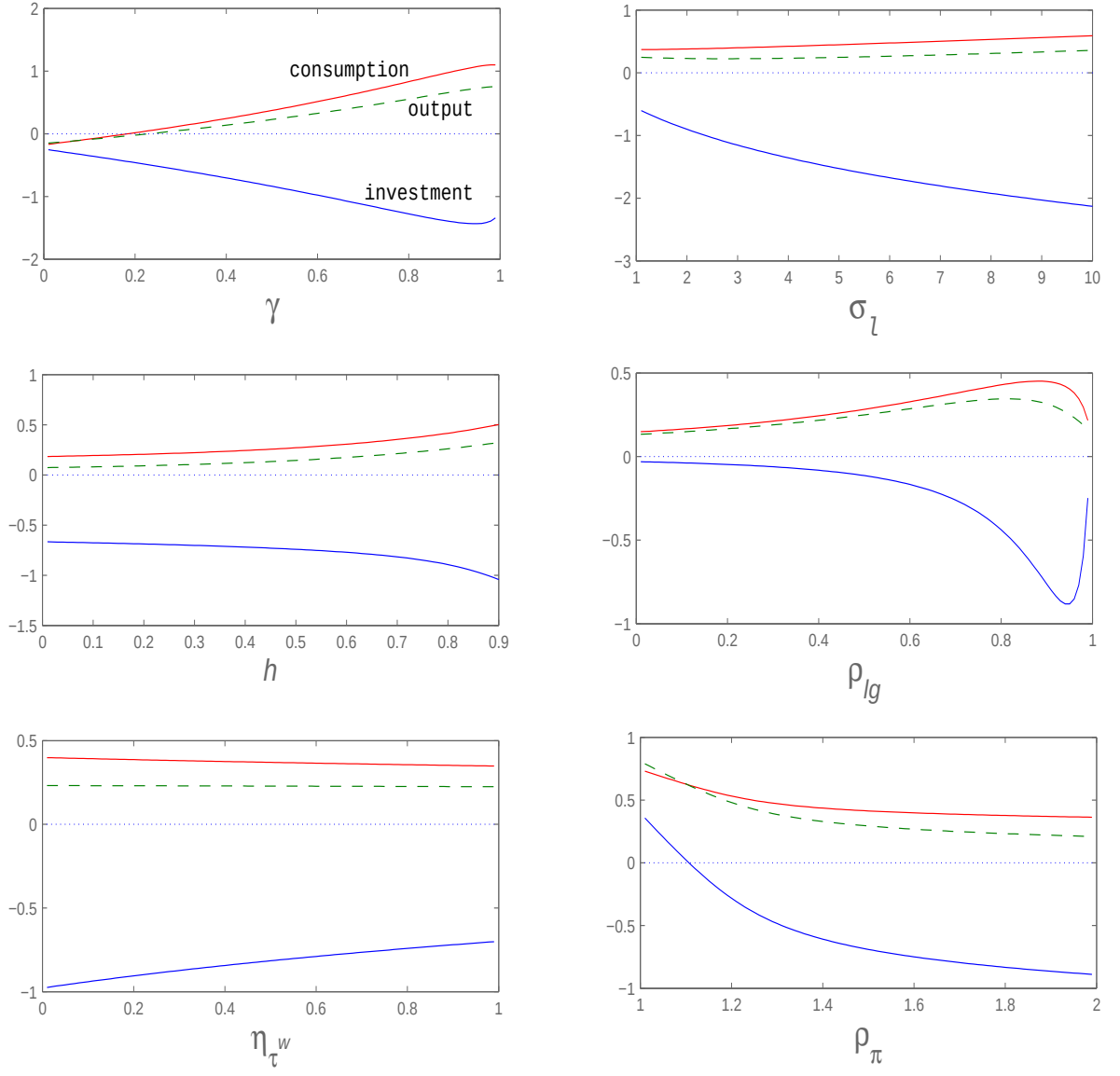


Fig. 12: Robustness - First year average responses to a government employment shock of output, consumption and investment for parameters ranges

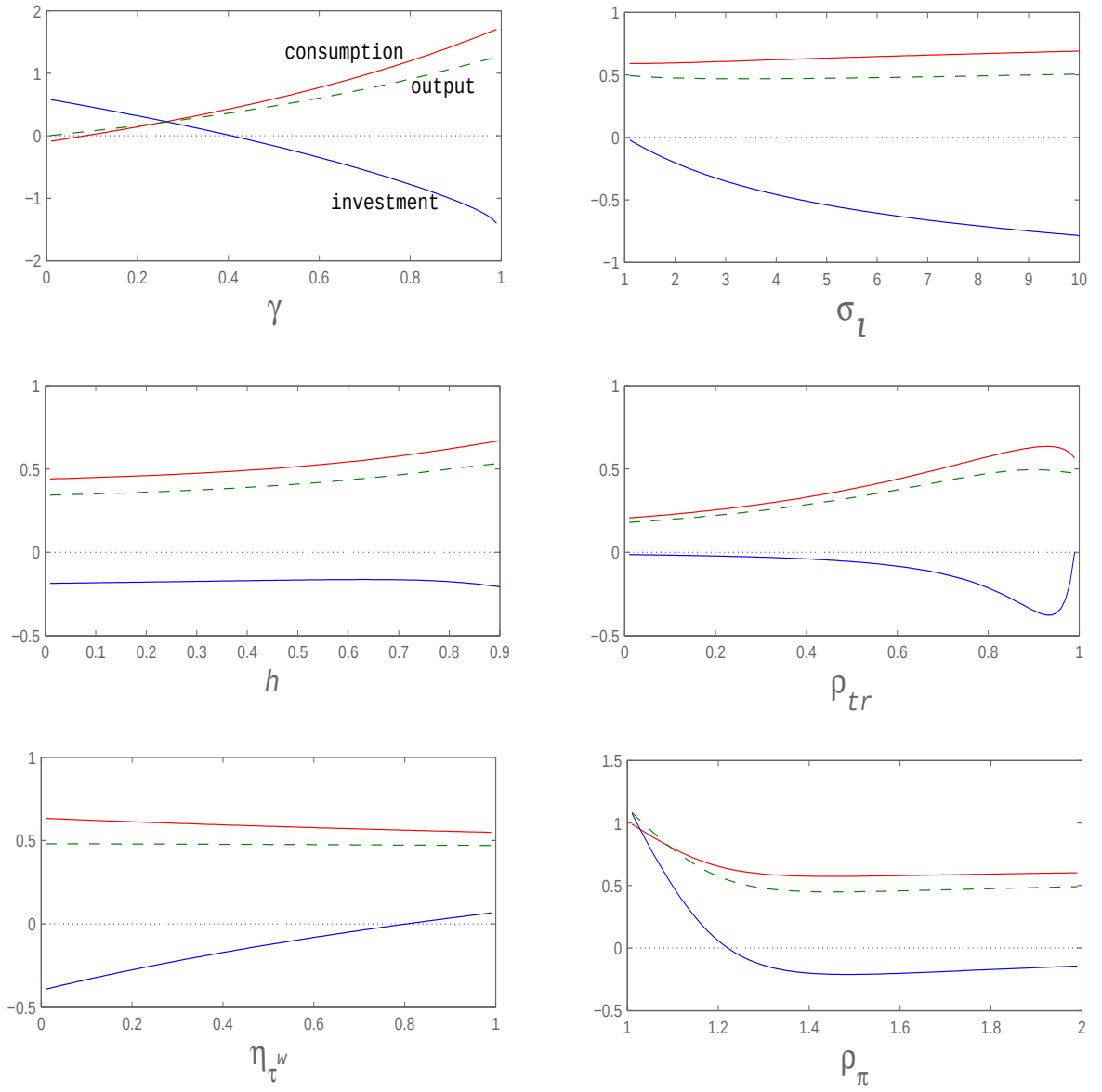


Fig. 13: Robustness - First year average responses to a government transfers shock of output, consumption and investment for parameters ranges

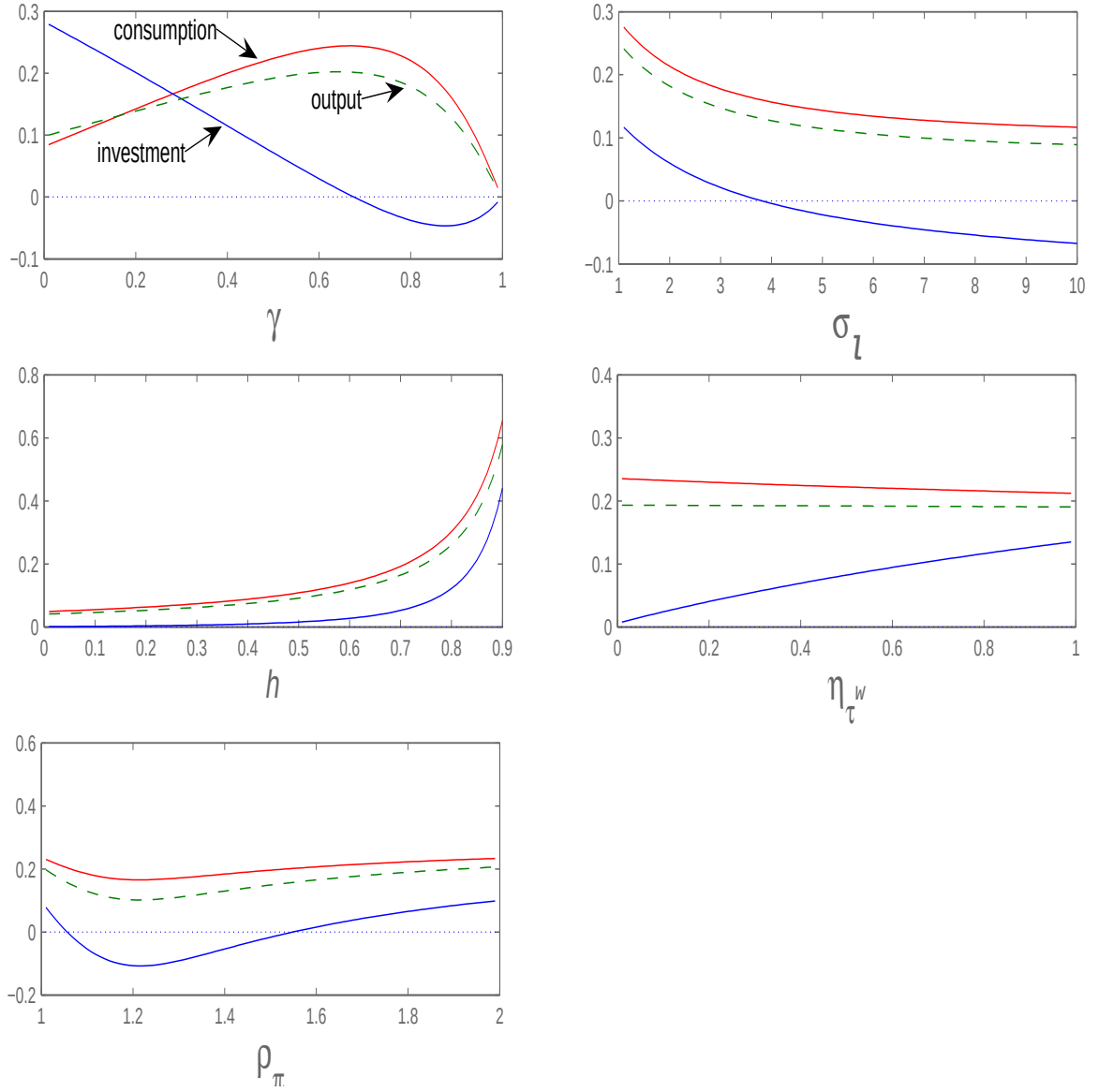


Fig. 14: Robustness - First year average responses to a labor income tax shock of output, consumption and investment for parameters ranges

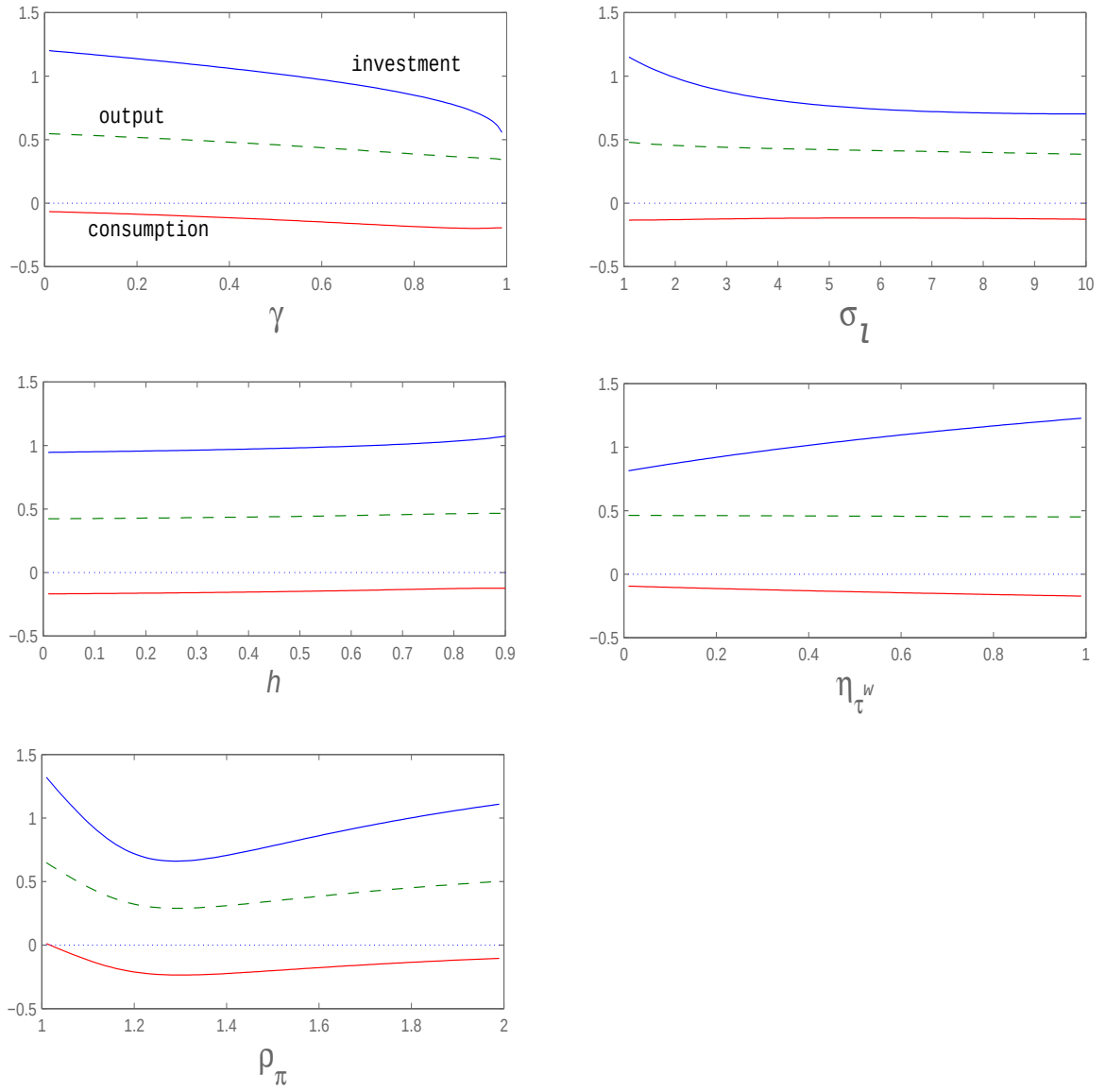


Fig. 15: Robustness - First year average responses to a capital income tax shock of output, consumption and investment for parameters ranges

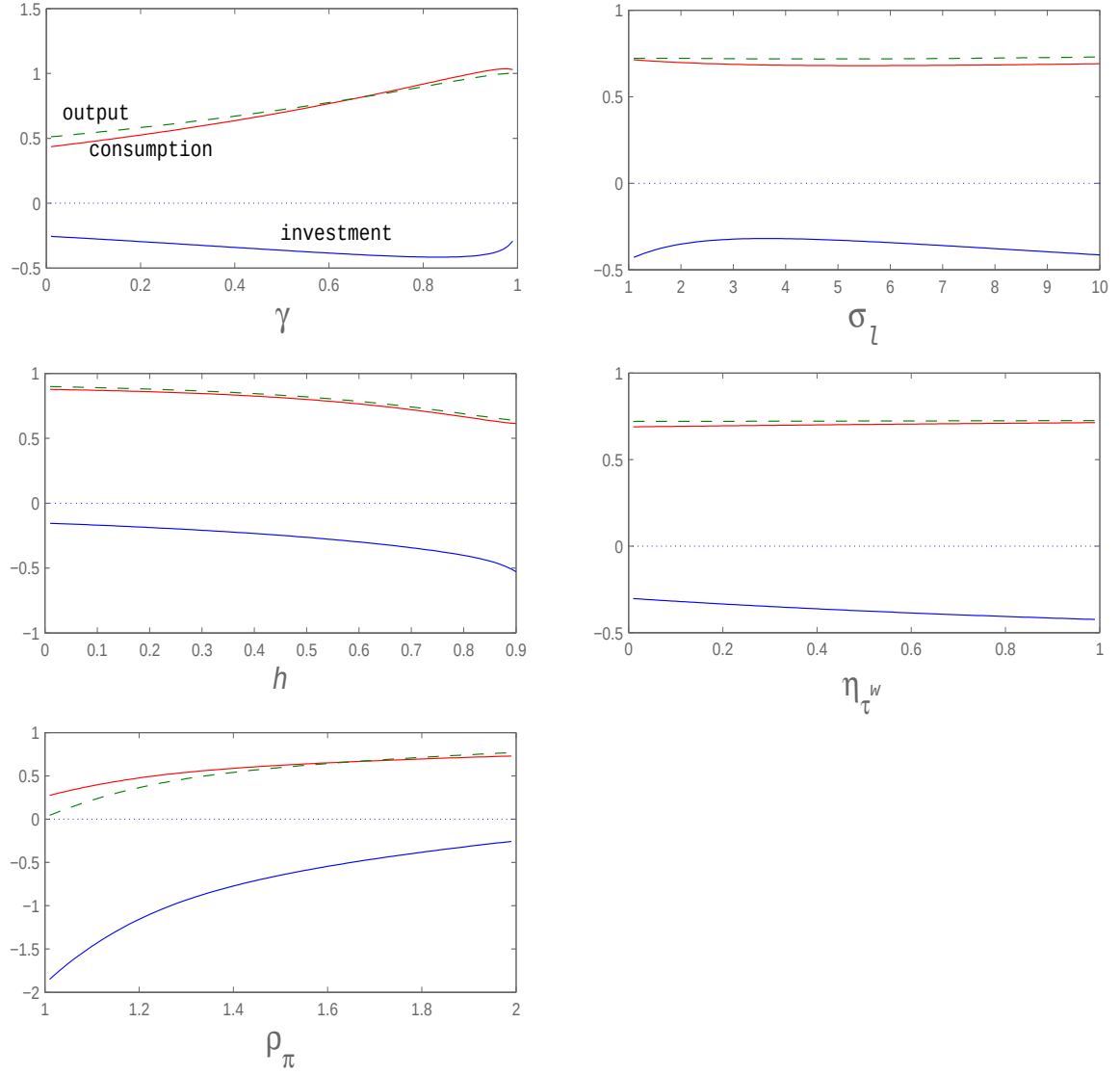


Fig. 16: Robustness - First year average responses to a consumption tax shock of output, consumption and investment for parameters ranges