The estimated general equilibrium effects of fiscal policy: the case of the euro area

Lorenzo Forni, Libero Monteforte, Luca Sessa

Banca d'Italia, Research Department*

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Abstract

We reconsider the macroeconomic effects of fiscal policy in the context of a new-keynesian dynamic stochastic general equilibrium model. We assume that a fraction of the agents are non Ricardian and estimate the model parameters using Bayesian techniques. Our results show that the estimates of important parameters of the model differ depending on how detailed the fiscal policy is modelled. In particular, when we properly model distortionary taxes and take into account the fact that government expenditure is a composite aggregate (including consumption of goods and compensations for government employees), the estimated share of non Ricardian agents is significant and the model is able to replicate the widespread evidence that private consumption responds positively to government expenditure shocks. Previous papers, which mainly considered lump-sum taxes and treated government consumption as one single aggregate, obtained a smaller estimated share of non Ricardian households and no significant effect of government spending shocks on macroeconomic variables.

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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 revenues, as well as on the interaction with monetary policy.

Recent years have witnessed significant changes in the fiscal position of both the United States and the euro area. The main motivation behind this shift has been related with cyclical considerations as policy makers have tried to strengthen or to not hinder economic activity. Most of the discretionary measures undertaken in this direction, both on the spending and on the revenue side, were backed by very little consensus among economist on their effects. This lack of consensus stems from the difficulty economists have in building models able to replicate the main empirical regularities concerning government variables.

Real Business Cycle (RBC) models, for example, fail to reproduce important empirical regularities concerning the effects of government policies. In particular, since they assume rational agents, any increase in government expenditures will bring about - as the government intertemporal budget constraint has to be satisfied - an increase in taxes. This in turn will produce a negative wealth effect, as the present discounted value of taxes increases. The negative wealth effect will induce a decrease in private consumption and a contemporaneous increase in labor supply, which in turn will decrease the marginal productivity of labor and therefore wages. These theoretical correlations are at odds with empirical evidence. A number of studies, mainly in the context of VAR analysis, have shown that private consumption responds positively to government spending shocks[1]. Moreover, the negative correlation between consumption and employment, as between employment and real wages, following government spending shocks is widely believed to be inconsistent with empirical evidence. The new-keynesian paradigm suffers from the same drawbacks as the ones just pointed out for RBC models, except for the fact that it is able to produce a positive correlation between employment and wages.

In order to overcome these problems, the literature has recently moved away from the representative infinitely-living rational agent. In particular two approaches have been explored: the first one has introduced some form of finite horizon or overlapping generations in standard RBC or new-keynesian models; the second one, which is the one explored in

[1] Galí et al. (2005) provide an extensive and very clear review of the literature on the topic.

this paper, has added limited rationality or credit constrained agents in standard new-keynesian models.

As for the first approach, Romanov (2003), Sala (2004) and Cavallo (2005), among others, consider agents with a finite horizon by introducing a constant probability of dying á la Blanchard (1985). The idea is that, although expenditures increases on the part of the government will increase the level of expected future taxes, agents - while fully benefiting from the increase in expenditures - will not likely live enough to pay their entire share of the financing. A feature of these models is that the positive effect on private consumption is stronger the longer the period over which the financing is spread. However, since the keynesian effect of the expenditures shock depends essentially on the probability of dying before paying taxes and this probability is reasonably small over the short to medium term, these model cannot deliver a significant positive response of private consumption after a government spending shock.

The second approach, following Campbell and Mankiw (1989) and Mankiw (2000), assumes that rational and rule of thumb (or credit constrained) agents coexist. In particular, Galí et al. (2005) present a new-keynesian model where a share of the agents consume their current income. They show that both price stickiness and the presence of rule of thumb consumers are necessary 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"[2]. Coenen and Straub (2005) take this idea to the data. They introduce rule of thumb consumers in a new-keynesian model a' la Smets and Wouters (2003) - from now on SW - and estimate the parameters of the model using Bayesian inference method on euro area data. Differently from Galí et al., Coenen and Straub (2005) assume also sticky wages. This latter assumption introduces inertia in the wage adjustment process, therefore dampening the main mechanism through which a government expenditures shock increases real incomes in Galí et al. (2005). The main result of

[2]Galí et al. (2005) pg. 29 and 30.

Coenen and Straub (2005) is that the estimated share of rule of thumb consumers is small (around 1/4) and therefore not able to deliver a positive response of private consumption to a government expenditures shock. Therefore apparently the model would not be able to replicate the stylized fact regarding the positive comovement of private and public consumption.

In this paper we also follow the second approach and introduce non Ricardian consumers in a new keynesian DSGE model very similar, in any other respect, to SW. In doing so we follow the approach suggested in Galí et al. (2005) and already pursued by Coenen and Straub (2005), with the addition of sticky wages. However, we model fiscal policy in more detail and use a richer data set, which leads us to very different conclusions.

In particular, we model in some detail both government revenues and expenditures. As for the revenues, we consider and estimate fiscal policy rules defined on distortionary taxation, while previous literature has mainly focused on lump-sum taxes (for example, both Galí et al. (2005) and Coenen and Straub (2005) consider a fiscal policy rule defined on lump-sum taxes). In order to do so, we have estimated effective tax rates on labor income, capital income and consumption on a quarterly basis for the uro area following the methodology of Mendoza, Razin and Tesar (1994)[3]. On the expenditures side, we take into consideration the fact that the variable generally used in the literature as a proxy for government expenditures on goods and services, that is the National Account (NA) data on government consumption expenditures, includes both consumption of goods/services and compensations for government employees, as early recognized by Rotemberg and Woodford (1992) and more recently by Finn (1998). Actually, in the case of the euro area in the last twenty five years, the proportion of employees compensations in the total of the NA definition of government consumption expenditures is predominant, around 60% on average. While government expenditures on goods and services is a component of aggregate demand, compensations for government employees affect the economy mainly through their effects on the labor market. We therefore define government consumption excluding compensations for public employees and model public employment separately.

Our results show that the estimates of important parameters of the model differ depending on how detailed the fiscal policy is modelled. In particular, when we properly model distortionary taxes and the two main distinct aggregates which make up government expenditures, the estimated share of non Ricardian agents is significant and the

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

model is able to replicate the widespread evidence that private consumption responds positively to government expenditures shocks.

2 The setup

The economy is populated by a measure one of households of which a fraction γ are non Ricardian while $(1-\gamma)$ are Ricardian. Non Ricardian consumers do not have access to financial or capital markets. Therefore, Ricardian households own all capital and rent it to firms since. Asset markets (not modelled) are assumed to be complete. 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 do not participate in the financial market, but they can still smooth consumption by adjusting their holding of money (for example, Coenen et al. (2005)). In this case non Ricardian agents' consumption does not respond one to one to variation in disposable income[4]. However, consumption smoothing will be less than complete, as the real return of money is generally negative. Other authors have made assumptions such that non Ricardian agents' consumption responds more strongly to variations in disposable income. In particular, Galí et al. (2005) assume non Ricardian agents consume their current income; in their work, the strong response of non Ricardian consumption to disposable income variations is a necessary conditions 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. (2005) 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 labor supply will depend on their static trade-off between consumption and leisure and, if wages are sticky, will tend to reflect the shocks to disposable income (that is consumption) and therefore to be rather volatile. On the other hand, when the labor of the two types of agents is a perfect substitute (even if differentiated), the labor supply of non Ricardian households will be less volatile. Both Galí et al. (2005) and Coenen and Straub (2005) take this second approach and assume that both types of agents receive the same wage

[4] In fact, as Coenen et al. (2005) show in the case of a monetary policy shock, the dynamic of aggregate consumption is not very different from the one of SW, who do not have non Ricardian agents.

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 for Ricardian ones.[5] The labor packer 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 in order to solve the model are reported in the Appendix.

2.1 Consumers Problem

2.1.1 Ricardian households

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

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

There is external habit formation in consumption with $h \in [0,1)$ where $C(i)$ is aggregate per capita consumption of Ricardian agents. Two demand shifters (preference shocks) are assumed: ε_t^b affects the overall utility in period t while ε_t^l affects the consumption-leisure intratemporal trade-off. Both shocks are assumed to follow a first-order autoregressive process with an i.i.d. error term (η):

$$\varepsilon_t = \rho \varepsilon_{t-1} + \eta_t \tag{2}$$

[5] Erceg, Guerrieri and Gust (2005) consider a new-keynesian model with non Ricardian agents and make the same assumption as ours regarding the labor market, although their focus is on a different issue (the US external balance).

The flow budget constraint for the Ricardian is given by (dropping the index i referring to the single household for notational simplicity):

$$\left[(1-\tau_t^w)w_t l_t + (1-\tau_t^k)R_t^k \overline{k}_t u_t + D_t\right] + B_t + Tr_t + \frac{\tau_t^c}{1+\tau_t^c}P_t I_t = \tag{3}$$
$$\left[P_t c_t^R + P_t I_t + \frac{B_{t+1}}{R_t}\right] + \left[P_t \psi(u_t)\overline{k}_t + \frac{\varphi}{2}\left(\frac{w_t}{w_{t-1}} - \pi\right)^2 W_t\right]$$

where $[(1-\tau_t^w)w_t l_t]$ is net labor income, $\left[(1-\tau_t^k)R_t^k \overline{k}_t u_t\right]$ is net nominal income from renting capital services $k_t = \overline{k}_t u_t$ (where $\overline{k}_t$ are physical units of capital, while u_t is utilization intensity) to firms at the rate R_t^k, D_t are dividends distributed by firms to the Ricardians (who, by assumption, own the firms). The fiscal authority makes net lump sum transfers (Tr_t) and finances its expenditures by issuing one period maturity discount bonds (B_t) and by levying taxes on labor income (τ_t^w), capital income (τ_t^k) and consumption (τ_t^c)[6]. Consumption tax introduces a wedge between the price set by firms ($\widetilde{P}_t$) and the one faced by consumers $P_t = (1+\tau_t^c)\widetilde{P}_t$. In particular, since we assume that no indirect taxes are paid on purchases of investment goods, the price of investment should be equal to the wholesale price $\widetilde{P}_t$. However, for notational simplicity, we want to avoid having two price levels (P_t and $\widetilde{P}_t$) in the consumers' problem. Thus, we include among the uses (r.h.s. of the budget constraint) the investment expenditure expressed in prices gross of taxes ($P_t I_t$) and we add among the resources (l.h.s. of the budget constraint) a rebate equal to $\frac{\tau_t^c}{1+\tau_t^c}P_t I_t$, so that the difference between the two is equal to the actual expenditure on investment goods ($\widetilde{P}_t I_t$). Among the uses it is included 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 (as in Kim, 2000) and is expressed in terms of the equilibrium wage rate, W_t. 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 $\psi(u_t)$ where $\psi(1) = 0$. Hence $\psi(u_t)\overline{k}_t$ denotes the cost (in terms of consumption units) associated with the utilization level u_t.

[6] In this version, for simplicity and without significant effects on the results, we assume no taxes are levied on interest income on goverment bonds and on dividends. We assume also there are no depreciation allowances.

The physical capital accumulation law is

$$\overline{k}_{t+1} = (1-\delta)\,\overline{k}_t + \left[1 - s\left(\frac{\varepsilon_t^i I_t}{I_{t-1}}\right)\right] I_t \tag{4}$$

where not all new investment gets transformed into capital and the term $\left[1 \,{}_{\underline{t}}{}^{I_t}\, s\left(\frac{\varepsilon^i}{I_{t-1}}\right)\right] I_t$ describes (in terms of capital loss) the cost of adjustment the consumer incurs if he varies the investment level with respect to the previous period[7]. ε_t^i is a shock to the investment cost function, which is assumed to follow a first order autoregressive process as in (2). Investment and capital are expressed in units of the consumption good.

2.1.2 Non Ricardian households

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

$$c_t^{NR} P_t = (1-\tau_t^w) w_t l_t + Tr_t \tag{5}$$

2.2 Aggregations

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

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

as households within each of the two groups (Ricardian, R, and non Ricardian, NR) are identical. Therefore, aggregate consumption is given by:

$$C_t = (1-\gamma) C_t^R + \gamma C_t^{NR}$$

Moreover, since only Ricardian households hold bond, accumulate physical capital through investment, and receive dividends aggregate variables in per-capita terms are

[7] The function $s(.)$ has the following general properties (see, for example Christiano, Eichenbaum and Evans, 2005):

$$s(1) = s'(1) = 0$$
$$s''(1) > 0$$

given by the following identities:

$$B_t = (1-\gamma)B_t^R$$

$$K_t = (1-\gamma)K_t^R$$

$$I_t = (1-\gamma)I_t^R$$

$$D_t = (1-\gamma)D_t^R$$

2.3 Firms problem

Both types of consumers have a preference for variety such that:

$$c_t = \left[\int_0^1 c_t(j)^{\frac{\theta_c - 1}{\theta_c}} dj\right]^{\frac{\theta_c}{\theta_c - 1}} \tag{6}$$

where $c_t(j)$ is the consumption of the good produced by firm j. The maximization of c_t w.r.t. $c_t(j)$ leads to the following demand functions:

$$c_t(j) = \left(\frac{P_t}{p_t(j)}\right)^{\theta_c} c_t \tag{7}$$

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

$$P_t = \left[\int_0^1 p_t(j)^{1-\theta_c} dj\right]^{\frac{1}{1-\theta_c}} \tag{8}$$

There is a continuum of firms j producing differentiated final goods with the following Cobb-Douglas technology defined in terms of homogeneous labor input (defined as l_t^p, where the index p refer to the employment level in the private sector, since - as we will see below - we will introduce also employment in the public sector) and capital services rented from Ricardian households:

$$y_t(j) = k_t(j)^{\alpha}(l_t^p(j)\, z_t)^{1-\alpha} \tag{9}$$

where z_t is a shock that follows the process

$$\log(z_t) = (1-\rho_z)\log(\overline{z}) + \rho_z \log(z_{t-1}) + \eta_t \tag{10}$$

and $\overline{z}$ indicates the state value of z_t, while η_t is a white noise process.

From the solution of the firms cost minimization problem, we have that

$$l_t^p(j) = y_t(j)\left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{-\alpha} {z_t}^{\alpha-1} \tag{11}$$

$$k_t(j) = y_t(j)\left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{1-\alpha} {z_t}^{\alpha-1} \tag{12}$$

and the marginal cost in nominal terms is

$$MC_t = \zeta\frac{W_t^{1-\alpha}{R_t^k}^{\alpha}}{z_t^{1-\alpha}} \tag{13}$$

where $\zeta = \left[\frac{(1-\alpha)^{\alpha-1}}{\alpha^{\alpha}}\right]$.

Firms maximize profits defined as the difference between total revenues and total costs (inclusive of the price adjustment cost). That is, they solve the following problem:

$$\max_{\{\widetilde{p}_t\}} E_0\sum_{t=0}^{\infty}\beta^t\lambda_t\left(y_t(j)\widetilde{p}_t(j) - y_t(j)MC_t(j) - \frac{\kappa}{2}\left(\frac{\widetilde{p}_t(j)}{\widetilde{p}_{t-1}(j)} - \pi\right)^2\widetilde{P}_t y_t\right) \tag{14}$$

where $\beta^t\lambda_t$ is the utility weighted discount rate (based on the first order condition of the Ricardian households) and y_t is defined in (9). The tilde over prices indicates wholesale (producer) prices $\widetilde{p}_t\,(j)$ chosen by the firm, while the price paid by the final consumers includes indirect taxes. $\widetilde{P}_t$ denotes the market equilibrium producer price.

2.4 The labor market

The labor market plays a very important role in our model, as shocks to government expenditures on final goods and public employees affect aggregate variables mainly through their effects on labor market and agents' labor income (which translates directly into consumption for the non Ricardian households).

The market can be described as follows. A perfectly competitive firm, which we might call the labor packer, buys the differentiated individual labor services supplied by Ricardian and non Ricardian households and transforms them into an homogeneous composite labor input that, in turn, is sold to firms producing the final goods. This firm is basically a CES aggregator of differentiated labor services and solves the following problem:

$$\max_{l_t^p(i)} L_t^p = \left[\int_0^1 l_t^p(i)^{\frac{\theta_L-1}{\theta_L}}di\right]^{\frac{\theta_L}{\theta_L-1}} \tag{15}$$

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

for a given level of the overall wage bill $\overline{E}_t$. Note that we are assuming that non Ricardian households supply the same differentiated labor services as the Ricardian and that firms allocate their demand for each type of labor services i uniformly across both Ricardian and non Ricardian households. The solution gives the demands for each kind of differentiated labor service in the private sector $l_t^p(i)$:

$$l_t^p(i) = \left(\frac{W_t}{w_t(i)} \right)^{\theta_L} L_t^p \tag{16}$$

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

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

Each type i of Ricardian household is assumed to be wage setter for type i labor, by solving his optimization problem having regard of the labor demand constraint (16).

Type i non Ricardian household sets his 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 for Ricardian ones. This set of assumptions regarding the behavior of non Ricardian households in the labor market is the same as is Erceg et al. (2005) and very similar to the one adopted by Galí et al. (2005).

2.5 Fiscal policy

As for fiscal policy, we assume two alternative specifications. The first one assumes the government levies only lump-sum taxes. We label this specification as *standard*, since usually in the literature only policies on lump-sum taxes have been considered (see for example both Galí et al. (2005) and Coenen and Straub (2005)). Our *baseline* specification, however, recognizes that lump-sum taxes are generally not available and specifies the policy rules on distortionary tax rates.

2.5.1 Standard specification

In this specification we assume that only lump-sum taxes are available to policy makers. The government is responsible for choosing purchases of goods, hiring employees and distributing transfers (or net taxes). The government issues one period[8] nominal bonds to finance its primary deficit and interest payments, so that the stock of nominal government debt B_t evolves according to:

$$\left[\frac{B_{t+1}}{R_t} - B_t\right] = C_t^g + W_t L_t^g - NT_t \tag{17}$$

where C_t^g is government expenditures on final goods and services, $W_t L_t^g$ is compensation for public employees. Note that the sum of this two items corresponds to the NA definition of government consumption G_t, which is the variable usually used to proxy government purchases of goods and services. NT_t are net lump sum taxes, defined as the difference between lump-sum revenues (T_t) and transfer to households (TR_t).

In the literature it is usually assumed that G_t (in real terms) follows an exogenous autoregressive process, while - on the revenue side - that the government adopts a policy function on net taxes NT_t. In this case government expenditures follow the process:

$$g_t = \rho_{cg} g_{t-1} + \left(1 - \rho_g\right) g + \varepsilon_t^g \tag{18}$$

where $g_t = \log(G_t/P_t)$, g is the exogenously assumed steady state level and ε_t^g is an i.i.d. error term. In section 5 below, where we present our estimation results, this setup is labelled as specification A.

However, we also model public employment and government consumption of goods and services separately (specification B). In particular, we assume a specific exogenous process for each of the two components:

$$c_t^g = \rho_{cg} c_{t-1}^g + \left(1 - \rho_{cg}\right) c^g + \varepsilon_t^{cg} \tag{19}$$

$$l_t^g = \rho_{\mathrm{lg}} l_{t-1}^g + \left(1 - \rho_{\mathrm{lg}}\right) l^g + \varepsilon_t^{\mathrm{lg}} \tag{20}$$

where $c_t^g = \log(C_t^g/P_t)$, $l_t^g = \log(L_t^g)$, c^g and l^g are exogenously given steady state values, ε_t^{cg} and $\varepsilon_t^{\mathrm{lg}}$ are i.i.d. error terms. We assume that the wage paid by the government to the households, W_t, is the same that households receive from the private sector firms[9]. This goes together with the assumption that hours can be moved costlessly across the two sectors and that l_t^g and l_t^p are perfect substitutes in the utility function (which in fact we have defined in terms of total labor supply, $L_t = L_t^g + L_t^p$). This set up is very similar to the one considered by Cavallo (2005), although in a different context.

[8]Considering one period bonds is not very restrictive, see Benigno and Woodford (2006).

[9]Note that this assumption is not far from reality. In fact, hourly wages in the public sector tend to track private sector ones.

As for the fiscal rule, in this standard specification we follow previous work, in particular Galí et al. (2005) and Coenen and Straub (2005)), and consider a rule defined over lump-sum taxes (or transfers). These are assumed to respond to the level of debt and of government expenditures:

$$nt_t = \rho_{tr} nt_{t-1} + (1 - \rho_{tr}) \left[nt + \phi^b_{tr} b_t + \phi^g_{tr} s_t \right] + \varepsilon^{nt}_t \tag{21}$$

where $nt_t = \log(NT_t/P_t)$, $b_t = \log(B_t/P_t)$, $s_t = \log(S_t/P_t)$, where either $S_t = G_t$ (specification A) or $S_t = C^g_t + W_t L^g_t$ (specification B). nt is the steady state value and ε^{nt}_t is assumed to be i.i.d..

Under rule (21) the government stabilizes the debt level (in real terms) using lump-sum taxes. Such a policy would have no real effect in an economy populated only by Ricardian households.

2.5.2 Our baseline specification

In our baseline specification, the government can levy only distortionary taxes. As in the standard specification, the government issues one period nominal bonds to finance its primary deficit and interest payments, so that the stock of nominal government debt B_t evolves according to:

$$\left[\frac{B_{t+1}}{R_t} - B_t \right] = C^g_t + W_t L^g_t + TR_t - T_t \tag{22}$$

where now on the r.h.s. of the government budget constraint it appears the term T_t, which indicates overall government revenues. These are given by the following identity:

$$T_t = \tau^w_t w_t l_t + \frac{\tau^c_t}{1 + \tau^c_t} \left[P_t C_t + G_t \right] + \tau^k_t R^k_t k_t$$

where G_t is equal to C^g_t in our baseline specification (specification D), where we model C^g_t and L^g_t separately as in (19) and (20). As in the case with lump-sum taxes, we also consider the case (specification C) in which G_t is treated entirely as government consumption following the exogenous process (18).

Tax rates on labor income, capital income and consumption are decided by the government following similar rules to the one assumed for the lump-sum net taxes, that is:

$$\tau^w_t = \rho_{\tau^w} \tau^w_{t-1} + (1 - \rho_{\tau^w}) \left[\tau^w + \phi^b_{\tau^w} b_t + \phi^g_{\tau^w} s_t \right] + \varepsilon^{\tau^w}_t \tag{23}$$

$$\tau^c_t = \rho_{\tau^c} \tau^c_{t-1} + (1 - \rho_{\tau^c}) \left[\tau^c + \phi^b_{\tau^c} b_t + \phi^g_{\tau^c} s_t \right] + \varepsilon^{\tau^c}_t \tag{24}$$

$$\tau_t^k = \rho_{\tau^k}\tau_{t-1}^k + (1-\rho_{\tau^k})\left[\tau^k + \phi_{\tau^k}^b b_t + \phi_{\tau^k}^g s_t\right] + \varepsilon_t^{\tau^k} \qquad (25)$$

where τ are log tax rates, $s_t = \log(S_t/P_t)$, $S_t = G_t + TR_t$ in specification C and $S_t = C_t^g + W_t L_t^g + TR_t$ in our baseline (specification D). $\varepsilon_t^{\tau^w}$, $\varepsilon_t^{\tau^c}$ and $\varepsilon_t^{\tau^k}$ are i.i.d. errors terms. Since in this case tax rates are the policy instruments, we need to make an assumption regarding the behavior of transfers, TR_t. We assume transfers follows a standard exogenous process:

$$tr_t = \rho_{tr} tr_{t-1} + (1-\rho_{tr})\, tr + \varepsilon_t^{tr} \qquad (26)$$

where $tr_t = \log(TR_t/P_t)$, tr is an exogenously given steady state value and ε_t^{tr} is i.i.d..

As for steady state values, we assume $G = 30\%$ of GDP, $C^g = 10\%$, $B = 50\%$ on a yearly basis (equal to 2 on a quarterly basis) and L^g equal to 20% of total employment L. 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 20% for consumption and capital income taxes, 40% for labor income taxes). Given these steady state values, from the government budget constraint we obtain as a residual the steady state values of either net taxes (equal approximately to 30% of steady state GDP in both specification A and B) or transfers (around 20% in specification C and 10% in specification D).

Our fiscal policies do not allow taxes to respond to cyclical conditions. While in general there is consensus that debt stabilization is an important motive in the conduct of fiscal policy, it is less clear whether revenues or expenditures respond to cyclical conditions (measured for example by the output gap). The evidence is not unambiguous in this respect, as Galí and Perotti (2003) document. It is more supportive of the stabilization role of fiscal policy when estimates are conducted using real time data, as Forni and Momigliano (2004) show. However, these papers estimate fiscal rules where the public deficit responds to the output gap on a yearly basis. It is more difficult to find responses to the cycle for revenues and expenditures separately and on a quarterly basis. As a robustness check, we have run some preliminary experiments augmenting our policies with the gap between output and its steady state value. We find that the coefficients relating revenues to the gap are hardly identified and in general small enough not to affect significantly the results.

2.6 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 contemporaneous responses of the nominal rate R_t to deviations from steady state values of lagged inflation π_{t-1}, contemporaneous inflation change $\Delta\pi_t$, output y_t and output growth Δy_t . In log-linear terms,

$$\widehat{R}_t = \rho_R \widehat{R}_{t-1} + (1-\rho_R)(\rho_\pi \widehat{\pi}_{t-1} + \rho_y \widehat{y}_t) + \rho_{\Delta\pi}\Delta\widehat{\pi}_t + \rho_{\Delta y}\Delta\widehat{y}_t + \widehat{\varepsilon}_t^m \tag{27}$$

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

2.7 Market clearing conditions

Equilibrium in the goods market requires:

$$y_t = {k_t}^\alpha (l_t^p z_t)^{1-\alpha} = C_t + I_t + C_t^g + ADJ_t \tag{28}$$

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

$$ADJ_t = \frac{\varphi}{2}\left(\frac{w_t}{w_{t-1}} - \pi)\right)^2 \frac{W_t}{P_t} + \psi(u_t)\overline{k}_t + \frac{\kappa}{2}\left(\frac{\widetilde{P}_t}{\widetilde{P}_{t-1}} - \pi\right)^2 y_t$$

Market clearing conditions in the labor and capital markets are obtained by setting firms' demands for labor and capital, (11) and (12), equal to households' supply. For capital this implies:

$$k_t = \left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{1-\alpha} {z_t}^{\alpha-1} y_t \tag{29}$$

Employment in the private sector is given by:

$$L_t^p = \left(\frac{W_t}{R_t^k}\frac{\alpha}{1-\alpha}\right)^{-\alpha} {z_t}^{\alpha-1} y_t$$

while total labor is given by:

$$L_t = L_t^p + L_t^g$$

3 Solution of the model

The model has been solved using linear techniques. To that end all the equations of the model have been linearized by taking a first-order log-linear approximation around the deterministic steady state. First order conditions and their log-linearizations are reported in Appendix A and C respectively. Stacking all the relevant variables of the model in the vector X_t and using lower-case to denote log deviations from the steady state (i.e. $x_t \equiv \log(X_t) - \log(X)$) we can write the model as

$$AE_t\left(x_{t+1}\right) = Bx_t + Cz_t \tag{30}$$

$$E_t\left(z_{t+1}\right) = Sz_t \tag{31}$$

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. This system is then solved using one of the algorithms currently available for the solution of a linear rational expectations system. The solution takes the following state-space representation:

$$k_t = Mk_{t-1} + Nz_t$$
$$y_t = Pk_t + Qz_t$$

where k_t contains the predetermined (state) variables in the model and y_t the non-predetermined ones.

4 Estimation

We estimate our DSGE model using Bayesian inference methods, following SW. In particular we specify a prior distribution for each parameter to be estimated relying on information from earlier studies. Using prior information seems very reasonable, in particular when the period covered by the data is not very long as in our case. Moreover, using priors helps in reducing the numerical difficulties associated with a highly non linear estimation problem such as ours.

4.1 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 from a minimum of 31 to a maximum of 43 parameters to estimate depending on the specification). In order to obtain numerically a sequence from this unknown posterior distribution, we follow Schorfheide (2000) and SW and employ the Metropolis-Hasting algorithm.

4.2 Data and prior distribution

We use data on consumption, investment, wages, inflation and nominal interest rate. As for public sector variables, we use government consumption, transfers, public employment, tax rates on labor 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 obtain quarterly variables from annual ones and, for these latter series, we provide 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 in the model.

As for the prior distributions, we calibrated five 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%). We set both $\theta_c = \theta_l = 8.5$, which implies a steady state mark-up approximately equal to 13% for both prices and wages. We decided to calibrate these latter two parameters as it is difficult to jointly identify them and the adjustment cost parameters on prices and wages (φ and κ).

Table 1 shows the 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, both with a mean of 2 and a standard deviation of 0.25, so that both prior masses are concentrated on values slightly 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 Galí *et al.* (2005), and the habit coefficient h, whose mean is set at 0.7 as estimated on US data in Boldrin *et al.* (2001), are distributed according to a Beta distribution. In both cases a standard deviation of 0.1 as in e.g. Coenen-Straub (2005) guarantees that a large part of the admissible support is a priori spanned.

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 four quarters for both wages and prices (i.e. the average frequency for prices in the euro area according to the recent survey by Dhyne *et al.* (2005))[10]. The range covered by the prior distributions of both parameters is chosen so to span approximately from less than half to double the 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.

A Beta distribution is chosen for all the remaining parameters whose value is included between 0 and 1. One example are the autoregressive coefficients of the non-policy shocks, whose mean and standard deviation are set at 0.85 and 0.1 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 as in SW, the only exception being ρ_π, the coefficient measuring the response of the nominal rate to lagged inflation. For this parameter we assume a Gamma distribution (SW consider a normal distribution), with a 1.8 mean and a 0.01 standard deviation, resulting in a smaller a priori span centered on similar values to the ones assumed in SW. The autoregressive coefficient for the nominal rate ρ_R has a Beta distribution with a 0.8 mean as in SW but with a smaller standard deviation. The coefficients on output, output growth and on the

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

change in inflation are all normally distributed with a higher mean and a larger variance with respect to SW.

The policies on tax rates are a priori taken to be quite persistent, with an autoregressive coefficient distributed as a Beta with mean 0.8 and standard deviation equal to 0.1. Coefficients on the debt level and on expenditures, which represent the elasticities of the tax rates with respect to these variables, are all assumed to be distributed as a Gamma with mean 0.5 and standard deviation equal to 0.1.

The innovations to fiscal and monetary policies are assumed to be white noises with standard deviation distributed as Gamma with mean 0.1 and standard deviation equal to 0.02. This latter assumption guarantees a proper identification of the structural shocks from the policy ones. In particular, were the shock to the tax rules persistent, it would be difficult in our set up to disentangle the labor income tax rate shock from, for example, the preference shocks, or the capital tax rate shock from the investment one, as these shocks have similar effects on the economy. On the other hand, it would be difficult to believe that innovations to the tax rates on a quarterly basis are the main drivers of macroeconomic aggregates.

5 Estimation results

In this section we report estimation results for the different specifications regarding fiscal policy that we have outlined in section 2.5. To recap, we start from the simple specification where only lump-sum taxes exist (specification A in Table 2, where we summarize our estimation results), which is the set up assumed in previous work (i.e. Galí et al. (2005) and Coenen and Straub (2005)). We then take into account the fact that the NA definition of government consumption includes both expenditures on final goods/services and compensations for public employees, and model government employment as a specific process, while still assuming lump-sum taxes (specification B in Table 2). Then we consider two additional models where we simply move from lump-sum taxes to distortionary taxes (specification C and D). Model D is the one we consider as our benchmark, not only because we believe to be the more realistic, but also as it displays the higher marginal likelihood (reported in the last line of Table 2). Moreover, the model displays a good fit (Figure 1).

The estimates are obtained from the Metropolis-Hastings algorithm with 100,000 iterations and prior distributions as described in Table 1. The number of iterations seems to be sufficient to achieve convergence. With reference to our baseline specification (model D), Figure 1 plots the cumulated mean and standard deviation of the parameters (normalized with the long-run standard deviation), while Figure 2 plots prior and posterior distributions for the same set of parameters (excluding the monetary policy ones).

Overall, most parameters seems 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. In particular, the price adjustment cost, φ, and the wage adjustment cost, κ, seem to be extremely well identified. In fact, the sequences for these two parameters obtained from the Metropolis-Hastings hardly move, so that the variance of their posterior is extremely small (in particular when compared to the one of the prior). This very small variance of the posterior distribution explains also the plots of the cumulated means and standard deviations for these two parameters, as it appears at the denominator (as a normalization) of both measures.

On the other hand, some of the parameters of the fiscal policies seem not to be well identified. While in fact the posteriors of the autocorrelation coefficients are centered around values close to one (the exception being the autocorrelation coefficient for the capital tax rate), the only coefficient on the debt that seems to be well identified is the one on the labor income tax rate. This is not surprising as labor income tax rates include social security contributions. These have been increasing in the last twenty years in order to keep under control the social security deficits, which have been at the heart of the growth in the public debt in most European countries. Based on our estimates, the elasticities of tax rates with respect to expenditures are well identified with a mean around 0.4-0.5. This would suggest that on average an increase in total government expenditures of 1% has been accompanied by an increase of 0.4-0.5% in tax rates.

Table 2 summarizes estimated means and standard deviations for a selection of the parameters for our four specifications regarding fiscal policy. We note right away that the estimated mean of several important parameters does vary significantly from one specification to the other. In particular, moving from specification A to D, we note that the value of γ increase dramatically, from 0.12 to 0.70. Values of γ so different have significantly different implications regarding the effects of fiscal policy shock on the economy.

Other parameters do vary, but with a different pattern with respect to γ. For example, σ_c decreases significantly when we model public employment as a specific process (from model A to B, or from C to D), but not so much when we move from lump-sum to distortionary taxes (from A to C, or B to D). Similarly, the habit parameter h increases when we introduce public employment, but does not change substantially when we move from lump-sum to distortionary taxes.

Among the frictions, the estimates of the investment adjustment cost, s'', and of the capital utilization adjustment cost, ψ''/ψ', are rather stable across specification, while the price and wage adjustment cost parameters display some variation. The price friction on producer prices κ is, not surprisingly, estimated to be lower when we introduce distortionary taxation, since this includes consumption taxes, and part of the dynamics in prices gets captured by the dynamics in indirect taxes. Moreover, while in models with a unique process for government expenditures prices are estimated to be stickier than wages, the opposite occurs when we introduce a specific process for compensations of public employees. This happens on account of the larger variability of employment and wages in the latter model, where public employment shocks induce changes in employment in the private sector and hence in wages for all workers in the economy. For a relatively low variability in the detrended data series for wages, the model can replicate the data only for a higher value of the wage stickiness parameter φ.

Finally, we see that the estimated values of the monetary and fiscal policy parameters are rather stable across specifications. For the autocorrelation coefficient on the interest rate, ρ_R, and the coefficient on inflation of the Taylor rule, ρ_π, this partly reflects the rather tight priors that we have assumed. For the fiscal policy parameters, in all specification we have a very high autocorrelation parameter and, within lump-sum and distortionary taxation models respectively, broadly similar elasticities of taxes to the level of debt and of expenditures. As we have already pointed out, however, not all these parameters are well identified.

6 General equilibrium effects of government spending shocks

We now discuss the implications of our estimates regarding the effects of government spending shocks on the economy. We make use of our benchmark specification (model D). In this specification we can consider at least three types of spending shocks: innovations to government consumption properly defined (C_t^g), to government employment (L_t^g) and to a combination of these two shocks. Although we do not know in which proportions innovations to C_t^g and L_t^g would combine, we consider a combined shock weighting the shocks to the two components with their average share over the sample period (approximately, 60% for L_t^g and 40% for C_t^g).

Figure 4 shows impulse responses with respect to a shock to C_t^g, Figure 5 with respect to a shock to L_t^g and Figure 6 with respect to the combination of the two. Shocks are assumed to be equal to one standard deviation of the corresponding variable.

We can immediately observe that all shocks increase labor demand. The shock to spending does that by increasing demand for goods and services which, in turn, brings about an increase in demand for labor. On the other hand, the shock to government employment directly increases labor demand and determines an increase in both employment and real wages, and thus in labor income of both Ricardian and non Ricardian households.

In the case of a shock to C_t^g, the consumption response of Ricardian households is the (by now) well known one. They work more and consume less. The reduction in consumption is partly offset by a reduction in investment. In the case of a shock to L_t^g, the short-run response of Ricardian households is much more contained. In this latter case, the negative wealth effect coming from the higher future taxes is mitigated by the increase in labor productivity in the private sector due to the decrease in employment in that sector (in the case of a spending shock, on the contrary, private sector employment increases). In fact, after a shock to L_t^g, overall labor supply will increase, but not as much as to accommodate the entire increase in government employment. The reduction in private sector employment leads to a contraction in output and investment. The contraction in investment is quite long lasting, freeing resource for a smooth increase of Ricardian consumption.

Therefore, after an increase in government employment, the more muted increase in non Ricardian consumption relative to when public spending goes up (as the increase in labor income is more contained) is compensated by the fact that Ricardian households consumption does not fall (while it decreases after a standard increase in government spending). Given these differences in the response of output, investment and of Ricardian and non Ricardian consumption to the two shocks, it is not surprising that modelling public employment explicitly might lead to very different estimates of important parameters of the model.

Regardless of these differences, both shocks determine an increase in aggregate consumption. In particular, based on our estimates, a 1% of GDP increase in public consumption would bring about a 0.5% increase in total private consumption; a similar increase would be obtained with a 1% increase in public employment.

The effects of the combined shock is shown in Figure 6. Although this figure is obtained under a simplistic assumption regarding the way shocks to C_t^g and L_t^g actually combine, it is evident that the positive response of private consumption would be obtained under a wide range of hypothesis.

7 Interaction of fiscal and monetary policy [to be completed]

Perotti (2002), 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. This seem rather counter intuitive, unless one is willing to assume that either fiscal shocks do not have relevant effects on prices and output or that the monetary authority does not respond to prices and output variations originating from fiscal policy shocks (may be because it believes these are transitory). Our estimates suggest that fiscal shock have an effect on both output and prices. Moreover, regarding prices, there is ample evidence that fiscal shocks (both on the revenues and expenditures sides) have a significant, although not very strong, effect.[11]

In order to deepen our understanding of this issue, we experimented with different specifications of the monetary policy rule in order to see whether or not our results change. If they don't, we would probably agree with the statement of Perotti (2002).

In our baseline model we maintained a Taylor rule specified in terms of lagged inflation and where the output gap is a statistically computed measure rather than the deviation of output from the level obtained in the flexible price equilibrium. Canova (2005) has shown, although with reference to the US, that this specification is robust to the sample period considered and fits the data better than alternative specifications. We therefore first played with the variances of the priors on the parameters of our assumed Taylor rule in order to see how informative the data are on those parameters. Subsequently we considered alternative specifications of the Taylor rule.

[11] On this issue, see for example Canova and Pappa (2005) or Hernandez de Cos et al. (2003).

8 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 new-keynesian general equilibrium model and estimated its structural parameters through Bayesian techniques. As most part of the euro area official data on the 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 main result is that the estimates of important parameters of the model differ depending on how detailed the fiscal policy is modelled. In particular, when we take into proper consideration the fact that taxes are distortionary and that government expenditures is a composite aggregate (including consumption of goods and compensations for government employees), the estimated share of non Ricardian agents is significantly higher than previously estimated and the model is able to replicate the widespread evidence that private consumption responds positively to government expenditures shocks.

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. (2005) have shown - in a two country model where both areas share the main features as our model (in particular the presence of non Ricardian households) - that the negative wealth effects on Ricardian households of a government spending shock is dampened, although not eliminated, by the possibility for these households to borrow abroad. This result suggests that the external channel might even reinforce our finding that aggregate consumption increases after a government spending shock.

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Table 1: Prior distributions

Parameter		Distribution	Mean	Variance
Preferences				
inverse intertemporal substitution elasticity	σ_c	Gamma	2	0.0625
inverse labor supply wage elasticity	σ_l	Gamma	2	0.0625
fraction of non Ricardian	γ	Beta	0.5	0.01
habit parameter	h	Beta	0.7	0.01
Frictions				
investment adjustment cost	s''	Gamma	5	0.0625
price adjustment cost	φ	Gamma	100	500
wage adjustment cost	κ	Gamma	100	500
capital utilization adjustment cost	ψ''/ψ'	Gamma	0.2	0.01
Policy				
interest rate AR coeff.	ρ_R	Beta	0.8	0.0001
inflation coeff.	ρ_π	Gamma	1.8	0.0001
output coeff.	ρ_y	Normal	0.2	0.1
inflation change coeff.	$\rho_{\Delta\pi}$	Normal	0.5	0.1
output growth coeff.	$\rho_{\Delta y}$	Normal	0.5	0.1
labor tax rate AR coeff.	ρ_{τ^w}	Beta	0.8	0.01
labor tax rate debt coeff.	$\phi^b_{\tau_w}$	Gamma	0.5	0.01
labor tax rate Gov. expenditure coeff.	$\phi^g_{\tau_w}$	Gamma	0.5	0.01
consumption tax rate AR coeff.	ρ_{τ^c}	Beta	0.8	0.01
consumption tax rate debt coeff.	$\phi^b_{\tau_c}$	Gamma	0.5	0.01
consumption tax rate Gov. expend. coeff.	$\phi^g_{\tau_c}$	Gamma	0.5	0.01
capital tax rate AR coeff.	ρ_{τ^k}	Beta	0.8	0.0001
capital tax rate debt coeff.	$\phi^b_{\tau_k}$	Gamma	0.5	0.01
capital tax rate Gov. expend. coeff.	$\phi^g_{\tau_k}$	Gamma	0.5	0.01
Shocks				
productivity shock AR coeff.	ρ_z	Beta	0.85	0.01
intertemporal preference shock AR coeff.	ρ_{ε^b}	Beta	0.85	0.01
intratemporal preference shock AR coeff.	ρ_{ε^l}	Beta	0.85	0.01
investment efficiency shock AR coeff.	ρ_{ε^i}	Beta	0.85	0.01
Government employment shock AR coeff.	ρ_{l_g}	Beta	0.85	0.01
Government expenditure shock AR coeff.	ρ_g	Beta	0.85	0.01
transfers shock AR coeff.	ρ_{tr}	Beta	0.85	0.01
productivity shock st. dev.	σ_z	Gamma	0.1	0.0004
intertemp. pref. shock st. dev.	σ_{ε^b}	Gamma	0.1	0.0004
intratemp. pref. shock st. dev.	σ_{ε^l}	Gamma	0.1	0.0004
investment effic. shock st. dev.	σ_{ε^i}	Gamma	0.1	0.0004
Government employment shock st. dev.	σ_{l_g}	Gamma	0.1	0.0004
Government expenditure shock st. dev.	σ_g	Gamma	0.1	0.0004
transfers shock st. dev.	σ_{tr}	Gamma	0.1	0.0004
labor tax shock st. dev.	$\sigma_{\varepsilon^{\tau^w}}$	Gamma	0.1	0.0004
consumption tax shock st. dev.	$\sigma_{\varepsilon^{\tau^c}}$	Gamma	0.1	0.0004
capital tax shock st. dev.	$\sigma_{\varepsilon^{\tau^k}}$	Gamma	0.1	0.0004
monetary policy shock st. dev.	σ_{ε^m}	Gamma	0.1	0.0004

Table 2: Posterior means and standard deviations for selected parameters

	Lump sum taxes				**Distortionary taxes**			
	A Compensations of employees as part of Government consumption		**B** Government employees as a specific process		**C** Compensations of employees as part of Government consumption		**D** Government employees as a specific process	
	mean	st.dev.	mean	st.dev.	mean	st.dev.	mean	st.dev.
Preferences								
σ_c	2.34	0.02	0.81	0.12	1.83	0.02	0.56	0.05
σ_l	1.67	0.17	1.44	0.04	1.51	0.01	2.65	0.04
γ	0.12	0.03	0.28	0.05	0.39	0.01	0.70	0.02
h	0.79	0.02	0.96	0.02	0.76	0.02	0.98	0.01
Frictions								
s''	4.99	0.08	4.63	0.08	4.54	0.02	4.52	0.02
φ	143.76	0.00	131.29	0.01	108.74	0.00	207.32	0.01
κ	150.36	0.00	107.92	0.01	137.00	0.01	77.93	0.01
ψ''/ψ'	0.18	0.04	0.20	0.02	0.31	0.03	0.33	0.02
Policy coefficients								
ρ_R	0.81	0.01	0.82	0.01	0.82	0.01	0.82	0.01
ρ_π	1.80	0.01	1.80	0.01	1.80	0.01	1.80	0.01
ρ_y	-0.05	0.01	0.13	0.04	0.06	0.02	0.13	0.02
$\rho_{\Delta\pi}$	1.20	0.02	0.36	0.11	1.29	0.04	0.20	0.01
$\rho_{\Delta y}$	-0.02	0.02	0.04	0.06	0.08	0.02	0.00	0.02
ρ_{tr}	0.99	0.00	0.99	0.00				
ϕ^b_{tr}	0.24	0.04	0.12	0.02				
ϕ^g_{tr}	0.47	0.08	0.60	0.11				
ρ_{τ^w}					0.96	0.01	0.98	0.00
$\phi^b_{\tau^w}$					0.19	0.02	0.34	0.01
$\phi^g_{\tau^w}$					0.52	0.03	0.46	0.01
ρ_{τ^c}					0.99	0.00	0.99	0.00
$\phi^b_{\tau^c}$					0.47	0.04	0.42	0.06
$\phi^g_{\tau^c}$					0.50	0.03	0.47	0.01
ρ_{τ^k}					0.81	0.01	0.82	0.01
$\phi^b_{\tau^k}$					0.45	0.01	0.50	0.05
$\phi^g_{\tau^k}$					0.52	0.02	0.49	0.02
Acceptance rate	44.25%		36.91%		34.03%		27.91%	
Marginal likelihood	2513.1		2653.6		3655.3		3714.8	

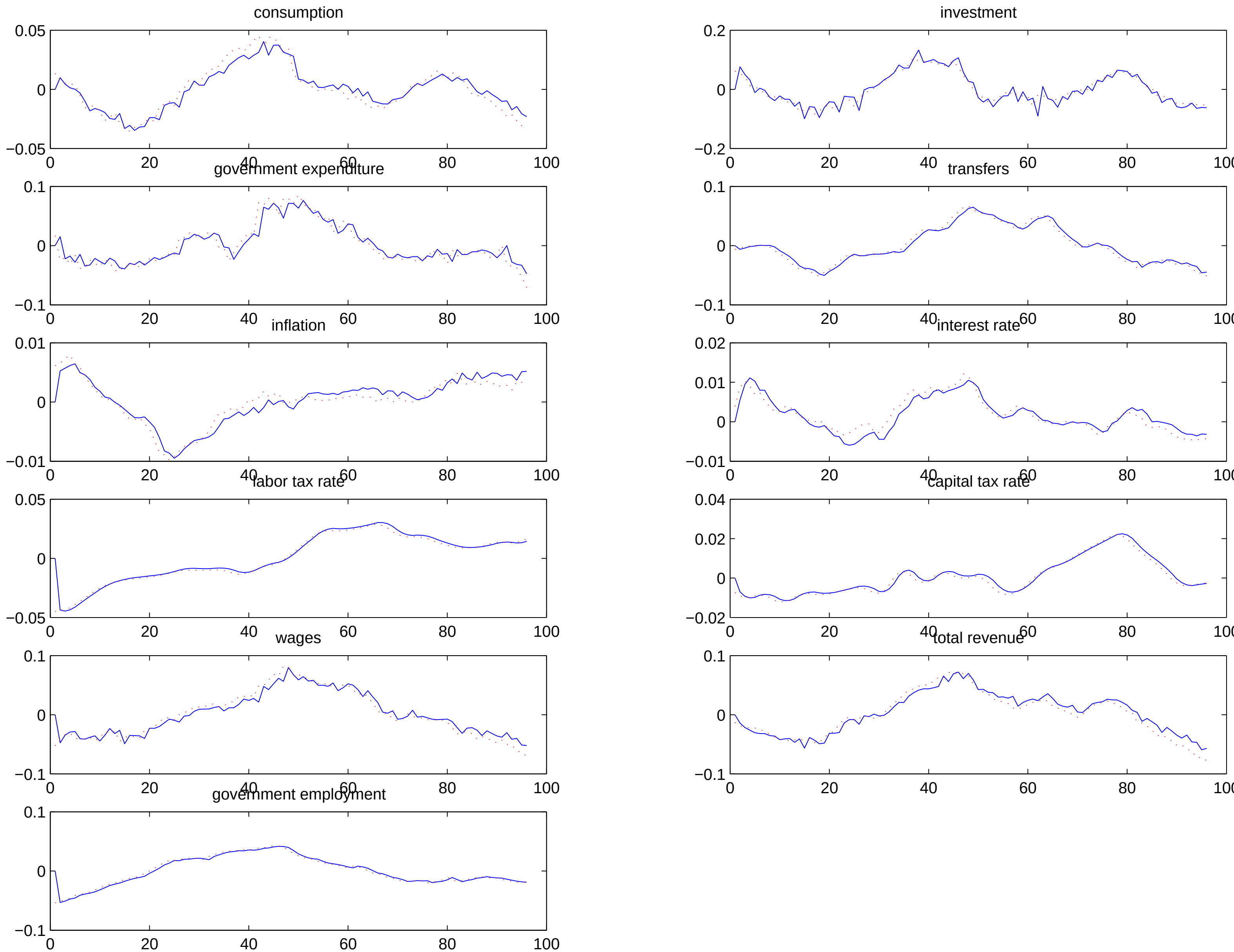


Figure 1: Model fit after MH procedure: data (solid line) vs. model (dashed line)

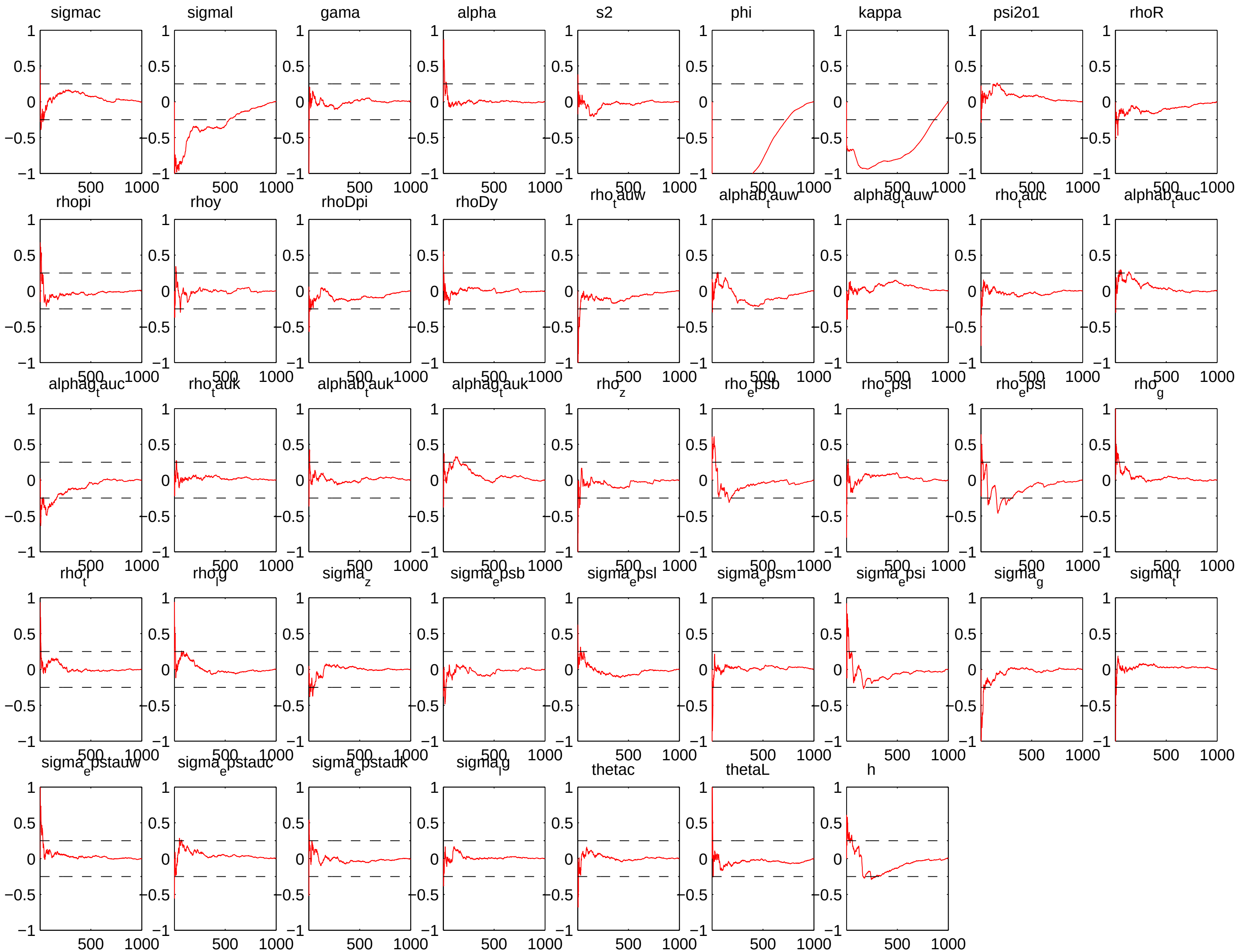


Figure 2:1 Convergence of parameters in MH procedure - means

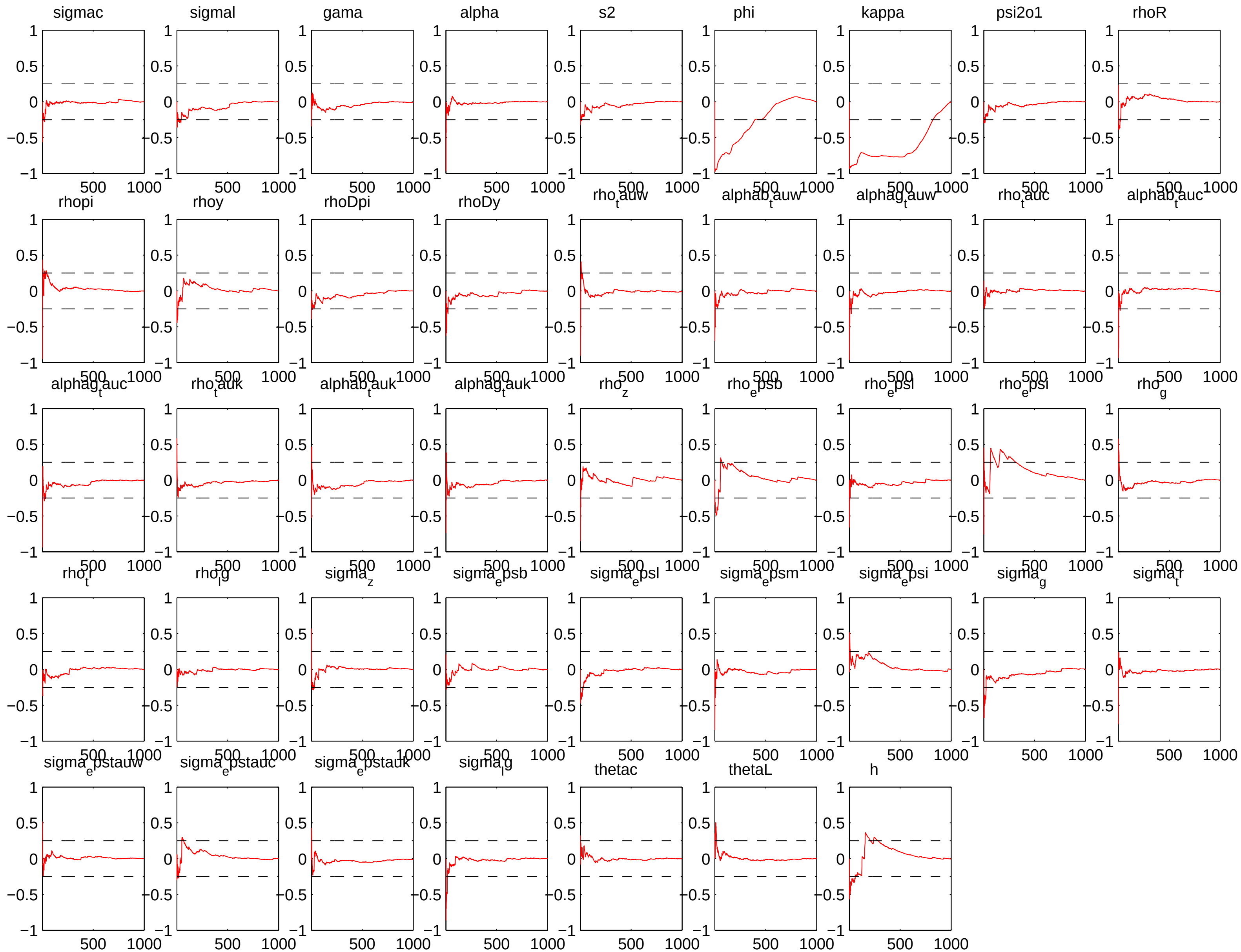


Figure 2.2 Convergence of parameters in MH procedure - standard deviations

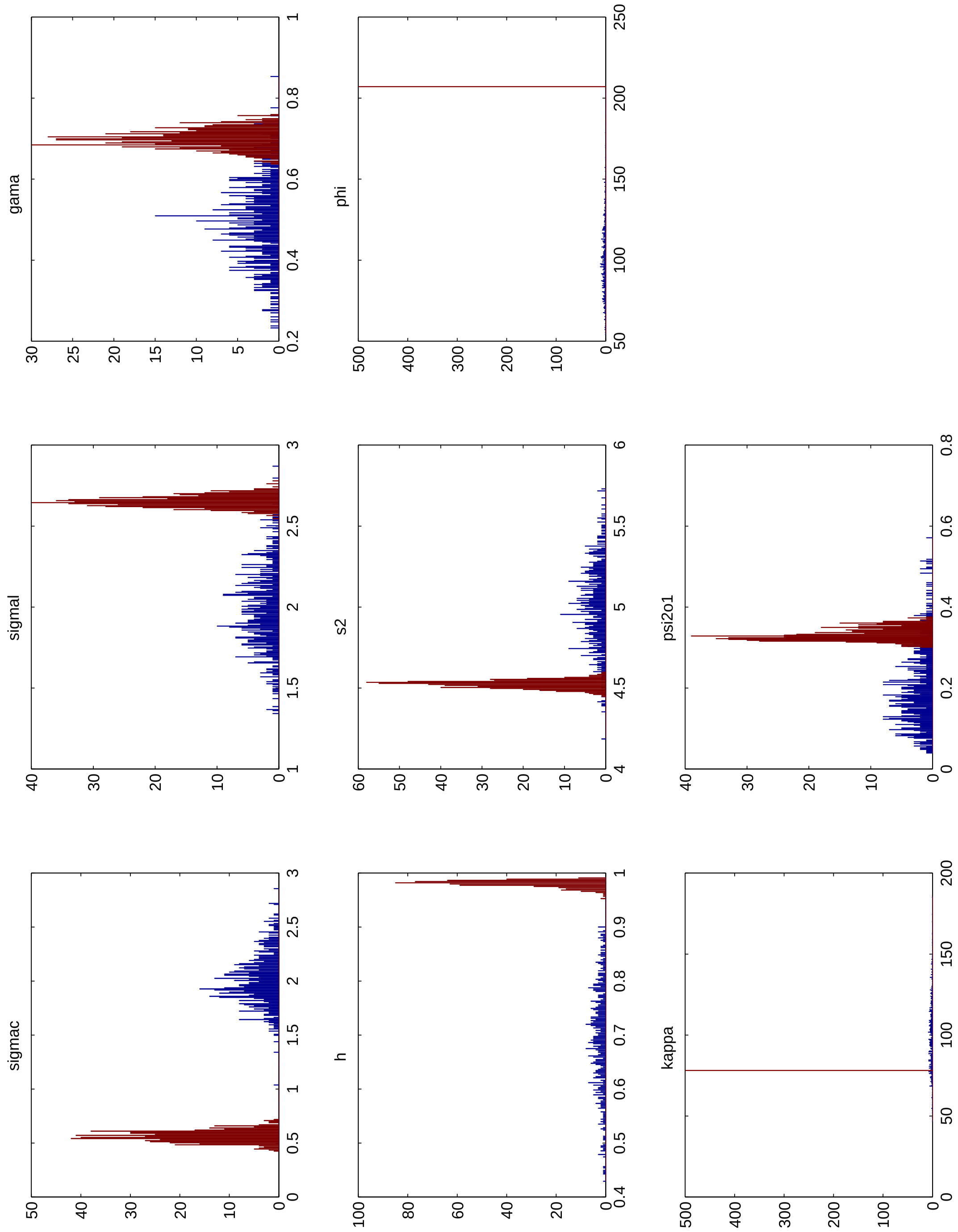


Figure 3:1 Prior (blue/darker) vs. posterior (red/brighter) distributions in MH procedure

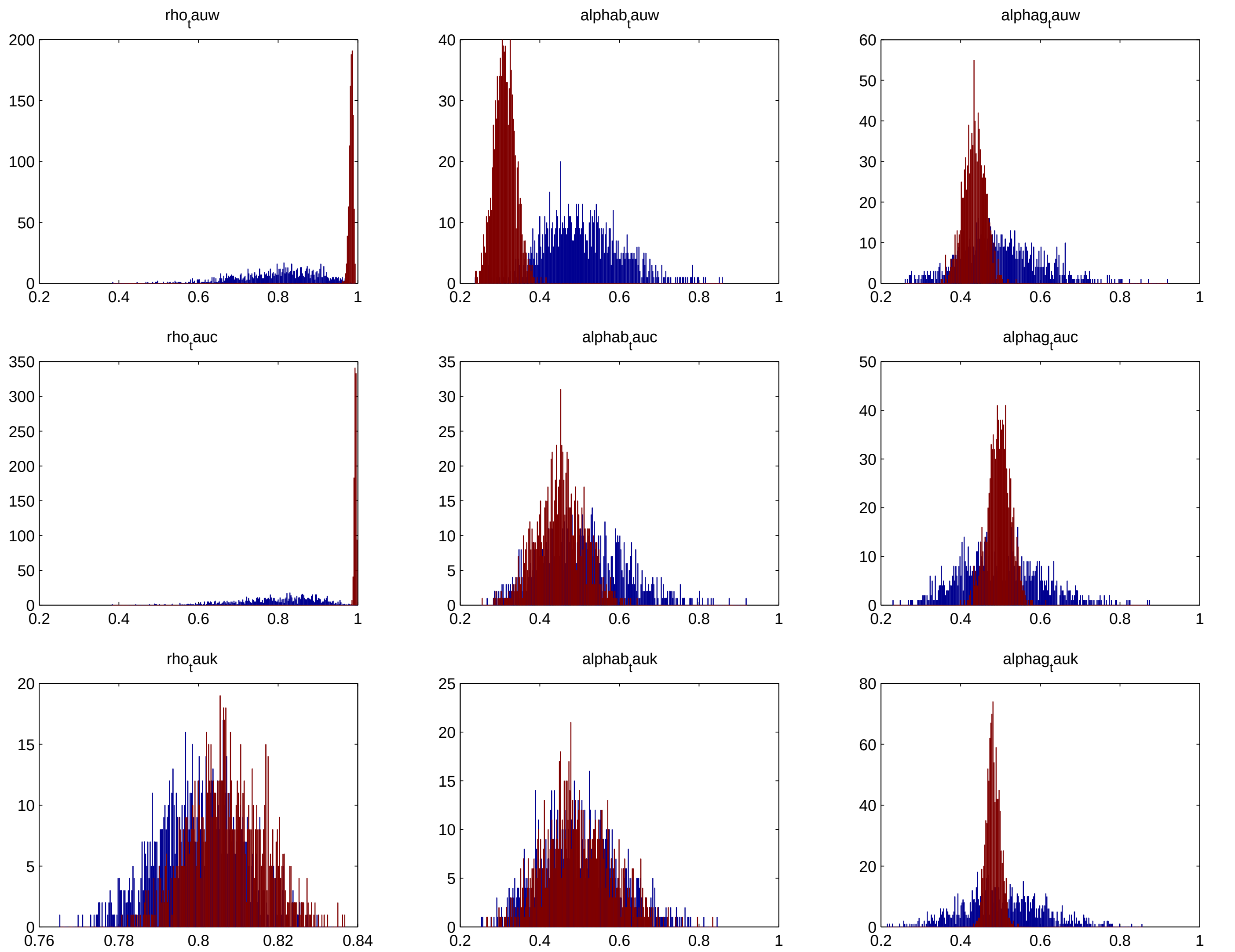


Figure 3.2 Prior (blue/darker) vs. posterior (red/brighter) distributions in MH procedure

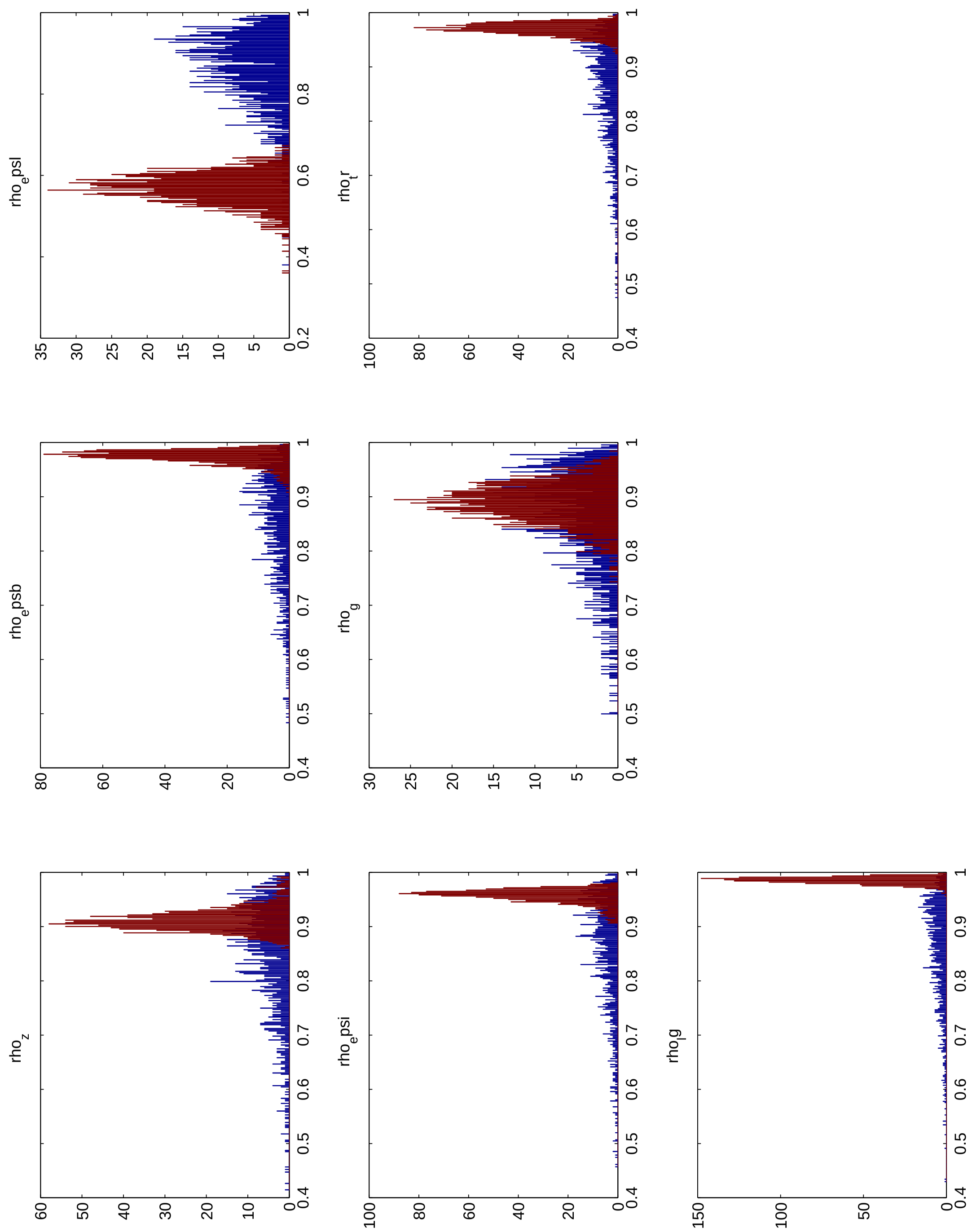


Figure 3:3 Prior (blue/darker) vs. posterior (red/brighter) distributions in MH procedure

Figure 4: Impulse responses from a government expenditure shock

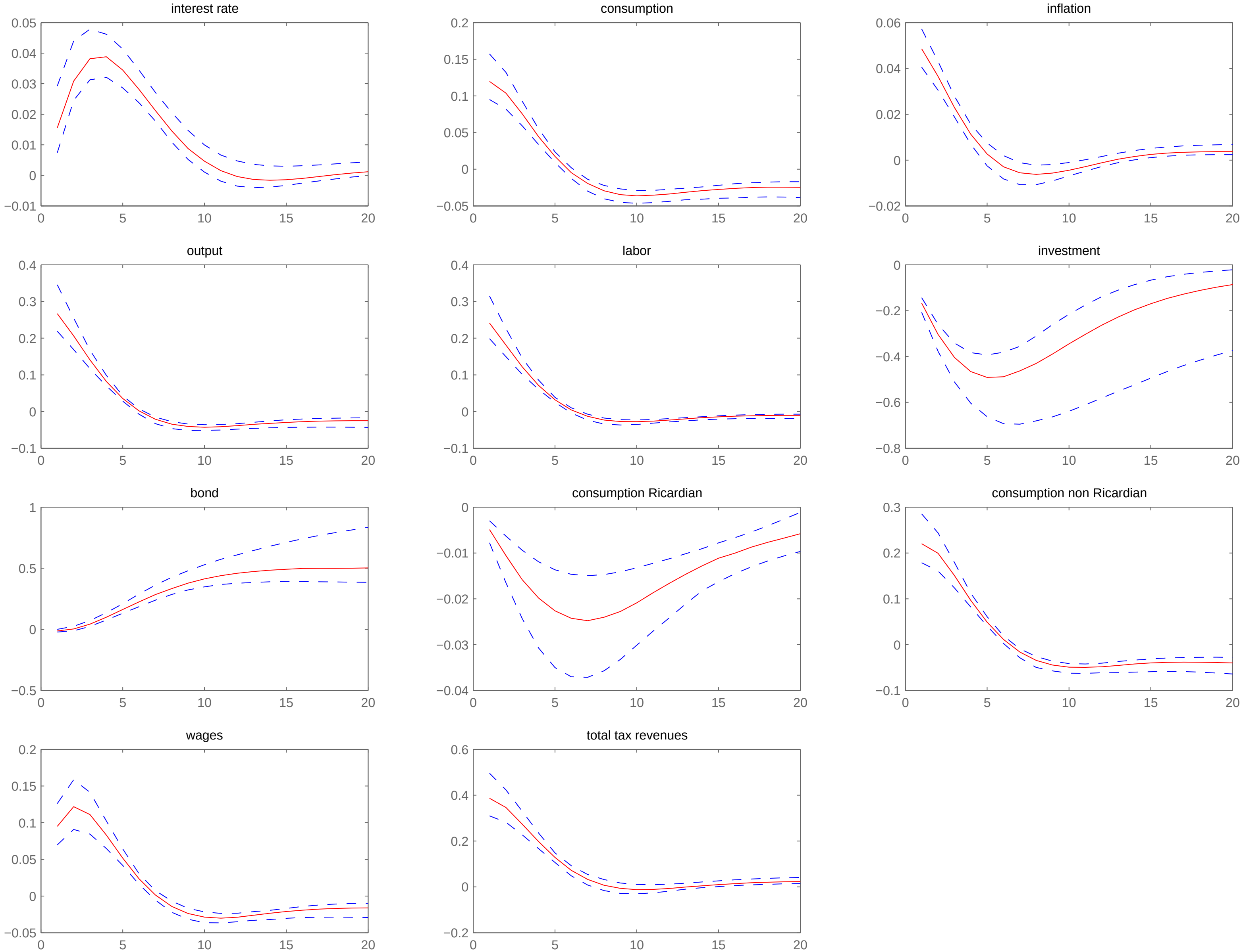


Figure 5: Impulse responses from a government employment shock

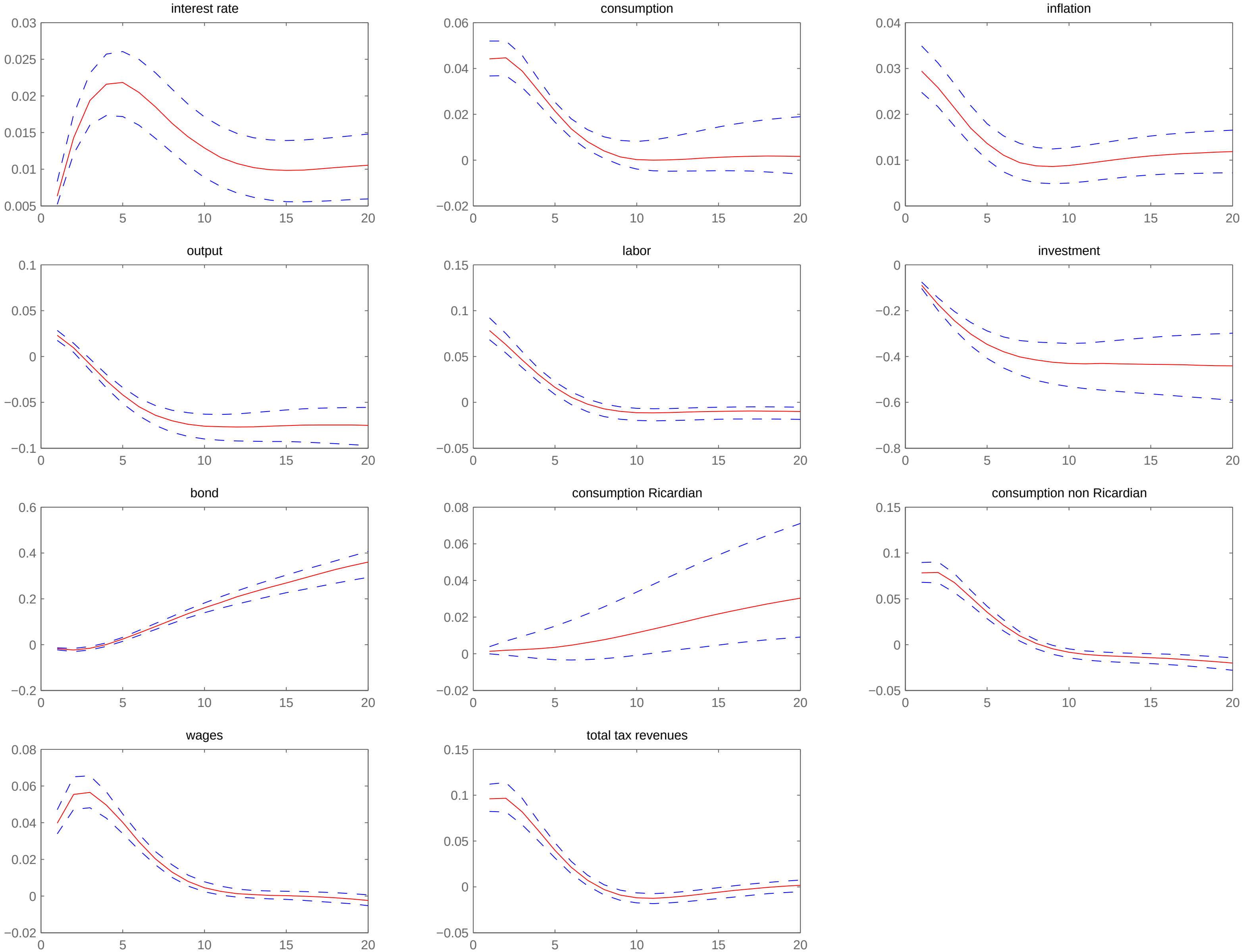
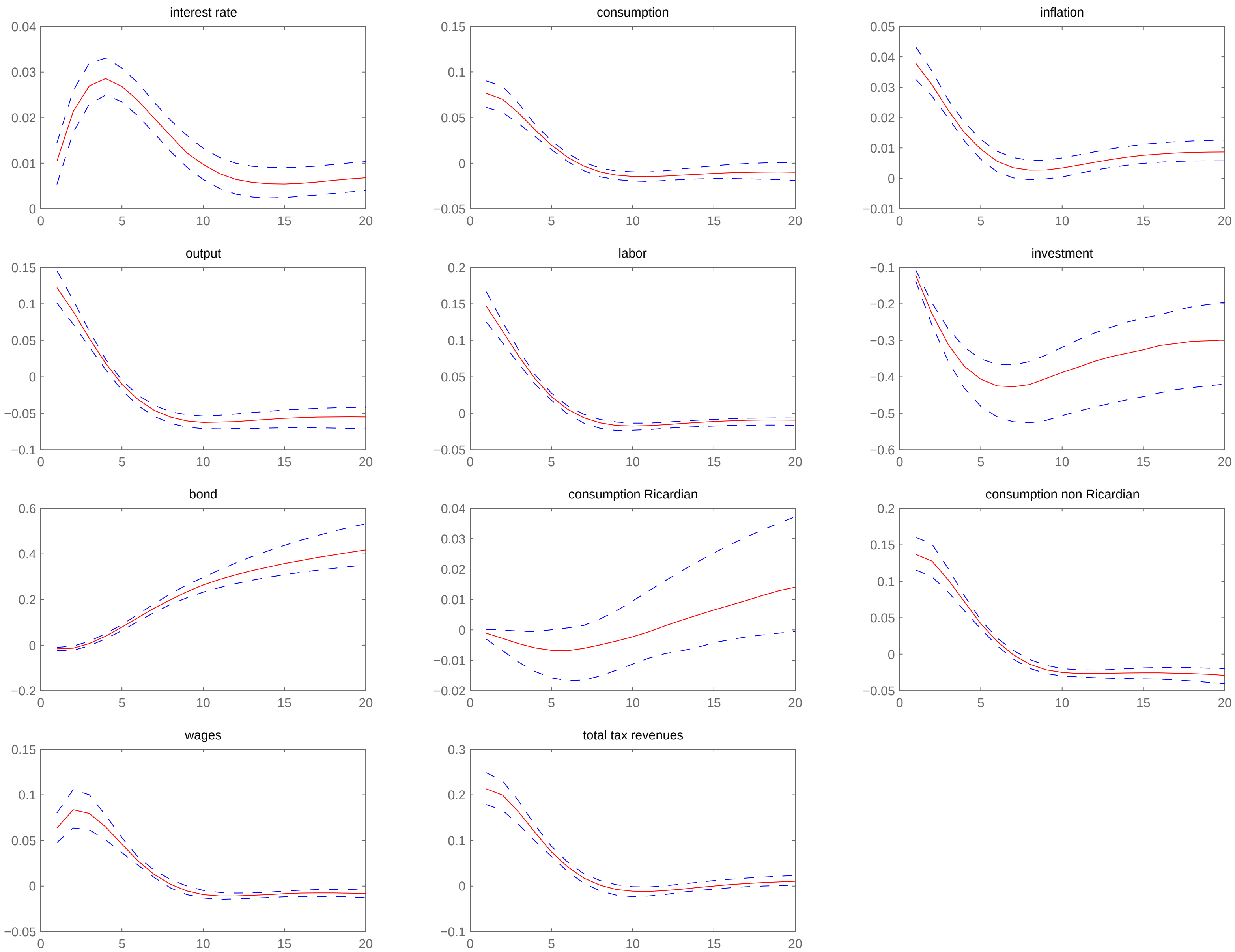


Figure 6: Impulse responses from a combined shock to government spending and employment



Appendix

A F.O.C.s

A Ricardian household maximizes (1) subject to (3) and (4) 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. The corresponding first order conditions, when evaluated in equilibrium, are then

$$\varepsilon_t^b (c_t^R - h c_{t-1}^R)^{-\sigma_c} = \lambda_t P_t \tag{32}$$

$$\lambda_t = \beta R_t E_t[\lambda_{t+1}] \tag{33}$$

$$\theta_L \varepsilon_t^b \varepsilon_t^l \frac{l_t^{1+\sigma_l}}{w_t} + \beta\varphi E_t \left[\lambda_{t+1}\left(\frac{w_{t+1}}{w_t} - \pi\right)\frac{W_{t+1} w_{t+1}}{w_t^2}\right] = \lambda_t \left[\varphi\left(\frac{w_t}{w_{t-1}} - \pi\right)\frac{W_t}{w_{t-1}} - (1-\theta_L)(1-\tau_t^w) l_t\right] \tag{34}$$

$$-\lambda_t \frac{P_t}{(1+\tau_t^c)} + \mu_t \left\{[1 - s_t(.)] - s_t'(.)\frac{I_t}{I_{t-1}}\right\} = \beta E_t \left[\mu_{t+1} s_{t+1}'(.)\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{35}$$

$$\mu_t = \beta E_t \left\{\lambda_{t+1}\left[(1-\tau_{t+1}^k) R_{t+1}^k u_{t+1} - \psi(u_{t+1}) P_{t+1}\right] + \mu_{t+1}(1-\delta)\right\} \tag{36}$$

$$\psi'(u_t) P_t = R_t^k (1 - \tau_t^k) \tag{37}$$

plus constraints (3) and (4).

Defining the producer price inflation as $\widetilde{\pi}_t \equiv \widetilde{P}_t / \widetilde{P}_{t-1}$, the f.o.c. for firms' price choice is

$$\begin{aligned} \lambda_t \left[(1-\theta_c) c_t(j) + \theta_c M C_t(j) \frac{c_t(j)}{\widetilde{p}_t(j)} - \widetilde{P}_t k(\widetilde{\pi}_t(j) - \pi)\frac{C_t}{\widetilde{p}_{t-1}(j)}\right] + \\ \beta E_t \left[\lambda_{t+1} \kappa(\widetilde{\pi}_{t+1}(j) - \pi)\widetilde{P}_{t+1} C_{t+1} \frac{\widetilde{p}_{t+1}(j)}{\widetilde{p}_t(j)^2}\right] = 0 \end{aligned} \tag{38}$$

from which, imposing a symmetric equilibrium (and dividing by $\lambda_t C_t$), one has

$$\left[(1-\theta_c) + \theta_c \frac{MC_t}{\widetilde{P}_t} - \widetilde{\pi}_t \kappa(\widetilde{\pi}_t - \pi)\right] + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t}\kappa(\widetilde{\pi}_{t+1} - \pi)\frac{c_{t+1}}{c_t}\widetilde{\pi}_{t+1}^2\right] = 0 \tag{39}$$

Here $\widetilde{P}_t \equiv P_t/(1+\tau_t^c)$, $\pi_t \equiv P_t/P_{t-1}$ and in the steady state $\pi \equiv \widetilde{\pi}$.

B Steady state

In the following we report the step we have followed to solve in close for for steady state values. Somehow differently from other authors, we solved in close form for all steady state variables, with the exception of fiscal policy variables as the debt level, government consumption and employment levels.

In steady state we have by assumption $u = 1$, $\psi(1) = 0$ and $s = s' = 0$. From (33) we have $R = \pi/\beta$, with π the long run objective of the monetary authority (that we identify with the trend). From (35) and (36) we obtain the real rental rate for the capital:

$$r^k = \frac{R^k}{P} = \frac{1 - \beta(1-\delta)}{\beta(1-\tau^k)(1+\tau^c)} \tag{40}$$

From the solution of the firm's price problem (39) we have:

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

and using also the marginal cost of the firm (13), we obtain the real wage:

$$mc = \zeta \frac{(W/P)^{1-\alpha}\left(R^k/P\right)^{\alpha}}{z^{1-\alpha}} = \frac{\theta_c - 1}{(1+\tau^c)\theta_c} \Rightarrow$$

$$w = \frac{W}{P} = z\left[\frac{(\theta_c - 1)}{\theta_c(1+\tau^c)\zeta\left(R^k/P\right)^{\alpha}}\right]^{\frac{1}{1-\alpha}} \tag{41}$$

where $\zeta = \left[\frac{(1-\alpha)^{\alpha-1}}{\alpha^{\alpha}}\right]$.

Having obtained factor prices, we now have to recover aggregate variables. In order to do so, we start from the steady state definition of the consumption level of non Ricardian households:

$$c^{NR} = (1-\tau^w)wl + tr \tag{42}$$

Real transfers (tr) can be obtained from the steady state version of the government budget constraint in real terms:

$$tr = b\left(\frac{\pi - R}{R}\right) + t - g - wl^g \tag{43}$$

Moreover, using also the identities:

$$t = \tau^w wl + \frac{\tau^c}{1+\tau^c}\left[c + c^g\right] + \left(\tau^k R^k k\right)$$

and

$$y = A^{\alpha} l^p \tag{44}$$

$$k = Al^p \tag{45}$$

where $A = \left(\frac{\alpha}{1-\alpha}\frac{w}{R^k}\right)$, we are able to rewrite the consumption level of non Ricardian as:

$$c^{NR} = D \cdot l^p + \frac{\tau^c}{1+\tau^c}c \tag{46}$$

where $D = \left[w + (b/y)(\frac{\pi - R}{R})A^\alpha + \tau^k r^k A - \frac{1}{1+\tau^c}(c^g/y)A^\alpha\right]$ includes only steady state values for factor prices (already solved in terms of exogenous parameters), parameters and exogenously assumed steady state values for b/y and c^g/y. Total private consumption c is defined by the identity:

$$c = \gamma c^R + (1-\gamma)c^{NR}$$

which can be rewritten, using (46), as follows:

$$c = E \cdot l^p + F \cdot c^R \tag{47}$$

where $E = \left[\frac{\gamma D}{(1-\gamma\frac{\tau^c}{1+\tau^c})}\right]$ and $F = \left[\frac{1-\gamma}{(1-\gamma\frac{\tau^c}{1+\tau^c})}\right]$.

Now let's solve for c^R in terms of l^p, c and exogenous parameters. From the budget constraint of Ricardian households in steady state we have:

$$c^R = (1-\tau^w)wl + (1-\tau^k)R^k\overline{k}u + d + b + tr - \frac{1}{1+\tau^c}i - \frac{b}{R} \tag{48}$$

Since

$$d = \frac{1}{1+\tau^c}\frac{1}{\vartheta^c}y$$

and making use of the steady state version of the capital accumulation equation (where $u = 1$ in steady state):

$$i = \delta k = \delta A l^p$$

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

$$c^R = G \cdot l^p + \frac{\tau^c}{1+\tau^c}c \tag{49}$$

where $G = \left[w + \frac{1-\gamma\tau^k}{1-\gamma}r^k A + \frac{1}{1+\tau^c}\frac{1}{\vartheta^c}\frac{A^\alpha}{1-\gamma} + \frac{\gamma}{1-\gamma}(b/y)(\frac{R-\pi}{R})A^\alpha - \frac{1}{1+\tau^c}\frac{1}{1-\gamma}\frac{1}{1+\tau^c}\delta A - \frac{1}{1+\tau^c}(c^g/y)A^\alpha\right]$.
Plugging in c^R from (49) in (47), we obtain:

$$c^R = H \cdot l^p \tag{50}$$

where $H = \left[\frac{G + \frac{\tau^c}{1+\tau^c}E}{1 - \frac{\tau^c}{1+\tau^c}F}\right]$.

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

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

and therefore

$$c^R = H \cdot (1 - l^g_{ss}) \cdot l \tag{51}$$

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:

$$l^{\sigma^l} \frac{\vartheta^l}{w} + \left[c^R(1-h)\right]^{-\sigma^c} \left[(1-\tau^w)(1-\vartheta^l)\right] = 0$$

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

$$c^R = \frac{1}{1-h} \left[\frac{(1-\tau^w)(1-\vartheta^l)w}{l^{\sigma^l}\vartheta^l}\right]^{\frac{1}{\sigma^c}} \tag{52}$$

Combining (52) with (51):

$$\frac{1}{1-h} \left[\frac{(1-\tau^w)(1-\vartheta^l)w}{l^{\sigma^l}\vartheta^l}\right]^{\frac{1}{\sigma^c}} = H \cdot (1 - l^g_{ss}) \cdot l$$

which allows us to solve for l:

$$l = \left\{ \frac{1}{H(1-h)(1-l^g_{ss})} \left[\frac{(1-\tau^w)(1-\vartheta^l)w}{\vartheta^l}\right]^{\frac{1}{\sigma^c}} \right\}^{\frac{\sigma^c}{\sigma^c+\sigma^l}}$$

Given l we can solve for c^R from (52), c from (47), and easily for c^{NR}, k, i, y, t and tr.

C Log-linearizations

Ricardian consumers are all identical, which, after aggregation, allows simplification when log-linearizing (32) so to have

$$\widehat{\chi}_t = -\frac{\sigma_c}{1-h}\left(\widehat{c}^R_t - h\widehat{c}^R_{t-1}\right) + \widehat{\varepsilon}^b_t \tag{53}$$

where $\chi_t \equiv \lambda_t P_t$, which is of use also in log-linearization of (33)

$$\widehat{\chi}_t = \widehat{R}_t + E_t[\widehat{\chi}_{t+1}] - E_t[\widehat{\pi}_{t+1}]\,. \tag{54}$$

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

$$\widehat{\pi}_t^W = \widehat{\omega}_t - \widehat{\omega}_{t-1} + \widehat{\pi}_t \tag{55}$$

and also, log-linearizing (34),

$$\widehat{\pi}_t^W = \beta E_t[\widehat{\pi}_{t+1}^W] + \frac{(1-\theta_L)(1-\tau^w)l}{\varphi\pi^2}\left[\widehat{\chi}_t + \widehat{l}_t - \frac{\tau^w}{1-\tau^w}\widehat{\tau}_t^w\right] + \frac{\theta_L l^{1+\sigma_l}}{\chi\varphi\pi^2\omega}\left[(1+\sigma_l)\widehat{l}_t - \widehat{\omega}_t + \widehat{\varepsilon}_t^b + \widehat{\varepsilon}_t^l\right] . \tag{56}$$

Defining $q_t = \frac{\mu_t(1+\tau_t^c)}{\chi_t}$, log-linearization of (35) and (36) yields

$$\widehat{I}_t = \frac{\widehat{I}_{t-1}}{1+\beta} + \frac{\beta}{1+\beta}E_t[\widehat{I}_{t+1}] + \frac{\widehat{q}_t}{s''(1+\beta)} - \frac{\beta}{1+\beta}E_t[\widehat{\varepsilon}_{t+1}^i] + \frac{\widehat{\varepsilon}_t^i}{1+\beta} \tag{57}$$

and

$$\widehat{\chi}_t + \widehat{q}_t - \frac{\tau^c}{1+\tau^c}\widehat{\tau}_t^c = E_t[\widehat{\chi}_{t+1}] + \tag{58}$$
$$+\beta\left[(1-\delta)E_t[\widehat{q}_{t+1}] + r^k(1+\tau^c)(1-\tau^k)E_t[\widehat{r}_{t+1}^k] - r^k\tau^k(1+\tau^c)E_t[\widehat{\tau}_{t+1}^k] - \frac{(1-\delta)\tau^c}{1+\tau^c}E_t[\widehat{\tau}_{t+1}^c]\right]$$

where we used the steady state equalities $q = 1$, $s(.) = s'(.) = 0$, $u = 1$, $\psi(1) = 0$, $\psi'(1) = r^k(1-\tau^k)$, and $r^k = [1-\beta(1-\delta)]/\beta(1-\tau^k)(1+\tau^c)$. Log-linearization of (37) directly follows:

$$\frac{\psi''(u)}{\psi'(u)}\widehat{u}_t = \widehat{r}_t^k - \frac{\tau^k}{(1-\tau^k)}\widehat{\tau}_t^k . \tag{59}$$

Zero steady state adjustment costs imply also that the log-linearized version of constraint (4) is

$$\widehat{\overline{k}}_{t+1} = (1-\delta)\,\widehat{\overline{k}}_t + \delta\widehat{I}_t \tag{60}$$

where

$$\widehat{k}_t = \widehat{u}_t + \widehat{\overline{k}}_t , \tag{61}$$

and, from the capital market equilibrium (29),

$$\widehat{k}_t = \widehat{y}_t + (1-\alpha)\left[\widehat{w}_t - \widehat{r}_t^k - \widehat{z}_t\right] . \tag{62}$$

As for budget constraints, it is enough to log-linearize that of non Ricardian households (5)

$$c^{NR}\widehat{c}_t^{NR} = \omega l[(1-\tau^w)(\widehat{\omega}_t + \widehat{l}_t) - \tau^w\widehat{\tau}_t^w] + tr\,\widehat{tr}_t \tag{63}$$

and the aggregate resource constraint (28)

$$y\widehat{y}_t = c\widehat{c}_t + I\widehat{I}_t + c^g\widehat{c^g}_t + \psi'(1)\overline{k}\widehat{u}_t \tag{64}$$

where

$$c\widehat{c}_t = (1-\gamma)\,c^R\widehat{c}_t^R + \gamma c^{NR}\widehat{c}_t^{NR} \tag{65}$$

and

$$\widehat{y}_t = (1-\alpha)\,\widehat{z}_t + (1-\alpha)\,\widehat{l}_t^p + \alpha\widehat{k}_t \tag{66}$$

with

$$l\,\widehat{l}_t = l^p\,\widehat{l}_t^p + l^g\,\widehat{l}_t^g\,. \tag{67}$$

No adjustment in the steady state also imply $\frac{MC}{P} = \frac{\theta_c - 1}{\theta_c(1+\tau^c)}$, so that the log-linearized version of (39) turns out to be equal to

$$\widehat{\widetilde{\pi}}_t = \beta E_t[\widehat{\widetilde{\pi}}_{t+1}] + \frac{\theta_c - 1}{\kappa\widetilde{\pi}^2}\left[\widehat{mc}_t + \frac{\tau^c}{1+\tau^c}\widehat{\tau}_t^c\right] \tag{68}$$

where from (13)

$$\widehat{mc}_t = (1-\alpha)\,(\widehat{w}_t - \widehat{z}_t) + \alpha\widehat{r}_t^k\,. \tag{69}$$

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

$$\widehat{\pi}_t = \widehat{\widetilde{\pi}}_t + \frac{\tau^c}{1+\tau^c}(\widehat{\tau}_t^c - \widehat{\tau}_{t-1}^c)\,. \tag{70}$$

As for log-linearized version of the government budget constraint, having regard that in the steady state $R = \pi/\beta$, it is

$$\beta b\left(E_t[\widehat{b}_{t+1}] + E_t[\widehat{\pi}_{t+1}] - \widehat{R}_t\right) = b\widehat{b}_t + c^g\widehat{c^g} + wl^g(\widehat{w}_t + \widehat{l}_t^g) + tr\,\widehat{tr}_t - t\,\widehat{t}_t \tag{71}$$

where

$$\begin{aligned} t\,\widehat{t}_t = \tau^w\omega l\left[\widehat{\tau}_t^w + \widehat{\omega}_t + \widehat{l}_t\right] + \frac{\tau^c}{(1+\tau^c)^2}(c+c^g)\widehat{\tau}_t^c + \\ + \frac{\tau^c}{1+\tau^c}c\widehat{c}_t + \frac{\tau^c}{1+\tau^c}c^g\widehat{c^g} + \tau^k r^k k\left[\widehat{\tau}_t^k + \widehat{r}_t^k + \widehat{k}_t\right] \end{aligned} \tag{72}$$

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 data set used to estimate the model contains quarterly time series covering the period from 1980:1 to 2004:4. The national accounts for the whole economy and for the government sector are seasonally adjusted and, when available, also working day adjusted. Data for private consumption and investment are extracted from the EUROSTAT ESA95 national accounts. The euro area official data have a break in 1991, because of the German unification, thus for previous years we used the series reconstructed by the ECB for the Area Wide Model (AWM data base, available on the web site of the EABCN, updated at the 2003:4).

Some effort has been devoted to the construction of the fiscal policy series, as most part of the euro area official data for the government sector are available on annual basis. Recently a number of quarterly series for the most important items of the Government accounts have been released, but they are available for a short time span (they start in the first quarter of 1999) and are unadjusted neither for the seasonality nor for the number of the working days.

We obtained the quarterly fiscal policy variables of interest for our purposes from annual series, applying standard techniques commonly adopted by national statistical offices[12]. The source of the annual data is mainly the AMECO data base of the European Commission. In AMECO the ESA 95 data for the euro area start only in 1995. We had therefore to join the ESA 95 series with ESA 79 before 1995. The euro area ESA 79 data are available from 1991, as before didn't exist national statistics for East Germany. Operationally, we had to join ESA95 with ESA79 (for the euro area) to recover informations from 1991 to 1995. To go back 1991 we made use of ESA79 data for a linear aggregation of euro area countries data, excluding East Germany. To avoid artificial jumps, related to base year or to different definitions, we applied shift factors to insure consistency in the series levels.

We also had to construct implicit tax rates, as they are not provided by statistical offices with the time span as large as we need. We followed the methodology of Mendoza,

[12] In particular, we followed the Chow and Lin (1971) method, as modified by Barbone, Bodo and Visco (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.

Razin and Tesar (1994) using annual data from the OECD's Revenue Statistics. As in this data base there are series only for individual countries, we reconstructed the area series aggregating individual country series.

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

Private consumption (C) = real private consumption; source: National Accounts ESA 95 after 1991 and AWM-ECB data set before.

Private investment (I) = real private investments; source: National Accounts ESA 95 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. Source: Eurostat starting from 1990; for previous years the HICP has been projected backward using the consumer price deflator.

Private per-capita compensation (w) = private sector per-capita compensation, constructed as difference between the total economy minus the public sector compensations; source for the total series: National Accounts ESA 95 after 1991 and AWM-ECB data set before; source for the government series: ECOUT after 1991 and AWM-ECB data set before.

Government consumption (G) = real government consumption; source: National Accounts ESA 95 after 1991 and AWM-ECB data set before. The deflator is the Household Inflation Consumer Prices (HICP) as in π.

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 the Government consumption and the non market compensations; source for the quarterly indicator: National Accounts ESA 95 after 1991 and AWM-ECB data set before. The deflator is the Household Inflation Consumer Prices (HICP) as in π.

Government transfers (TR) = real government transfers to households; source for annual series: AMECO. The quarterly indicator is a linear trend. The deflator is the Household Inflation Consumer Prices (HICP) as in π.

Total revenues (T) = real government total revenues; source for annual series: ECOUT. 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 consumption; 3) the National Accounts data on social contributions. The deflator is the Household Inflation Consumer Prices (HICP) as in π.

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:

$$thh = \frac{TD_h}{(GOS_h + W)} \tag{73}$$

2) the labor tax rate is given by:

$$\tau^w = \frac{(thh \cdot W + SC + T_w)}{(W + SC_e)} \tag{74}$$

where:

TD_h= households direct taxes

GOS_h = households gross operating surplus

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 obtained by a linear trend.

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

$$\tau^c = \frac{TI}{(C + C^g - TI)} \tag{75}$$

where:

TI= indirect 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 obtained by 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:

$$\tau^k = \frac{(thh \cdot GOS_h + TD_k)}{NOS} \tag{76}$$

where:

TD_k= direct taxes on corporations

NOS = net operating surplus of the economy

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 obtained by a linear trend.

D.3 Comparison of our quarterly fiscal series with alternative sources [to be completed]

Official quarterly series for euro area fiscal policy data are available starting in 1999:1. Although coverage and definitions might be slightly different, we could compare our series for total revenue T [, transfers TR, government consumption G, government purchases of good and services C^g] with the corresponding official one[13]. We compared the same series, starting from 1980:1, also with the corresponding ones obtained from the ECB Area Wide Model (AWM) quarterly data set. To better understand the size of the differences, the data are expressed as ratios over the nominal GDP.

In figure D1 [to be inserted] we compare our series on total revenues with the one of the AWM and with the official quarterly series seasonally adjusted (the latter starting from 1999:1). Excluding the different profile in the first half of the eighties, our and AWM series appear quite similar. In figure D4 we show the same series, with a zoom on recent years, to better look at the official one. Our series almost overlaps with the official one, while there is a difference of about one percentage point of GDP between our and the AWM series. The discrepancies in the quarterly profile between the three series are probably related to the different adjustment for seasonality in the two series.

In figure D2 [to be inserted] we plot our series and the AWM one for government consumption. We note that the differences are negligible and the correlation coefficient is close to one. This is not a surprise as the government consumption is the only fiscal policy series produced on a quarterly basis in the national accounts.

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

In figure D3 [to be inserted] we plot our series and the AWM one for government social transfers. The differences in the quarterly shape are not remarkable. The correlation coefficient is around 0.8 and the greater differences are before the nineties, signaling some incoherence in the definition of the older series. From the nineties onward the series look rescaled but with a similar profile.