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by

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Fiscal Policy in an Estimated Open-Economy Model for the Euro Area

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Abstract

This paper uses an estimated DSGE model for the euro area to study the effects of fiscal stabilisation policies. There are at least two features of the euro area economy which makes this analysis interesting. First, there are nominal rigidities in goods and labour markets, and there are financial market frictions with a significant share of liquidity constrained households. Second, the government is a major sector of the euro area economy. In this paper we look at fiscal stabilisation via government consumption, investment, transfers and wage taxes. We find empirical evidence for systematic countercyclical fiscal policy. Consistent with previous findings, there is a small positive fiscal multiplier in the case of transitory fiscal shocks. We find that fiscal policy is effective in stabilising GDP in the presence of demand and supply shocks. Fiscal policy helps to reduce the demand externality arising from nominal rigidities. In addition automatic stabilisation via government transfers helps to smooth consumption of liquidity-constrained household. Fiscal policy partly compensates the financial market distortion. With distorted goods, labour and financial markets we find that the estimated fiscal policy rules reduce fluctuations in euro area GDP by about 14 percent.

JEL Classification System: E32, E62
Keywords: DSGE modelling, fiscal policy, stabilisation policies, euro area

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Introduction

In recent years considerable progress has been made in the estimation of New-Keynesian dynamic stochastic equilibrium (DSGE) models. Because these models explicitly derive behavioural equations from intertemporal optimisation of the private sector under technological, budget and institutional constraints such as imperfections in factor, goods and financial markets, they are well suited to analyse the impact of fiscal and monetary policy. In this framework, macroeconomic fluctuations are seen as the optimal response of the private sector to demand and supply shocks in various markets, given the constraints mentioned above. Therefore, they allow us to analyse to what extent fiscal and monetary policies can alleviate existing distortions by appropriately responding to macroeconomic shocks.

DSGE models have so far been used extensively to study the effects of monetary policy and the stabilising role of monetary rules. In particular it has been demonstrated that an active role for monetary policy arises from the presence of nominal rigidities in goods and factor markets. So far, not much work has been devoted towards exploring the role of fiscal stabilisation in the New Keynesian model. Empirical work has concentrated mainly on an analysis of the effects of government spending shocks. (see Gali et al. (2003), Coenen and Straub (2005) and Forni et al. (2006)). This work was motivated by understanding correlation patterns between fiscal variables and private consumption in macroeconomic time series. To our knowledge, less attention has been devoted to an empirical analysis of the stabilising role of fiscal policy itself. This paper therefore extends this literature by focussing on an analysis of the magnitude of fiscal stabilisation in the euro area at an aggregate level, *i.e.* we ask the question, what has been the stabilising power of fiscal policy in responding to euro area wide shocks over the period 1981-2005?

There are at least two features of the euro area economy which makes this analysis interesting. First, markets in the euro area do not function perfectly. There is substantial empirical evidence that prices and wages adjust sluggishly to supply and demand shocks as documented in numerous studies of wage and price behaviour, starting from early Phillips curve estimates (see, for example, Phelps (1967)) and extending to recent estimates using both backward as well as forward looking price and wage rules (see e.g. Gali et al. (2001)). The recent work by Gali et al. (2003), Coenen and Straub (2005) and Forni et al. (2006) has also highlighted the presence of liquidity constraints as an additional market imperfection. The introduction of non-Ricardian behaviour in the model could give rise to a role for fiscal stabilisation, since liquidity constrained households do not respond to interest rate signals and there is little that can be done by monetary policy.

Second, the government sector forms a major share of the euro area economy. Government consumption constitutes 20% of GDP. Government transfers to households make up a similar share. The latter help to smooth income of private households over the business cycle, especially in the form of pensions and unemployment insurance. Government expenditure is financed by consumption, labour income and capital taxes. The tax system, especially the income tax, provides additional stabilisation via a progressive tax code.

Obviously, a prerequisite for such an analysis is a proper empirical representation of the data generating process. The seminal work of Smets and Wouters (2003) has shown that DSGE models can in fact provide a satisfactory representation of the main macroeconomic aggregates. This paper extends the basic DSGE model in four directions. First, it respects the unit root character of macroeconomic time series by allowing for stochastic trends in TFP, second it treats the euro area as an open economy, third it adds financial market imperfections in the form of liquidity constrained households to imperfections in the form of nominal rigidities in goods and labour markets and, fourth, it introduces a government sector with stabilising demand policies. We empirically identify government spending rules by specifying current government consumption and transfers as functions of their own lags as well as current and lagged output and unemployment gaps. In other words, our fiscal rules resemble the well-known Taylor rule for interest rates. However, we do not find a significant response of fiscal policy to deviations of inflation from the target rate. From the operation of the euro area unemployment insurance system we know that unemployment benefits provide quasi-automatic income stabilisation. Indeed we find a significant response of transfers to cyclical variations in employment. A priori government consumption is not explicitly countercyclical, though it can already provide stabilisation by keeping expenditure fixed in nominal terms over the business cycle. The empirical evidence suggests that fiscal policy is used in a countercyclical fashion in the euro area. The question we focus on in this paper is *how much* stabilisation is provided by active fiscal policy, taking into account all the stochastic shocks that we identify over the period 1981Q1 to 2005Q3. We find that fiscal policy has reduced the standard deviation of output growth by about 14 percent over that period.

Our results can be compared to other papers that have investigated the stabilising effects of fiscal policy. Fatas and Mihov (2003) question the conventional wisdom that fiscal policy is counter-cyclical. They investigate the effect of discretionary policy and use government spending data for a large cross-section of countries. They regress government spending growth on output growth (and additional control variables) and interpret the residual of the estimated equation as the indicator of the discretionary spending shock. They find that highly volatile discretionary fiscal policy exerts a strong destabilising effect on the economy. The volatility of output induced by discretionary fiscal policy lowers economic growth by more than 0.8 percentage points for every percentage point increase in volatility.

Artis and Onorante (2006) analyse whether in the past discretionary fiscal policy in EMU has been effective in smoothing the economic cycle, or whether fiscal policy has been procyclcial and increased the amplitude of the cycle. They estimate a small model for growth, the deficit ratio and inflation and compare the variance of synthetic economic cycles created by shutting down the permanent shock of the estimated structural model and producing counterfactual economic cycles by changing assumptions on the fiscal shocks. They find that fiscal policy has had overall a limited, if any, smoothing effect on the cycle. Shutting down the discretionary component of fiscal policy approaches closest the “best fiscal policy” in their simulations.

Our paper is structured as follows. In section one we describe the model and characterise the shocks hitting the euro area economy. Section two briefly presents the empirical fit of our DSGE model. Section three analyses fiscal stabilisation and section four concludes.

1. The Model

We consider an open economy which faces an exogenous world interest rate, world prices and world demand. The domestic and foreign regions produce a continuum of differentiated goods.

The goods produced in the home country are imperfect substitutes for goods produced abroad. The model economy is populated by households and firms and there is a monetary and fiscal authority, both following rules based stabilisation policies. We distinguish between households which are liquidity constrained and consume their disposable income and households who can trade on financial markets.

1.1 Firms:

There is a final goods and an investment goods production sector, populated with two types of firms. In the final goods sector n^d firms indexed by *j* produce goods which are imperfect substitutes Final output is consumed by private households and the government (domestic and abroad) and serves as an input for a perfectly competitive investment goods sector. Firms in the investment goods sector transform final goods into a single investment good which is used in the final goods sector. Firms are owned by households and pay dividends.

1.1.1 Final output producers

Each firm produces a variety of the domestic good which is an imperfect substitute for varieties produced by other firms. Because of imperfect substitutability, firms are monopolistically competitive in the goods market and face a demand function for goods. Domestic firms sell to private domestic households, to other firms the government and to exporting firms. All demand sectors have identical CES preferences across varieties, with a time-varying elasticity of substitution $1/\tau_t$. The demand function for firm *j* consistent with preferences (see section 1.4 for a more detailed description) is given by

$$(1) \qquad Y_t^j = \frac{1}{n^d}\left(\frac{P_t^j}{P_t}\right)^{-\frac{1}{\tau_t}}\left[\left(C_t^D + G_t^D + I_t^D + EX_t\right)\right]$$

In what follows it is assumed that firms influence the demand for domestic goods with their pricing decision, however, they are small with respect to the total market and therefore take as given P_t ,PC_t ,C_t, G_t, I_t and EX_t. Output is produced with a Cobb Douglas production function

$$(2) \qquad Y_t^j = (ucap_t^j K_t^j)^{1-\alpha}(L_t^j - LO_t^j)^{\alpha} U_t^{\alpha} = (ucap_t^j K_t^j)^{1-\alpha}[L_t^j \cdot (1 - LOL_t^j)]^{\alpha}(U_t)^{\alpha}$$

with capital (K_t^j) and labour (L_t^j) minus overhead labour (LO_t^j) as inputs. L_t^j is itself a CES aggregate of labour supplied by individual households *i*, $L_t^j = \left[\int_0^1 L_t^{i,j\,\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$ where the parameter $\theta > 1$ determines the degree of substitutability. Firms also decide about the degree of capacity utilisation ($ucap_t^j$). The technology shock U_t follows a random walk with drift

$$(3a) \qquad U_t = g_t^U + U_{t-1} + e_t^U, \quad e_t^U \sim N(0, \sigma^U)$$

And the drift term g_t^U follows an AR(1) process

(3b) $$g_t^U = g^{U0}(1-\rho^{GU}) + \rho^{GU} g_{t-1}^U + \varepsilon_t^{GU} \quad \varepsilon_t^{GU} \sim N(0,\sigma^{GU})$$

We allow the share of overhead labour LOL_t^j to follow an AR(1) process around its long run value

(4) $$LOL_t^j = (1-\rho^{LOL})LOL + \rho^{LOL} LOL_{t-1}^j + \varepsilon_t^{LOL}, \qquad \varepsilon_t^{LOL} \sim N(0,\sigma^{LOL})$$

The objective of the firm is to maximise the present discounted value of its cash flows. The link to the household sector is as follows. Domestic firms are owned by domestic households. All investment is equity financed and the firms pay dividends to the household sector. Dynamic considerations enter the problem of the firms because firms face quadratic costs of changing capital, employment and prices. Finally firms must also choose the optimal level of capacity utilisation.

(5) $$\begin{aligned} Max\ V_0^{rj} &= E_0 \sum_{t=0}^{\infty} d^t \frac{\left[(1-t_t^p)(P_t^j(.)Y_t^j - W_t L_t^j - adc^P(P_t^j) - adj^L(L_t^j) - adj^{CAP}(ucap_t^j)) - PI_t I_t^j - adj^K(K_t^j)\right]}{P_t} \\ &- \sum \eta_t^j d^t (1-t_t^p)\left[Y_t^j - (ucap_t^j K_t^j)^{1-\alpha}(L_t^j(1-LOL_t^j)U_t)^{\alpha}\right] \\ &- \sum \mu_t^j d^t \left[K_t^j - I_t^j - (1-\delta)K_{t-1}^j\right] \end{aligned}$$

where $d^t = \prod_{l=0}^{t}\left(\frac{1}{1+r_l+rp_l}\right)^l$ is the discount factor, which consists of the short term interest rate and a risk premium (*rp*). The risk premium can be subject to random shocks and generated by the following autoregressive process

(6) $$rp_t = \rho^{rp} rp_{t-1} + (1-\rho^{rp})rp + \varepsilon_t^{rp}, \qquad \varepsilon_t^{rp} \sim N(0,\sigma^{rp})$$

For adjustment costs we choose the following convex functional forms.

(7) $$\begin{aligned} adj^L(L_t^j) &= W_t\left(L_t^j e_t^L + \frac{\gamma_L}{2}\Delta L_t^{j\,2}\right) \\ adj^P(P_t^j) &= \frac{\gamma_P}{2}\frac{(P_t^j - P_{t-1}^j)^2}{P_{t-1}^j} \\ adj^K(K_t^j, I_t^j) &= PI_t\left(\frac{\gamma_K(1+e_t^I)}{2}\frac{I_t^{j\,2}}{K_{t-1}} + \frac{\gamma_I}{2}\frac{(I_t^j - I_{t-1}^j)^2}{I_{t-1}^j}\right) \end{aligned}$$

$adj^{CAP}(ucap_t^j) = PI_t K_t (a_1(ucap_t^j - ucap^*) + a_2(ucap_t^j - ucap^*)^2)$, with $ucap^*=1$.

The adjustment costs for capital and labour are subject to autocorrelated random shocks

$$e_t^I = \rho^I e_{t-1}^I + \varepsilon_t^I \text{ with } \varepsilon_t^I \sim N(0,\sigma^I)$$
$$e_t^L = \rho^L e_{t-1}^L + \varepsilon_t^L \text{ with } \varepsilon_t^L \sim N(0,\sigma^L)$$

The firm determines labour input, the capital stock, capacity utilisation and prices optimally in each period given the technological and administrative constraints as well as demand conditions. The first order conditions, neglecting second order terms, are given by:

(8a) $$\left(\alpha \frac{Y_t^j}{L_t^j}(1+LOL_t^j)\eta_t^j + \frac{{}_tW_{t+1}}{{}_tP_{t+1}}\frac{\gamma_L}{R_t}({}_tL_{t+1}^j - L_t^j) - \frac{W_t}{P_t}\gamma_L(L_t^j - L_{t-1}^j)\right) = \frac{W_t}{P_t^j}(1+e_t^L)$$

(8b) $$L_t^{i,j} = \left(\frac{W_t^{i,j}}{W_t}\right)^{-\theta} L_t^j \quad \text{with} \quad W_t = \left[\int_0^1 W_t^{i\,1-\theta}\right]^{\frac{1}{1-\theta}}$$

(8c) $$\gamma_K(1+e_t^I)\frac{I_t^j}{K_{t-1}^j} + \gamma_I\frac{\Delta I_t^j}{I_{t-1}^j} - \beta\gamma_I(1+{}_t\pi_{t+1}^I - {}_t\pi_{t+1})\frac{\Delta_t I_{t+1}^j}{I_t^j} = \mu_t^j\frac{P_t}{PI_t} - 1$$

(8d) $$(1-t_t^p)(1-\alpha)\frac{Y_t^j}{K_t^j}\eta_t - \frac{PI_t}{P_t}((a_2-a_1)+(a_1-2a_2)ucap_t^j + a_2 ucap_t^{j\,2})(1-t_t^p) =$$
$$\mu_t^j - (1-r_t-rp_t-\delta)_t\mu_{t+1}^j$$

(8e) $$\frac{PI_t}{P_t}(a_1+2a_2(ucap_t^j-1)) = (1-\alpha)\frac{Y_t^j}{K_t^j ucap_t^j}\eta_t^j$$

(8f) $$\eta_t^j = 1-(\tau^0+e_t^\tau) - \gamma_P\left[\beta_t\pi_{t+1}^j - \pi_t^j\right]$$

Firms equate the marginal product of aggregate labour, net of labour adjustment costs to the real wage rate (eq. 8a). As can be seen from the left hand side of equation (8a), the convex part of the adjustment cost function penalises changes in employment. In a second step firms decide about demand for different varieties of labour (8b). Equations (8c-e) jointly determine the optimal capital stock and optimal capacity utilisation. The firm equates the marginal product of capital to the rental price of capital, adjusted for capital costs. The firm also equates the marginal product of capital services (*K*ucap*) to the marginal cost of capacity utilisation. Equation (8f) defines the mark up factor as a function of the elasticity of substitution and changes in inflation. We follow Smets and Wouters and allow for additional backward looking elements by assuming that a fraction (*1-sfp*) of firms keep prices fixed at the t-1 level. This leads to the following specification:

(8e') $$\eta_t^j = 1-(\tau^0+e_t^\tau) - \gamma_P\left[\beta(sfp^*{}_t\pi_{t+1}^j + (1-sfp)\pi_{t-1}^j) - \pi_t^j\right] \quad 0 \le sfp \le 1$$

with $e_t^\tau = \rho^\tau e_{t-1}^\tau + \varepsilon_t^\tau$, $\quad \varepsilon_t^\tau \sim N(0,\sigma^\tau)$.

1.2.2 Investment goods producers

There is a perfectly competitive sector which combines domestic and foreign final goods, using the same CES functions as households and governments do to produce investment goods for the domestic economy. Denote the aggregate of domestic and foreign inputs used by the investment goods sector with I_t^{inp}, then real output of the investment goods sector is produced by the following linear production function,

(9) $$I_t = I_t^{inp} U_t^I$$

where U_t^I is a technology shock to the investment good production technology which itself follows a random walk with trend

(10) $$\log(U_t^I) = g^{UI} + \log(U_{t-1}^I) + e_t^{UI} \text{ with } e_t^{UI} = \rho^{UI} e_t^{UI} + \varepsilon_t^{UI} \text{ and } \varepsilon_t^{UI} \sim N(0, \sigma^{UI})$$

Given our assumption concerning the input used in the investment goods production sector, investment goods prices are given by

(11) $$PI_t = PC_t / U_t^I .$$

1.2 Households:

The household sector consists of a continuum of households $h \in [0,1]$. A share $(1-slc)$ of these households are not liquidity constrained and indexed by $i \in [0,1-slc)$. They have full access to financial markets, they buy and sell domestic and foreign assets (government bonds and equity). The remaining share *slc* of households is liquidity constrained and indexed by $k \in [1-slc,1]$. These households do not trade on asset markets and consume their disposable income each period. We follow Coenen et al. (2005) and assume that both types of households supply differentiated labour services to unions which act as wage setters in monopolistically competitive labour markets. The unions pool wage income and distribute it in equal proportions among their members. Nominal rigidity in wage setting is introduced by assuming that the household faces adjustment costs for changing wages. These adjustment costs are borne by the household.

1.2.1 Non Liquidity constrained households

Each non liquidity constrained household decides about four types of assets, domestic and foreign nominal bonds (B_t^i, B_t^{iF}), stocks of domestic companies ($Q_t K_t^i$) and cash balances (M_t^i). Households maximize an intertemporal utility function subject to a budget constraint. The Lagrangian of this maximisation problem is given by:

(12)

$$Max \quad U_0^i = E_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_t^i) + V(1-L_t^i) + Z(M_t^i / P_t) \right)$$

$$-\sum \lambda_t \beta^t \left(\begin{array}{l} \frac{(1+t_t^c)PC_t}{P_t} C_t^i + \frac{M_t^i}{P_t} + \frac{B_t^i}{P_t} + \frac{E_t B_t^{i,F}}{P_t} + \frac{PC_t Q_t K_t^i}{P_t} - \frac{M_{t-1}^i}{P_t} - \frac{(1+i_{t-1})B_{t-1}^i}{P_t} \\ - \frac{(1+i_{t-1}^F)(1-risk(\frac{E_t B_{t-1}^{iF}}{P_{t-1}Y_{t-1}}))E_t B_{t-1}^{iF}}{P_t} - \left(\frac{(1+div_t)PC_t Q_t K_{t-1}^i}{P_t} \right) - \frac{(1-t_t^w)W_t^i}{P_t} L_t^i \\ + \frac{\gamma_w L_t^i}{2P_t} \frac{\left(W_t^i - W_{t-1}^i \right)^2}{W_{t-1}^i} - \frac{NETTR_t^i}{P_t} \end{array} \right)$$

The utility function is additively separable in consumption (C_t^i) and leisure ($1-L_t^i$). We assume CES utility for consumption and for leisure and in addition we allow for habit persistence. Thus temporal utility for consumption is given by

(13a) $$U(C_t^i) = \frac{(1-habc)}{(1-\sigma^c)} \exp(e_t^C)(C_t^i - habcC_{t-1})^{1-\sigma^c}$$

and for leisure

(13b) $$V(1-L_t^i) = \frac{\omega}{1-\kappa}(1+habl)^{-1}((1+habl)(1-L_t^i - e_t^{NPART}) - habl(1-L_{t-1} - e_{t-1}^{NPART}))^{1-\kappa}$$ with $\kappa > 0$.

The variable e_t^C denotes autocorrelated shock to preferences:

$e_t^C = \rho^C e_{t-1}^C + \varepsilon_t^C, \qquad \varepsilon_t^C \sim N(0, \sigma^C)$

and e_t^{NPART} denotes an autocorrelated shock to the share of households non-participating in the labour force $e_t^{NPART} = \rho^{NPART} e_{t-1}^{NPART} + \varepsilon_t^{NPART}, \qquad \varepsilon_t^{NPART} \sim N(0, \sigma^{NPART})$.

The consumption index is itself an aggregate over varieties of domestic and foreign goods which are imperfect substitutes. These preferences are expressed by a nested CES utility function. It is assumed that households, firms and the government have identical preferences over domestic and foreign varieties in order to facilitate aggregation. The sub utility functions are described in more detail in section 1.4 below.

The household decides about consumption, asset allocation, the supply of labour and real money holdings[1]. As shown by the budget constraint, the household has four sources of income, net labour income ($(1-t_t^w)W_t^i L_t^i$), net transfer income from the government ($NETTR_t^i$), dividend

[1] With an interest rate rule as specified below, an optimality condition for money would only determine the desired money holdings of the household sector without any further consequence for the rest of the economy. For that reason any further discussion on money demand is dropped here.

income from the domestic corporate sector $(div_t PC_t Q_t K^i_{t-1})$ and interest income from government and foreign bonds. A trading friction for foreign bonds is introduced, expressed as a function of the net foreign asset to GDP ratio $(risk(E_t B^{iF}_{t-1}/Y_t) + e^{RPE}_t)$ and an autocorrelated random shock $e^{RPE}_t = \rho^{RPE} e^{RPE}_{t-1} + \varepsilon^{RPE}_t$, with $\varepsilon^{RPE}_t \sim N(0, \sigma^{RPE})$. The risk premium captures the cost for the domestic household of undertaking positions in the international capital market. As borrower, the household is charged a premium on the foreign interest rate and as lender he receives a remuneration which is below the foreign interest rate. The first order conditions of the household with respect to consumption and financial wealth are given by the following equations:

(14a) $$\frac{\partial U_0}{\partial C^i_t} => U^i_{C,t} - \lambda_t \frac{(1+t^c_t)PC_t}{P_t} = 0$$

(14b) $$\frac{\partial U_0}{\partial B^i_t} => -\lambda_t + {}_t\lambda_{t+1}\beta(1+i_t)\frac{P_t}{{}_tP_{t+1}} = 0$$

(14c) $$\frac{\partial U_0}{\partial B^{iF}_t} => -\lambda_t + {}_t\lambda_{t+1}\beta(1+i^F_t)(1-risk(\frac{NFA_t}{P_tY_t}))\frac{P_t}{{}_tP_{t+1}}\frac{{}_tE_{t+1}}{E_t} = 0$$

(14d) $$\frac{\partial U_0}{\partial K^i_t} => -\lambda_t \frac{PC_tQ_t}{P_t} + {}_t\lambda_{t+1}\beta\frac{\left((1+div_t)_t PC_{t+1}\,{}_tQ_{t+1}\right)}{{}_tP_{t+1}} = 0$$

From the FOC we obtain the following arbitrage equations

(14b') $$(1+i_t)\frac{P_t}{{}_tP_{t+1}} = (1+i^F_t)(1-risk(\frac{NFA_t}{P_tY_t}))\frac{{}_tE_{t+1}}{E_t}\frac{P_t}{{}_tP_{t+1}}$$

(14d') $$(1+i_t)\frac{P_t}{{}_tP_{t+1}} = \left((1+div_t)\frac{{}_tQ_{t+1}}{Q_t}\right)\frac{{}_tPC_{t+1}}{PC_t}\frac{P_t}{{}_tP_{t+1}}$$

The first arbitrage condition requires that up to a risk premium, the return from a domestic bond is equal to the return from a foreign bond expressed in the domestic currency. The second arbitrage condition requires that the return from equity, i. e. dividends plus changes in the value of the capital stock plus changes in the price of capital goods is equal to the nominal interest rate.

1.2.2 Liquidity constrained households

Liquidity constrained households do not optimize but simply consume their entire labour income at each date. Real consumption of household *k* is thus determined by net wage income plus transfers

(15) $$(1+t^c_t)P^c_t C^k_t = (1-t^w_t)W_tL_t + NETTR^k_t = (1-t^w_t)W_tL_t + TR^k_t - Tax_t$$

1.2.3 Wage setting

Workers from each household have market power in the labour market, because they offer services, which are imperfect substitutes to services offered by other workers. There is a continuum of monopolistically competitive unions indexed over the same range as households $h \in [0,1]$ which act as wage setters for the differentiated labour services. In a monopolistic labour market the elasticity of substitution between different types of labour determines the mark-up of wages over the equilibrium wage. This elasticity is defined by

(16d) $$\frac{\partial L_t^i}{\partial W_t^i} = -\theta \left(\frac{W_t^i}{W_t} \right)^{-\theta} \frac{L_t^i}{W_t^i}.$$

Now the wage setting rule can be derived taking derivatives of the Lagrangian w.r.t. wages. Using symmetry: $W_t^i = W_t$ and neglecting second order terms allows us to formulate a wage setting rule in terms of wage inflation π_t^W as

(17) $$\pi_t^w = \frac{(\theta-1)(1+t_t^C)PC_t}{\gamma_w W_t}\left[\frac{-V_{L,t}}{U_{C,t}}(1+mup^w) - \frac{(1-t_t^w)W_t}{PC_t(1+t_t^C)}\right] + \beta(sfw_t\,\pi_{t+1}^w + (1-sfw)\pi_{t-1}^w)$$

with a wage mark up term $mup^w = \frac{1}{\theta}$ which goes to zero as the substitutability between different types of labour goes to infinity. Households are setting the real net consumption wage as a mark up over the value of leisure which is defined as the marginal utility of leisure divided by the marginal utility of consumption.. This formulation generalises the neoclassical labour supply model along two dimensions. First, because of imperfect substitutability between different types of labour, households can set a consumption wage which is above the reservation wage as determined by the value of leisure. The magnitude of the wage mark up depends on the degree of substitutability between varieties of labour. Second, by introducing convex wage adjustment costs ($\gamma_w > 0$), workers want to smooth wage adjustments, taking into account current and future expected labour market conditions. Notice, like in the goods market, we assume that a fraction (*1-sfw*) of workers index wage inflation to inflation in period t-1. This first order condition can be reformulated as a wage setting rule

1.2.4 Aggregation

The aggregate of any household specific variable X_t^h in per capita terms is given by $X_t = \int_0^1 X_t^h dh = (1-slc)X_t^i + slcX_t^k$ since households within each group are identical. Hence aggregate consumption is given by

(18a) $$C_t = (1-slc)C_t^i + slcC_t^k$$

and aggregate employment is given by

(18b) $N_t = (1-slc)N_t^i + slcN_t^k$ with $N_t^i = N_t^k = N_t$.

Since liquidity constrained households do not own financial assets we have $B_t^k = B_t^{k^F} = K_t^k = 0$.

1.3 Policy:

We assume that fiscal and monetary policy is partly rules based and partly discretionary. Policy responds to an output gap indicator of the business cycle. Consistent with our production function the output gap is given by

(19) $$YGAP_t = \left(\frac{ucap_t}{ucap_t^{ss}}\right)^{(1-\alpha)} \left(\frac{L_t}{L_t^{ss}(1-e_t^{NPART})}\right)^{\alpha}.$$

where L_t^{ss} and $ucap_t^{ss}$ are moving average steady state employment rate and capacity utilisation:

(19a) $\log(ucap_t^{ss}) = (1-\rho^{ucap})\log(ucap_{t-1}^{ss}) + \rho^{ucap}\log(ucap_t^j)$

(19b) $\log(L_t^{ss}) = (1-\rho^{Lss})\log(L_{t-1}^{ss}) + \rho^{Lss}\log(L_t)$

This concept of an output gap was chosen because we want to be as close as possible to the standard practice of calculating output gaps that is used in fiscal surveillance in the euro area (see Denis et al. (2002)).

1.3.1 Fiscal Policy

Both expenditure and receipts are responding to business cycle conditions. On the expenditure side we identify the systematic response of government consumption, government transfers and government investment to the business cycle.

We allow the share of government consumption in GDP

$$\log(\frac{PC_tG_t}{P_tY_t}) = \log(GSN_t) = gsn_t$$

and the share of government investment

$$\log(\frac{PC_tGI_t}{P_tY_t}) = \log(GISN_t) = gisn_t$$

to respond systematically to the business cycle according to the following rules

(20) $$gsn_t = (1-gslag)\overline{gsn} + gslag \cdot gsn_{t-1} + \sum_{i=0}^{Lg} t_{g,i}^{Y}\log(YGAP_{t-i}) + e_t^G$$

(21) $$gisn_t = (1-gislag)\overline{gisn} + gislag \cdot gisn_{t-1} + \sum_{i=0}^{Lg} t_{gi,i}^{Y}\log(YGAP_{t-i}) + e_t^{GI}$$

Government consumption and government investment can temporarily deviate from their long run targets in response to fluctuations of the output gap. Due to information and implementation lags the response may occur with some delay. This feature is captured by a distributed lag of the output gap in the reaction function. A discussion about the actual identification of the number of lags is given later in Section 2.

Concerning the transfer rule we impose more institutional information. The transfer system in the euro area provides income for unemployed and for pensioners and acts as an automatic stabiliser. The state–contingent nature of transfers implies a correlation with cyclical conditions, namely the current employment gap. The degree of stabilisation is proportional to the unemployment benefit and pension replacement rate b^U and b^P respectively and we can write the following transfer rule

(22) $$\frac{TR_t}{W_t L_t} = t_{TR}^L \frac{POP_t^W}{L_t}\left(\frac{POP_t^W - L}{POP_t^W}\right) + t_{TR}^{dep} \frac{POP_t^W}{L_t}\left(\frac{POP_t^{Old}}{POP_t^W}\right)$$

We define $trsn = \frac{TR}{WL}$ and rewrite the transfer rule in terms of log deviations of the employment rate from its steady state level

(23) $$trsn_t = \overline{trsn} + t_{TR}^L \log(\frac{L_t}{L_t^{ss}(1 - e_t^{NPART})}) + t_{TR}^{dep} \frac{POP_t^{Old}}{POP_t^W} + e_t^{TR}$$

Discretionary fiscal action is characterised by the variables e_t^g (*g=G,GI,TR*) which follow autocorrelated processes $e_t^g = \rho^g e_{t-1}^g + \varepsilon_t^g$, $\varepsilon_t^g \sim N(0, \sigma^g)$.

Government revenues R_t^G are financed by taxes on consumption as well as capital and labour income.

(24) $$R_t^G = t_t^w W_t L_t + t_t^c P_t^c C + t_t^p (P_t Y_t - W_t L_t)$$

Following the OECD estimates for revenue elasticities (van den Noord (2000)) we assume that consumption and capital income tax follow a linear scheme, and a progressive labour income tax schedule

(25a) $$t_t^w = t_0^w Y_t^{t_1^w} \exp(e_t^{TW})$$

where t_0^w measures the average tax rate, t_1^w the degree of progressivity and e_t^{TW} is an autoregressive shock. A simple first-order Taylor expansion around a zero output gap yields

(25b) $$t_t^w = t_0^w + t_0^w t_1^w \log(YGAP_t) + e_t^{TW}$$

The government budget constraint is given by

(26a) $$B_t = (1 + i_t) B_{t-1} + PC_t G_t + TR_t - R_t^G - Tax_t$$

and there is a residual lump-sum tax (*Tax)* used for controlling the debt to GDP ratio according to the following rule

(26b) $$\Delta Tax_t = bgadj_1(\frac{B_{t-1}}{Y_{t-1}P_{t-1}} - btar) + bgadj_2\Delta\left(\frac{B_t}{Y_tP_t}\right)$$

where *btar* is the government debt target.

1.3.2 Central bank policy rule (interest rate rule)

Monetary policy is modelled via the following Taylor rule, which allows for some smoothness of the interest rate response to the inflation and output gap

(27) $$\begin{aligned} i_t &= ilag * i_{t-1} + (1-ilag)*[Ex.R + g^U + \pi^T] + t_M^{\pi}(\pi_t^C - \pi^T) + t_{M,1}^Y \log(YGAP_{t-1}) \\ &+ t_{M,2}^Y \log(YGAP_{t+1} / YGAP_t) + e_t^M \end{aligned}$$

The term e_t^M captures autocorrelated discretionary shocks to monetary policy given by $e_t^M = \rho^M e_{t-1}^M + \varepsilon_t^M$, $\varepsilon_t^M \sim N(0,\sigma^M)$ and π^T is the inflation target.

1.4 Trade and the current account

So far we have only determined aggregate consumption, investment and government purchases but not the allocation of expenditure over domestic and foreign goods. In order to facilitate aggregation we assume that households, the government and the corporate sector have identical preferences across goods used for private consumption (*C*), public consumption (*G*) and investment (*I*). Let $X^l \in \{C^l, I^l, G\}$ be demand of an individual household, investor or the government, then her preferences are given by the following utility function

(28a) $$X^l = \left[\omega^{\frac{1}{\sigma}} X^{l^d\frac{\sigma-1}{\sigma}} + (1-\omega)^{\frac{1}{\sigma}} X^{l^f\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{(\sigma-1)}}$$

where X^{l^d} and X^{l^f} are indexes of demand across the continuum of differentiated goods produced respectively in the domestic economy and abroad, given by.

(28b) $$X^{l^d} = \left[\sum_{h=1}^{n^d}\left(\frac{1}{n^d}\right)^{\frac{1}{\tau}} x_h^{l^d\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}} \quad , \quad X^{l^f} = \left[\sum_{h=1}^{n^f}\left(\frac{1}{n^f}\right)^{\frac{1}{\tau}} x_h^{l^f\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}}$$

We define τ_t to measure the inverse of the time varying elasticity of demand for variety *h* and assume that it is itself stochastic and also allow for some cyclical variation. The term τ_t is given by (see eq. (15e'))

(28c) $\tau_t = \tau^0 + e_t^{\tau}$

The elasticity of substitution between bundles of domestic and foreign goods X^{1^d} and X^{1^f} is σ. Thus aggregate imports are given by

(29) $$IM_t = (1-\omega^X)\left(\frac{PC_t}{PM_t}\right)^{\sigma}(C_t + I_t + G_t)\exp(e_t^{IM})$$

where PC and PM is the (utility based) consumer price deflator and import price deflator respectively and e_t^{IM} is a persistent AR process:

(29a) $e_t^{IM} = \rho^{IM} e_{t-1}^{IM} + \varepsilon_t^{IM}$, $\varepsilon_t^{IM} \sim N(0, \sigma^{IM})$.

We assume similar demand behaviour in the rest of the world, therefore exports can be treated symmetrically and are given by[2]

(30) $$EX_t = (1-\omega^{XW})\left(\frac{(PC_t^{W} E_t)^{\alpha^X} P_t^{(1-\alpha^X)}}{PX_t}\right)^{\sigma^X}(Y_t^{W})^{\alpha^X} Y_t^{(1-\alpha^X)}\exp(e_t^{EX})$$

where PX_t and E_t are export prices an the nominal exchange rate, PC_t^W are world consumer prices (in foreign currency)

(30a) $$PC_t^W = PW_t^{\omega^{XW}} \frac{P_t}{E_t}^{(1-\omega^{XW})}$$

and e_t^{EX} is a persistent AR shock as for imports:

(30b) $e_t^{EX} = \rho^{EX} e_{t-1}^{EX} + \varepsilon_t^{EX}$, $\varepsilon_t^{EX} \sim N(0, \sigma^{EX})$

Prices for exports and imports are set by domestic and foreign exporters respectively. The exporter buys goods from domestic producers and sells them in the foreign (domestic) market. It is assumed that the exporters are monopolistically competitive in their respective export markets. Exporters charge a mark-up over domestic prices (linear technology) and their pricing is subject to convex adjustment costs . Thus export prices are given by

(31a) $\eta_t^{Xj} PX_t = cxP_t$

with a mark-up factor determined by

(31b) $$\eta_t^{Xj} = 1 - (\tau^{X0} + e_t^{\tau X}) - \gamma_{PX}\left[\beta(sfpx \cdot \pi_{t+1}^{Xj} + (1-sfpx)\pi_{t-1}^{Xj} - \bar{\pi}^{Xj}) - (\pi_t^{Xj} - \bar{\pi}^{Xj})\right]$$

$0 \leq sfpx \leq 1$

Where $e_t^{\tau X}$ follows the AR process: $e_t^{\tau X} = \rho^{\tau X} e_{t-1}^{\tau X} + \varepsilon_t^{\tau X}$, , $\varepsilon_t^{\tau X} \sim N(0, \sigma^{\tau X})$

[2] Exports *EX* include intra euro area trade, with a share (1-α^X).

We assume that monopolistic competition applies to the foreign firms as well. There is no pricing to market and import prices are given by

$$(32) \qquad PM_t = cxw\left((E_t PW_t)^{\alpha^X} P_t^{1-\alpha^X}\right)^{spm} (PM_{t-1})^{(1-spm)} \exp(e_t^{PM})$$

with $e_t^{PM} = \rho^{PM} e_{t-1}^{PM} + \varepsilon_t^{PM} \qquad \varepsilon_t^{PM} \sim N(0, \sigma^{PM})$

Exports and imports together with interest receipts/payments determine the evolution of net foreign assets (*NFA*) denominated in domestic currency.

$$(33) \qquad E_t NFA_t = (1 + i_t^F) E_t NFA_{t-1} + PX_t EX_t - PM_t IM_t$$

2. Estimation

Our technological assumptions imply that domestic and foreign GDP and its components are stationary in growth rates. Our model implies that various nominal ratios such as the consumption to GDP ratio (*CSN*), the investment to GDP ratio (*ISN*), the government consumption to GDP ratio (*GSN*), the government investment to GDP ratio (*GISN*), the government transfers to wages ratio (*TRSN*) the export (*EXSN*) and import (*IMSN*[3]) share in GDP, the wage share (*WSN*), the employment rate (*L*) and the real exchange rate (*ER*) are stationary. Concerning nominal variables we assume that the domestic and foreign inflation target is a constant. This implies that domestic wage inflation rate (π^w), foreign and domestic price inflation (π, π^F) rates and nominal domestic and foreign interest rates (i, i^F) are stationary, as well as certain price ratios, in particular the relative consumer price (*PC/P*) and the relative import (*PM/P*)and export price (*PX/P*) ratios. These variables, together with the following exogenous variables: growth of population of working age (g^{popa}), the demographic dependency ratio (*deprat*) and the technology shock to the investment good production (U^I) form our information set. World economy series [i^F, π^F, g^{YW}] are considered as exogenous and are modeled as a VAR(1) process. To assure stationarity of the Y/Y^W ratio, an equilibrium correction term is added to the g^{YW} equation. This introduces a small feedback of domestic demand into world demand. The model is estimated on quarterly data for the euro area over the period from 1981Q1 to 2005Q3, taken from the ECB AWM data base and updated with Eurostat quaterly national accounts database.

The parameters listed in Table 1 are calibrated and kept constant over the estimation exercise:

[3] Concerning the import and export share we remove a trade integration trend prior to estimation.

TABLE 1. Calibrated parameters

Structural parameters		Steady states	
α	0.54	deprat	0.3
β	0.996	$\overline{gsn}$	0.2
δ	0.025	$\overline{gisn}$	0.025
bgad1	4.e-6	$\overline{g^{UI}}$	0.0013
bgad2	4.e-3	π, π^F	0.005
Bgtar	2.4	$\overline{g^{popa}}$	0.00125
τ	0.1	$\overline{g^Y}, \overline{g^{YW}}$	0.003
ρ^G, *trslag*	0	$\overline{g^{UP}} = \overline{g^Y} - \frac{1-\alpha}{\alpha}\overline{g^{UI}}$	0.0019
ρ^{ucap}	0.975	$\overline{ucap}$	1
ρ^{POP}	0.98	$\overline{L}$	0.62
t^p, t^c, t^{w0}	0.2		
α^X	0.5		

Other parameters are determined according to steady state constraints:

- $a_1 = (1-\tau)*(1-\alpha)1/\text{KSN}$, determined in order to assure the steady state constraint UCAP=1, where $KSN = K/Y*PI/P$ is the nominal capital to GDP share.
- ω is determined in order to assure the steady state condition $\overline{L} = 0.62$

The dynamical forms of government spending and government investment have been identified by estimating separately from the rest of the model an array of models of the general form:

$$(34)\quad y_t = \frac{b_{1,0}L^{\delta} + b_{1,1}L^{1+\delta} + \ldots + b_{1,n}L^{n+\delta}}{1 - a_1 L - \ldots - a_m L^m} u_{1,t} + \ldots + \frac{b_{k,0}L^{\delta} + b_{k,1}L^{1+\delta} + \ldots + b_{k,n}L^{n+\delta}}{1 - a_1 L - \ldots - a_m L^m} u_{k,t} + e_t$$

where *L* is the lagged operator. The selection of the model is then taken considering both the R^{T^2} statistics, based on the response error, and information criteria.

For both government consumption and investment, the input is the output gap. This implied a two step-procedure, where first the dynamical structure was identified using a HP-filtered output gap. The obtained structure and coefficients are fed into the DSGE model, which is estimated given the previously identified coefficients. At this stage, we obtain a model based output gap which is again fed into the separated identification procedure which gives the final structure. This second step identification is then used to define the prior distribution of the coefficients in the government spending rules, which are then estimated together with the other parameters in the DSGE model. Thus, the estimated government consumption rule takes the form

$$(35)\quad gsn_t = (1 - gslag)\cdot \overline{gsn} + gslag \cdot gsn_{t-1} + t^Y_{G,0} \cdot \log(YGAP_t) + t^Y_{G,1} \cdot \log(YGAP_{t-1}) + e^G_t$$

The investment rule is given by

(36) $gisn_t = (1 - gislag) \cdot \overline{gisn} + gislag \cdot gisn_{t-1} + t^{Y}_{GI,1} \cdot \log(YGAP_{t-1}) + e^{GI}_t$
with $e^{GI}_t = \rho^{GI} \cdot e^{GI}_{t-1} + \varepsilon^{GI}_t$.

The model parameters are estimated applying the Bayesian approach as, e.g., Schorfheide (2000), Smets and Wouters (2003). From the computational point of view, the DYNARE toolbox for MATLAB has been applied (Juillard, 1996-2005).

2.1 Prior distributions

Exogenous AR shocks have beta distributions for auto-correlation coefficients with prior mean at 0.85 except for mark-up shock, monetary shock, investment specific technological shock, wage tax rule shock, where we set prior mean to 0.5, where we did not have any 'preference' between a persistent shock or a white noise. Standard errors have prior gamma distributions, with prior mean values at

- 0.1%-0.5% for 'persistent shocks' (accounting for different trends in the data, like participation rate, labour overhead, drift of technology) and for shocks to risk premia;
- 1% for technology and investment specific technological shocks and nominal GDP shares of government consumption, investment, transfers;
- 2% for import/export shocks;
- 5% for preference shock and mark-up shocks

For fiscal parameters, we set a prior around zero for $t^{Y}_{G,0}$ and $t^{Y}_{G,0} + t^{Y}_{G,1}$, to let the data drive pro-cyclical or counter-cyclical reaction of government consumption to output gap. For government investment, we set the prior of $t^{Y}_{IG,1}$ at 0.5, i.e. pro-cyclical response. For transfers we set prior mean of t^{L}_{TR} at 0.6, which roughly corresponds to a benefit replacement rate of about 40%. For wage tax, we set a prior at 0.8 for the reaction to output gap, following OECD estimate. Since no taxation data are used, it is hard to have a clear identification of t^{W}_{1} in the current exercise, so putting a prior range around OECD estimate has the meaning of checking that a calibrated value around 0.8 is not rejected from available data on consumption and government expenditures. Persistence in the government spending and investment rules has a prior at 0.85, while for transfers this is set to zero.

For price and wage rigidities we roughly follow Smets and Wouters, but allowing a wider variation in the upper bound (prior mean at 30). Capital and labour adjustment costs have similar priors, while for investment the prior is smaller (15). Prior consumption habit is set at 0.7. Inverse of intertemporal elasticities have prior gamma distributions with mean 1.25 and standard deviation 0.5, while θ has a mean 1.5 and standard deviation 1. The share of liquidity constrained households has a prior at 0.5, with standard deviation 0.1, similarly to Forni et al. (2006).

The share of forward looking behaviour in hybrid Phillips curves has prior mean at 0.5 in the range [0, 1].

2.2 Posterior estimation

The draws from the posterior distribution have been obtained by taking 800,000 runs of Metropolis. Convergence of the Markov Chain has been tested by cumulated means. The shape of the likelihood at the posterior mode and the Hessian condition number have been also considered to highlight lack of identification for some parameters[4]. In Table 2.1 we show prior distributions and posterior estimations of our structural parameters (see Table A1 in the annex for estimates of standard errors of shocks and AR coefficients of autocorrelated shocks and Figure A1 for the plots of priors and posterior distributions).

TABLE 2.1: Estimation Results

Parameter name		**Prior**			**Posterior**	
		distrib	**mean**	**Std**	**mean**	**std**
a_2	A2E	beta	0.05	0.024	0.0212	0.009882
$t^Y_{G,0}$	G1E	beta	0	0.6	-0.5339	0.141886
$t^Y_{G,1}$	G2E		0		0.53807	0.139362
$t^Y_{G,0} + t^Y_{G,1}$	GSUM	beta	0	0.04	0.0041	0.021663
γ_K	GAMIE	gamma	30	20	22.9549	4.474299
γ_I	GAMI2E	gamma	15	10	15.6589	5.406387
γ_L	GAMLE	gamma	30	20	63.1248	11.80929
γ_P	GAMPE	gamma	30	20	20.6431	7.343065
γ_{PX}	GAMPXE	gamma	30	20	24.411	13.40898
γ_W	GAMWE	gamma	30	20	26.5775	13.80058
gslag	GSLAG	beta	0.85	0.075	0.8865	0.034234
habc	HABE	beta	0.7	0.1	0.9352	0.023471
habl	HABLE	beta	10	4	8.1037	1.616638
$t^Y_{IG,1}$	IG1E	beta	0.5	0.22	0.5424	0.140532
igslag	IGSLAG	beta	0.85	0.075	0.8318	0.061033
ilag	ILAGE	beta	0.85	0.075	0.8597	0.023116
κ	KAPPAE	gamma	1.25	0.5	2.9125	0.485373
risk	RPREME	beta	0.01	0.004	0.0063	0.002974
rp	RPREMK	beta	0.01	0.004	0.0056	0.00267
ω^X	SE	beta	0.695	0.018	0.7295	0.005687
ω^{XW}	SWE		0.695		0.723305	0.008617
$\omega^X - \omega^{XW}$	SEDIFF	beta	0	0.0075	0.0062	0.00649
sfp	SFPE	beta	0.5	0.24	0.9218	0.052931
sfpx	SFPXE	beta	0.5	0.24	0.9539	0.033822
sfw	SFWE	beta	0.5	0.24	0.9523	0.026466

[4] Only for two structural parameters does the likelihood not dominate the prior, namely for export price and wage rigidities (γ_{PX} and γ_W). A similar lack of identification for γ_W seems also present in Smets and Wouters (2003) (see also Canova and Sala (2005) about identification problems in the Smets and Wouters model and inDSGE models in general)

σ^C	SIGC	gamma	1.25	0.5	2.64	0.476742
σ^X	SIGEXE	gamma	1.25	0.5	1.4431	0.135808
σ	SIGIME	gamma	1.25	0.5	0.6116	0.119259
slc	SLC	beta	0.5	0.1	0.6312	0.071708
spm	SPM	beta	0.5	0.2	0.4615	0.056821
θ	THETAE	gamma	1.5	1	2.1465	0.606874
t_M^{π}	TINFE	beta	0.3	0.1	0.32	0.03606
$t_{M,1}^Y$	TYE1	beta	0.3	0.2	0.0326	0.008626
$t_{M,2}^Y$	TYE2	beta	0.3	0.2	0.1627	0.072934
t_1^w	TW1	beta	0.8	0.32	0.7661	0.320313
t_{TR}^L	TR1E	beta	-0.6	0.2	-0.5367	0.058461
t_{TR}^{dep}	TR3E	beta	1	0.4	0.6178	0.193613
$\overline{trsn}$	TRSN	beta	0.4	0.04	0.3988	0.014337

The estimated fraction of forward looking price setting behaviour is high. The posterior mean for *sfp* is estimated at 0.92, which implies only 8 percent of firms keep prices fixed at the *t-1* level. The estimated share of liquidity-constrained consumers is 0.63, which is higher than estimates reported in Coenen and Straub (2005) and Forni et al. (2006). Note that our estimates also suggest a significant degree of habit persistence in consumption, *habc=0.93* and an intertemporal elasticity of substitution of around 0.4.

The estimated fiscal response parameters are counter-cyclical for government consumption and transfers. Government consumption is highly persistent and responds to the current change in the output gap (the posterior estimate of the sum $t_{G,0}^Y + t_{G,1}^Y$ is in fact not significantly different from zero). We find a negative response of transfers to the employment gap (t_{TR}^L), corresponding to a benefit replacement rate of about 0.4. The investment rule appears procyclical, with a high degree of persistence. The only parameter relevant for stabilisation policy on the revenues side is the degree of progressivity of wage taxes. Due to a lack of reliable data on tax rates we estimate this parameter with a tight prior distribution around an OECD estimate. The posterior mean of progressivity of the tax system t_t^{w1} is 0.77[5], which is close to our prior based on the OECD estimate of the elasticity of tax revenues with respect to the output gap[6]. By way of comparison, other studies that have analysed the actual behaviour of fiscal authorities have mainly focused on the overall deficit rather than on government expenditure catagories seperately. Gali and Perotti (2003) assess the extent to which the constraints associated with the Maastricht Treaty and the Stability and Growth pact have made fiscal policy in EMU countries more procyclical. They find discretionary fiscal policy (as measured by the primary cyclically adjusted deficit of general government) was procyclical in EMU countries before Maastricht and essentially acyclical after Maastricht. They also find an increase in the degree in counter-cyclicality of non-discretionary

[5] Note that the likelihood does not dominate the prior, i.e. not using taxation data implies a lack of identification for t_t^{w1}. The only conclusion we can draw is hence that the OECD prior is not rejected by the dataset used for estimation.

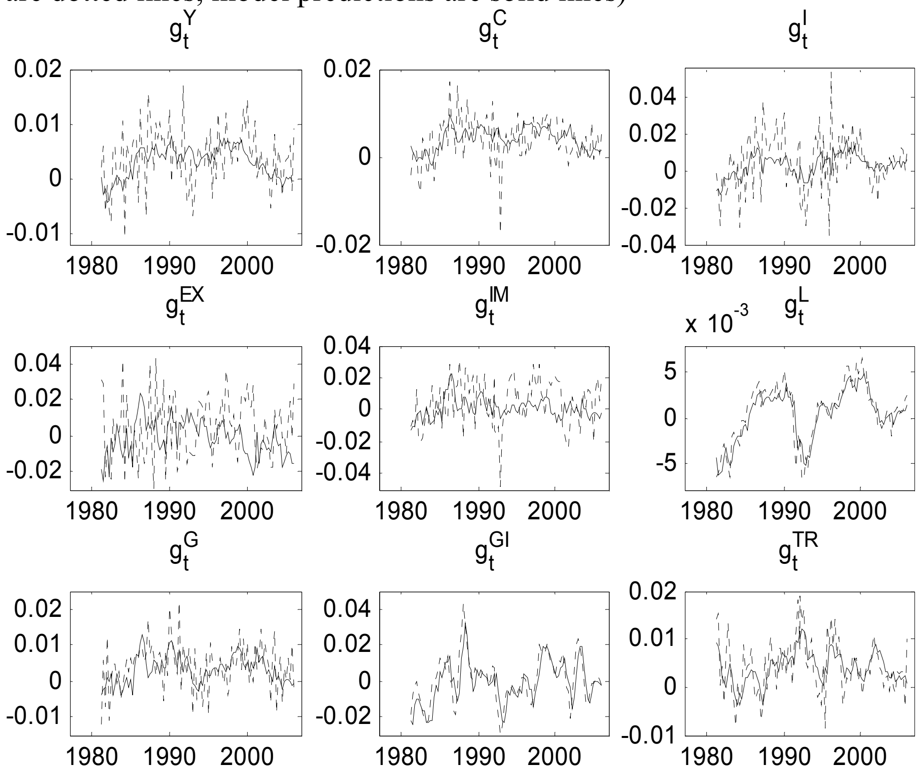
[6] The OECD calculates an elasticity of income tax revenue with respect to the output gap of 1.5 and an elasticity of the wage bill w.r.t. the gap of 0.7. This implies an elasticity of the tax rate w.r.t. to output gap of 0.8.

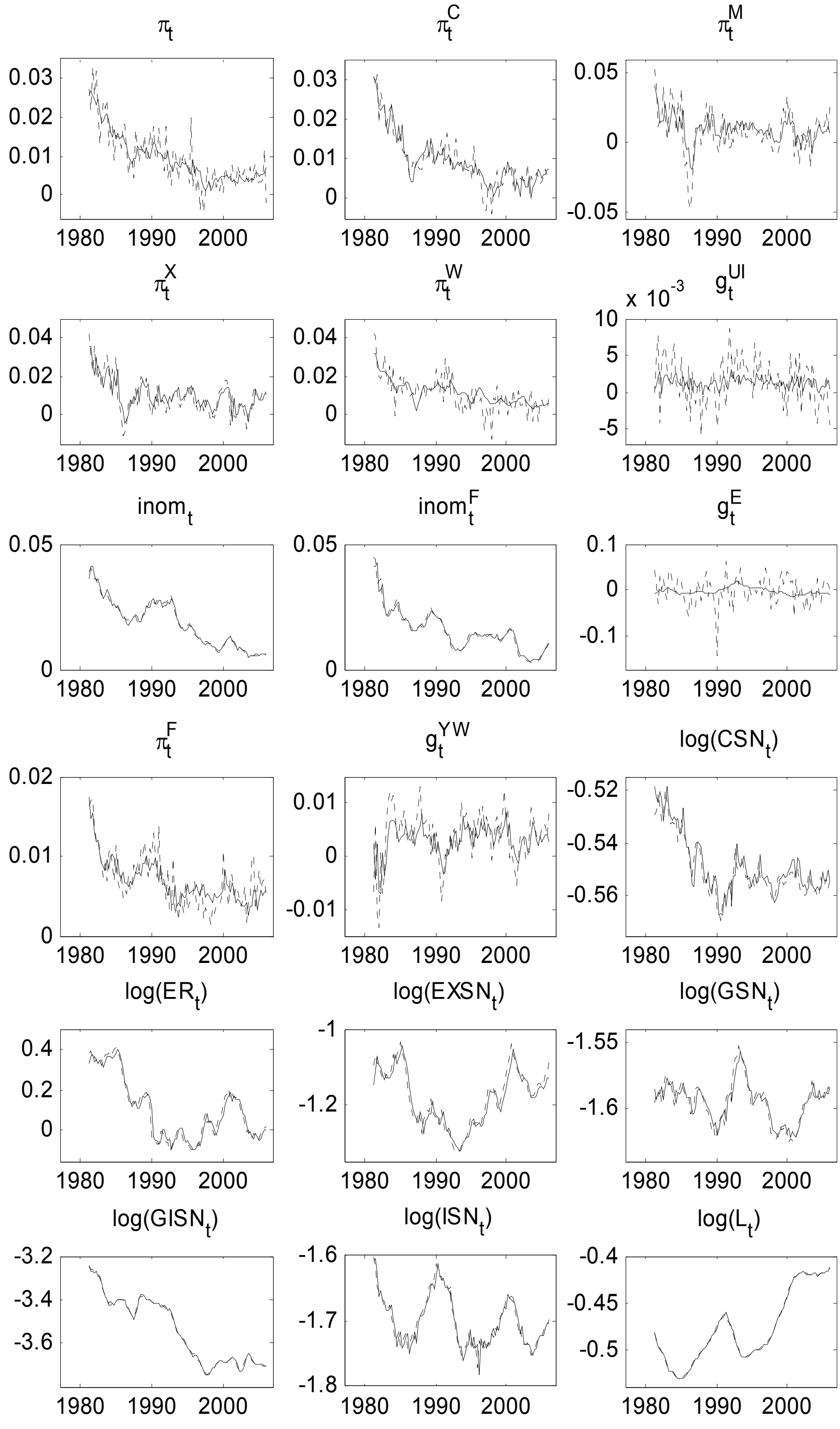
fiscal policy (as measured by the difference between the total primary deficit and the cyclically-adjusted primary deficit) in EMU countries. European Commission (2004, Ch.3) also find evidence of a change in the response of the total primary budget balance to the output gap, with an insignificant impact of the cycle on primary balances before 1994 and a significant positive impact of the output gap on the primary balance post 1994.

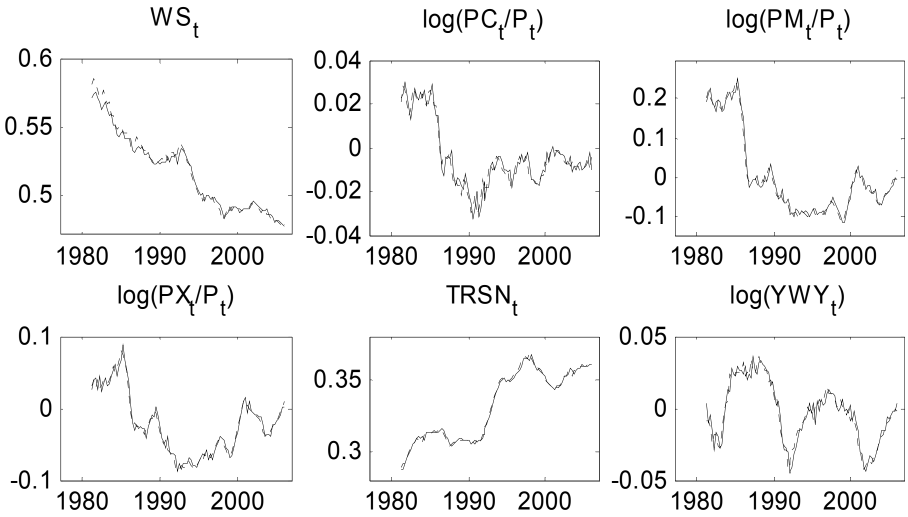
In Figure 1 we show the one step ahead predictions of the model for the growth rates of GDP (g^{Y}), consumption (g^{C}), investment (g^{I}), imports and exports (g^{IM} and g^{EX}), labour (g^{L}), government consumption (g^{G}), government investment (g^{GI}), government transfers (g^{TR}), as well as for inflations ($\pi, \pi^{C}, \pi^{M}, \pi^{X}$), wage inflation ($\pi^{W}$), growth rate of investment specific technological progress (g^{UI}), nominal interest rates (i, i^{F}), nominal exchange rate (g^{E}), world inflation (π^{F}), world GDP (g^{YW}).

We also show the fit of nominal ratios to GDP of consumption (CSN) export (EXSN), government consumption (GSN), government investment (GISN), investment (ISN), transfers to wages ratio (TRSN), the real foreign GDP to domestic GDP ratio (YWY) as well as the stationary real exchange rate (ER), labour (L), wage share (WS), consumption to GDP deflator (PC/P), import to GDP deflator (PM/P), export to GDP deflator (PX/P).

FIGURE 1. In-sample one step ahead predictions of the estimated model.
(Data are dotted lines; model predictions are solid lines)




πt
πt C
πt M
πt X
πt W
x 10-3
gt UI
inomt
inomt F
gt E
πt F
gt YW
log(CSNt)
log(ERt)
log(EXSNt)
log(GSNt)
log(GISNt)
log(ISNt)
log(Lt)
1980
1990
2000



2.3 Model comparisons

A quite widely applied method to assess the validity of the estimated DSGE models is to compare them with non-structural linear reduced-form models such as VARs or BVARs. In Table 2.2, where we compare our base model with BVAR models (lags 1 to 13) using Sims and Zha (1998) priors. The marginal likelihood of the BVAR models begins to deteriorate after order 9. Similarly to other estimated DSGE's in the literature, our base model has a better marginal likelihood than BVAR's. Although the robustness of these kinds of results may depend on different prior assumptions in both the DSGE and the BVAR, this is an indication that our base model has a reasonable empirical fit.

TABLE 2.2.

	Marginal likelihood
BVAR(1)	8528.0
BVAR(2)	8648.1
BVAR(3)	8677.0
BVAR(4)	8681.2
BVAR(5)	8692.8
BVAR(6)	8692.3
BVAR(7)	8694.1
BVAR(8)	8702.0
BVAR(9)	8703.9
BVAR(10)	8700.3
BVAR(11)	8694.7
BVAR(12)	8691.9
BVAR(13)	8685.5
Base DSGE model	9044.2

We also compared our base model with a model specifications where all the fiscal rules are exogenous, i.e. where

(37a) $gsn_t = (1 - gslag) \cdot \overline{gsn} + gslag \cdot gsn_{t-1} + e_t^G$

(37b) $gisn_t = (1 - gislag) \cdot \overline{gisn} + gislag \cdot gisn_{t-1} + e_t^{GI}$

(37c) $trsn_t = (1 - trslag) \cdot \overline{trsn} + trslag \cdot trsn_{t-1} + t_{TR}^{dep} \cdot \frac{POP_t^{Old}}{POP_t^W} + e_t^{TR}$

(37d) $t_t^w = t_0^w + e_t^{TW}$

This is shown in Table 2.3, where it can be seen that the base model improves the marginal likelihood by more than 100 log-points with respect to the model with exogenous G, GI, TR, TW (estimates are reported in Annex 2). Looking into more detail about the fit (RMSE's) of each singular series in the two model specifications, it can be seen that the improvement of the fit in our base model is very significant, as would be expected, for the government variables G, GI, TR. As far as other endogenous variables are concerned, the dynamics of wage inflation is also much better described by our base model, while the other endogenous variables have minor changes, e.g. the fit of aggregate consumption growth (g^C) and nominal interest rates for the base model is slightly worse, while it is slightly better for employment (g^L) and output (g^Y) growth and consumer price inflation (π_t^C).

TABLE 2.3

	Base Model	**Exogenous G, IG, TR, TW**
Marginal likelihood	9044.2	8891.6
rmse g_t^Y	0.005349	0.005381
rmse g_t^C	0.004805	0.004725
rmse g_t^I	0.014592	0.014599
rmse g_t^G	0.005871	0.006238
rmse g_t^{IG}	0.008378	0.009115
rmse g_t^{TR}	0.004831	0.006807
rmse g_t^L	0.001428	0.001435
rmse π_t^W	0.006207	0.007053
rmse $inom_t$	0.001116	0.001077
rmse π_t	0.004018	0.004029
rmse π_t^C	0.003013	0.003148
rmse π_t^M	0.012412	0.012328
rmse π_t^X	0.005971	0.00599
rmse g_t^E	0.029785	0.029739
rmse g_t^{EX}	0.021004	0.020241
rmse g_t^{IM}	0.017223	0.017225

3. Assessing the Role of Fiscal Policy

We now proceed to investigate the role of fiscal policy in stabilising the economy by analysing the impulse responses and variance decomposition of the estimated model. We first look at the effects of government consumption, investment and transfer shocks in the model, by comparing the responses of the estimated model with those without fiscal policy reactions to cyclical conditions, i.e. when $t^{Y}_{G,1} = t^{Y}_{G,2} = t^{Y}_{GI,1} = t^{L}_{TR,1} = t^{W}_{1} = 0$. We also compare the dynamic responses of the main economic variables to structural shocks in the estimated model with those when the fiscal response parameters are set to zero, i.e. in a model without systematic fiscal policy reactions to cyclical conditions and without persistence, i.e. $t^{Y}_{G,1} = t^{Y}_{G,2} = gslag = t^{Y}_{GI,1} = igslag = t^{L}_{TR,1} = t^{W}_{1} = 0$. This is followed by a direct comparison of the standard deviations for the main economic variables, as generated by the model with and without active fiscal policy.

3.1. How large are the effects of government consumption, investment and transfers shocks?

Figures 2 to 4 show the response to a government consumption, investment and transfers shock respectively, for the estimated model (solid lines) and the model without *active* fiscal policy, i.e. with $t^{Y}_{G,1} = t^{Y}_{G,2} = t^{Y}_{GI,1} = t^{L}_{TR,1} = t^{W}_{1} = 0$, but with the estimated persistence (dotted lines). The magnitude of the shocks is given by the posterior estimate, i.e. we used the full joint posterior distribution of structural parameters and shocks to produce the Bayesian uncertainty bounds of IRFs. The government consumption and investment shocks raise government spending as a share of output, but spending gradually returns to baseline. We are particularly interested in the effect of liquidity constraints on the response of consumption to this shock. The second, fourth and fifth panels show the responses of aggregate consumption *C*, non liquidity-constrained consumption C^i and liquidity-constrained consumption C^k respectively. After a government consumption shock, consumption of Ricardian households C^i falls on impact, but consumption of liquidity constrained consumers C^k rises as wage income increases, although in later periods liquidity-constrained consumption falls below baseline, as the build-up of debt leads to an increase in taxes and reduces after tax income. In the model without fiscal policy reactions (dotted lines) aggregate consumption is also higher. However, in the estimated model with active fiscal policy, transfers fall as employment rises, and the negative impact of this on liquidity-constrained consumption C^k means that aggregate consumption *C* now falls[7]. The spending shock crowds-out private investment. The responses of private consumption to a government investment shock are broadly similar, except that the estimated government investment rule is pro-cyclical.[8]

[7] Experiments show that only eliminating the reaction of the transfer rule to the employment gap would be sufficient to generate a positive response of aggregate consumption.

[8] Note that investment is assumed to be non-productive here, as we focus on short term stabilisation in this paper.

FIG. 2. IRF's to a government consumption shock.
Solid lines are posterior means and confidence intervals for the estimated model, while dotted ones are the posterior means without fiscal policy reactions.

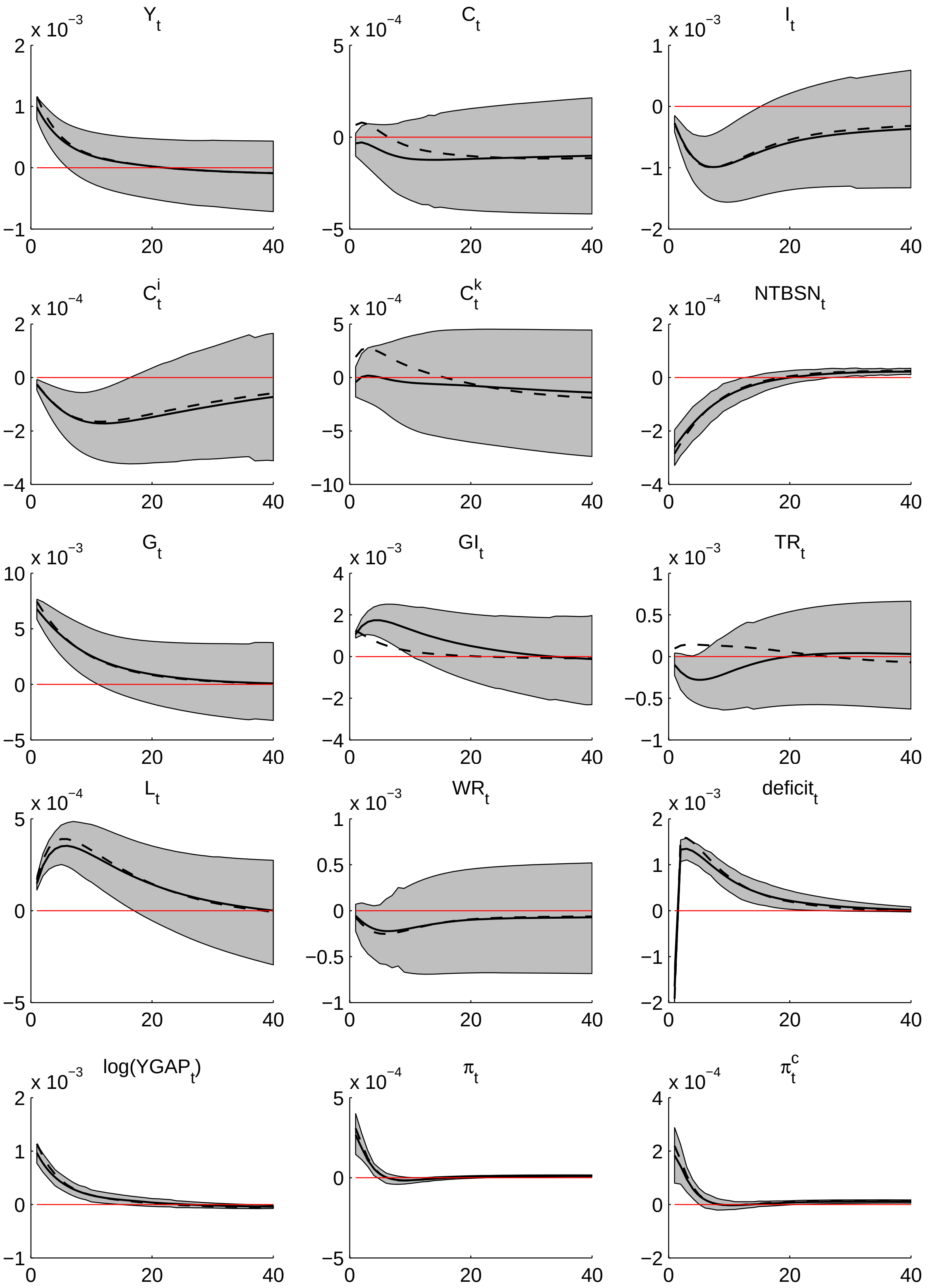


FIGURE 3. IRF's to a government investment shock.
Solid lines are posterior means and confidence intervals for the estimated model, while dotted ones are the posterior means without fiscal policy reactions.

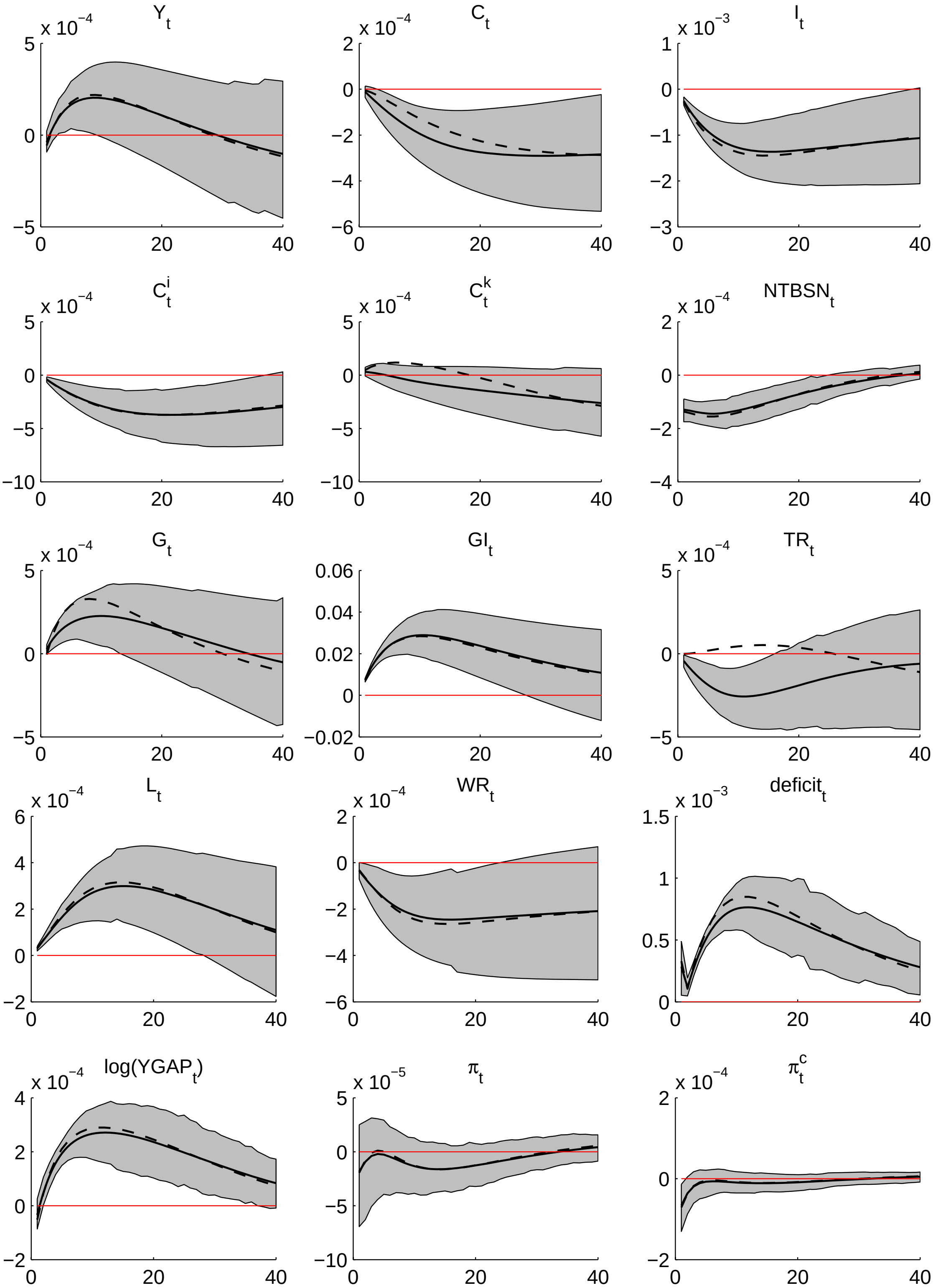


FIGURE 4. IRF's to a government transfers shock.
Solid lines are posterior means and confidence intervals for the estimated model, while dotted ones are the posterior means without fiscal policy reactions.

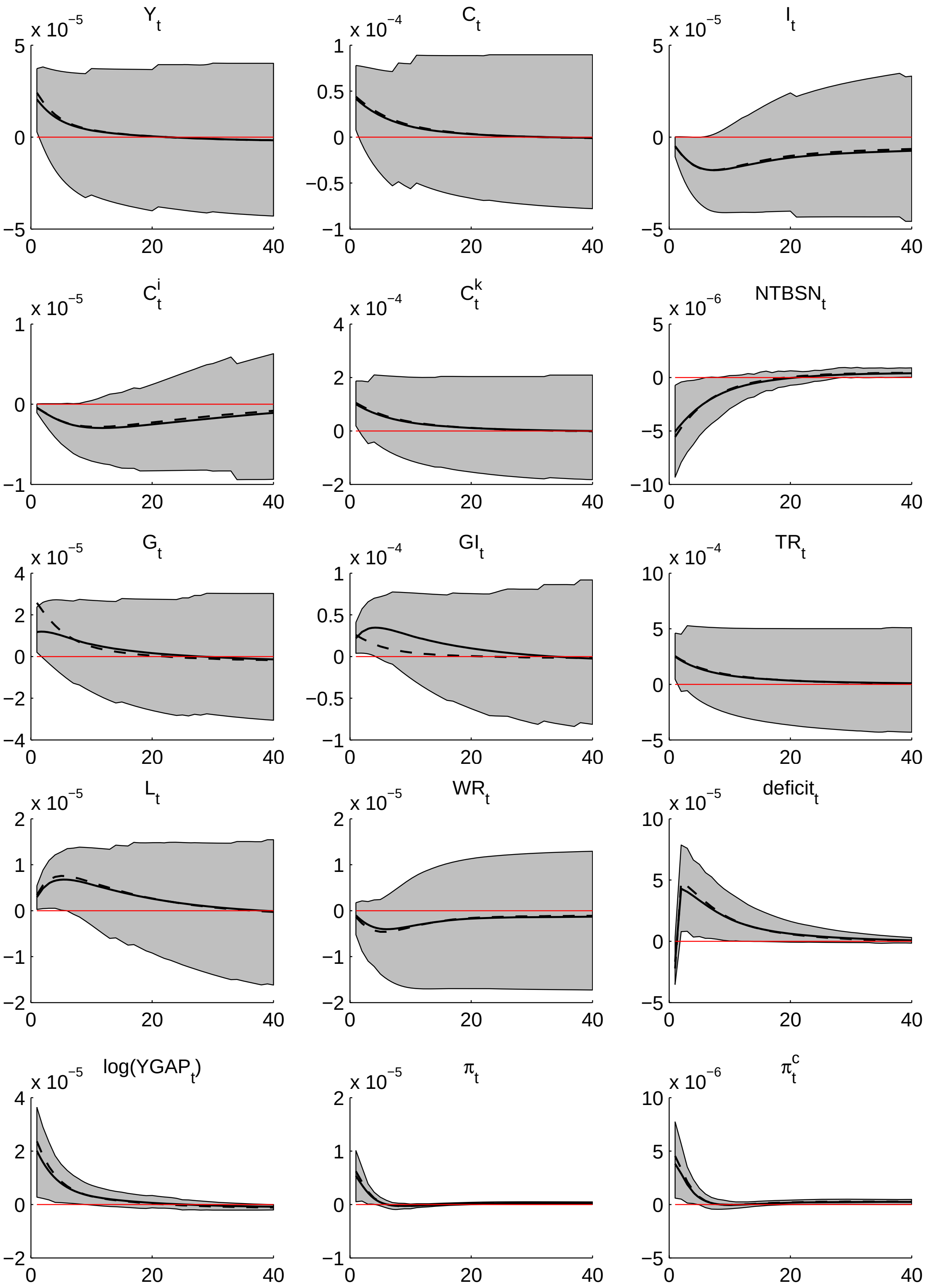


Figure 4 shows the responses to a government transfer shock. The increase in transfers raises disposable incomes and boosts liquidity-constrained consumption. There is a negative impact on consumption of non liquidity-constrained consumers, but this is much smaller and aggregate consumption is positively affected by the transfer shock. Again, fiscal policy crowds out private investment.

Our results can be compared to Coenen and Straub (2005). They estimate a DSGE model for the euro area similar to Smets and Wouters (2003), but introduce non-Ricardian households in the model similar to our liquidity constrained consumers. For a lower share of non-Ricardian households (between 0.25 and 0.37) they find a short-lived rise in liquidity- constrained consumption, but falling below its steady state level already after a few quarters, caused by a rise in lump-sum taxes due to the build up of government debt. Forni et al. (2006) find a positive response of consumption to both a government purchases and a government employment shock, but assume no fiscal response to cyclical conditions.

To assess the impact of the government spending shocks on output in terms of traditional "multipliers", the impact effect for a 1 percent of government spending shock on GDP is 0.7 in the first quarter, falling to 0.5 in the fourth quarter. It remains positive for three to four years, and then turns negative. Cumulated over the first year the multiplier is 0.6. This is somewhat smaller than results reported in Roeger and in 't Veld (2004) for the European Commission's global macromodel QUEST, which shows multipliers for the largest four European countries between 0.85 and 0.95[9]. The estimated impact fiscal multiplier is within the range found in empirical studies of fiscal policy using structural vector autoregression (SVAR) models. Blanchard and Perotti (2002) applied SVAR methodology to study the effects of fiscal policy in the US and various authors have extended the SVAR methodology to include other countries. Perotti (2005) finds large differences in the effects of fiscal policy, with the responses of GDP and consumption having become weaker over time. Only for the US is the consumption response found positive and did the GDP multiplier exceed 1 in the post 1980 period.[10]

3.2 What is the stabilising power of fiscal policy in the euro area?

We now turn to the stabilisation power of fiscal policy in the euro area economy over the period 1981q1 to 2005q3. Our empirical analysis takes into account all shocks that we identify in the model. Our strategy is to perform stochastic simulations with values drawn from the empirical distribution of the estimated shock processes under alternative fiscal policy rules. The benchmark rules for our analysis are the estimated tax rule (25) and spending rules (35)-(37). We compare the volatility of the euro area economy to a "no systematic fiscal policy" scenario, where we also exclude the lagged dynamic responses and nominal government consumption, investment and transfers are always proportional to nominal GDP up to a stochastic shock, and the wage tax rate is constant ($t_{G,1}^{Y} = t_{G,2}^{Y} = gslag = t_{GI,1}^{Y} = gislag = t_{TR,1}^{L} = t_{1}^{W} = 0$)

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[9] There the government consumption shock is a weighted average of government purchases and wage expenditures. Wage expenditure shocks have larger effects on GDP than government purchases shocks.

[10] Reconciling the consumption response to a government consumption shock with evidence from Fatas and Mihov (2001) and Gali et al. (2003) is complicated by the fact that we do not make the distinction between government purchases of goods and services and government wage expenditure. A disaggregation of government consumption may require a seperate modelling of private and public sector . (see Forni et al (2006)).

In order to better understand the results from this comparison it is useful to look first at the impulse response functions for a typical supply and demand shock under the two alternative fiscal policy regimes. The next section illustrates the differences for a TFP shock and a shock to world demand. Notice, not only the supply shock but also the demand shock has permanent output and price effects, since the latter is generated via a permanent shock to world output in this model.

3.2.1 TFP shock

Figure 5 presents the level comparison of the estimated effect of an orthogonalised shock to TFP (ε_t^U). The continuous line indicates the estimated model and the dotted line the model *without* systematic fiscal policy responses to output and employment gaps. As can be seen from Figure 5, a positive shock to TFP is associated with an increase in government consumption and transfers. It is well known (see Gali (1999)) that with nominal rigidities supply shocks lead to a demand externality. Because firms lower prices insufficiently as a response to a cost-reducing shock, there is a lack of aggregate demand. This is indicated by a negative output gap. Expansionary government consumption partially compensates for the shortfall in demand. The automatic stabilisation via government transfers work in the same direction, since they respond to the decline in employment and boost consumption of liquidity constrained households.

In order to highlight the role played by nominal rigidities and financial market frictions it is useful to look at the fiscal policy response to a TFP shock and its effect in the unconstrained economy (Figure 6). Because there is immediate price adjustment – e. g. real wages rise instantaneously - there is no shortfall of demand as indicated by an output gap measure which is practically zero. Thus there is hardly any active response of government consumption. Also notice, though there is a (positive) response of transfers because of a fall in employment, this has no stabilising effect on output since Ricardian consumers completely offset the policy by increased savings.

FIGURE 5. IRF's to a shock to TFP.

Solid lines are posterior means and confidence intervals for the estimated model, while dotted ones are the posterior means without fiscal policy reactions.

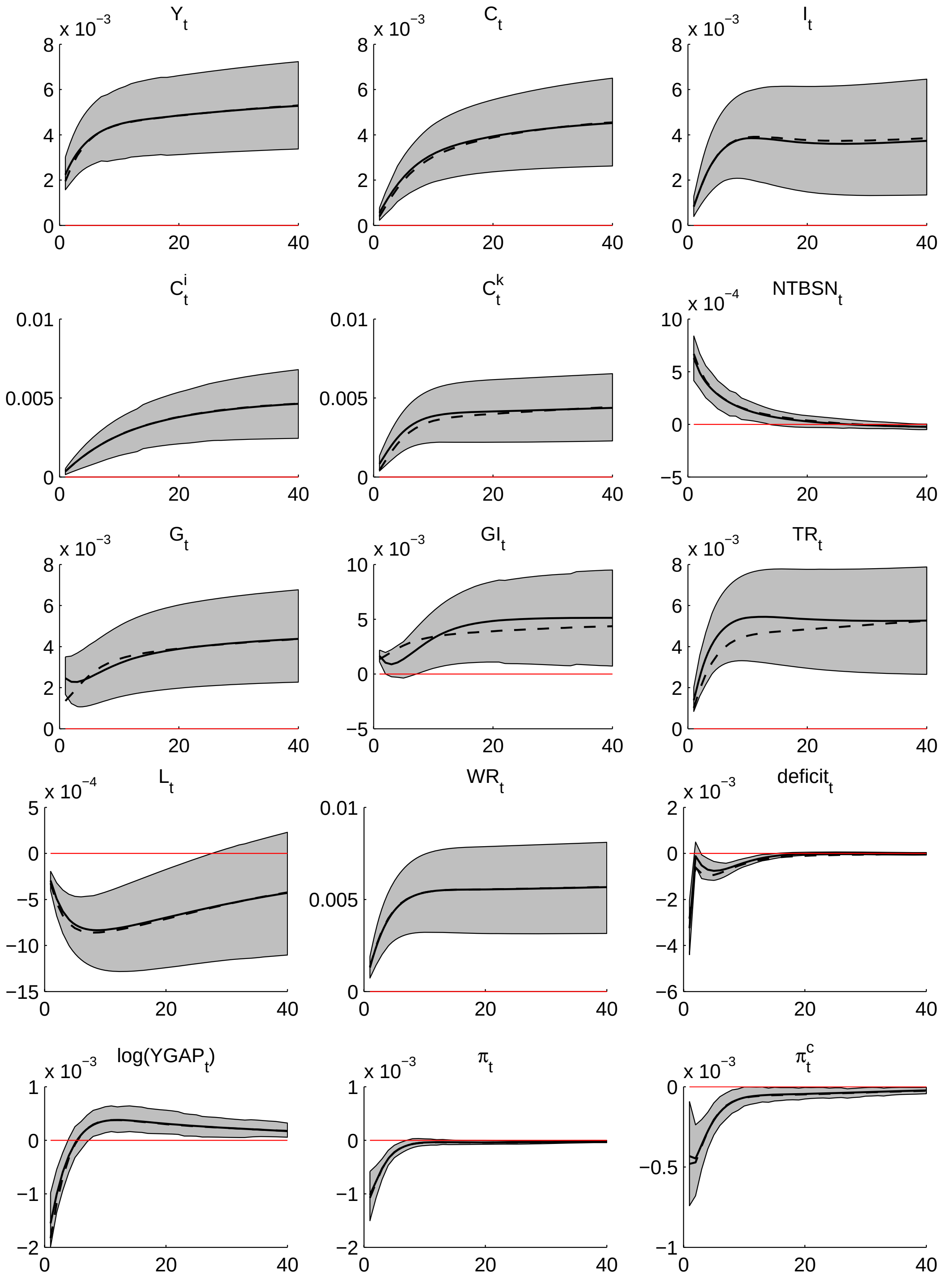
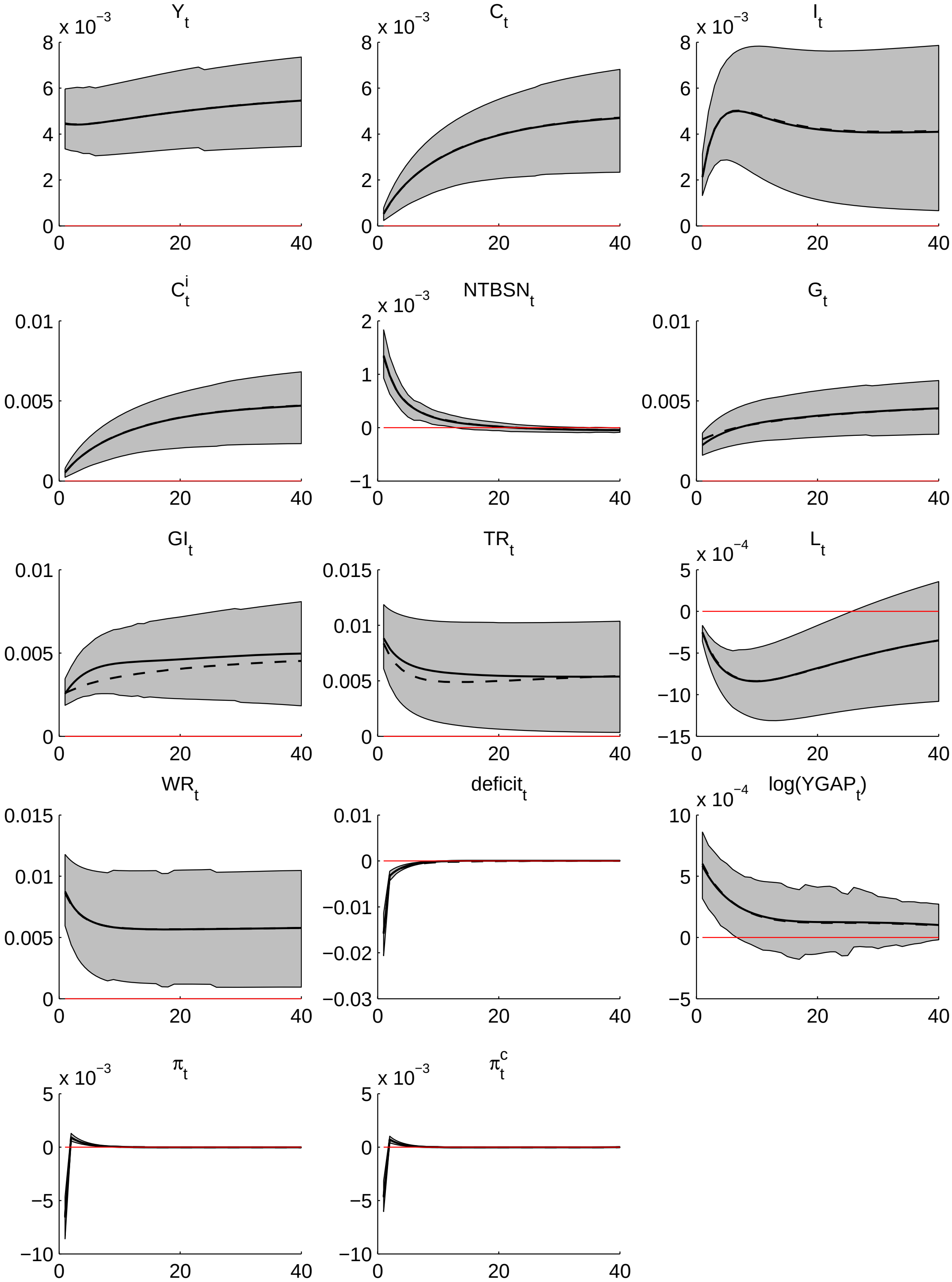


FIGURE 6. IRF's to a shock to TFP (for $slc = \gamma_P = \gamma_{PW} = \gamma_W = 0$)

Solid lines are for the estimated model, dotted lines are the posterior means without fiscal policy reactions.



3.2.2 World output shock

Figure 7 presents the level comparison of the estimated effect of an orthogonalised shock to world output (ε_t^{YW}). The continuous line indicates the estimated model and the dotted line the model *without* systematic fiscal policy responses to output and employment gaps. Because of nominal rigidities an increase in world demand leads to an increase in capacity utilisation and employment. The initial excess demand is only gradually reduced by an increase in domestic prices. Government expenditure increases in line with nominal GDP (government purchases and investment) and the wage sum (transfers), but government purchases and transfers increase by less than is the case when there is no stabilising response of fiscal policy (dotted line), thus limiting the increase in aggregate demand. The government investment rule is estimated to be pro-cyclical and investment rises more than proportional. The overall effect of fiscal stabilisation is to reduce the initial increase in employment and dampen the medium term reduction. Automatic stabilisation via transfers smoothes consumption of liquidity-constrained households C^k .

Output in the unconstrained economy, without nominal rigidities and financial market frictions, reacts less vigorously, because the demand shock is to a large part absorbed by an increase in prices and the real wage (Figure 8). The positive output effects results entirely from the terms of trade effect induced by a permanent shift in world demand for domestic goods. Because of the price adjustment, the measured output gap is smaller than in the constrained economy. This reduces the fiscal impulse generated by government consumption. Because of the absence of liquidity constrained households, transfers do not affect private consumption.

FIGURE 7. IRF's to a shock to world demand.
Solid lines are posterior means and confidence intervals for the estimated model, while dotted ones are the posterior means without fiscal policy reactions.

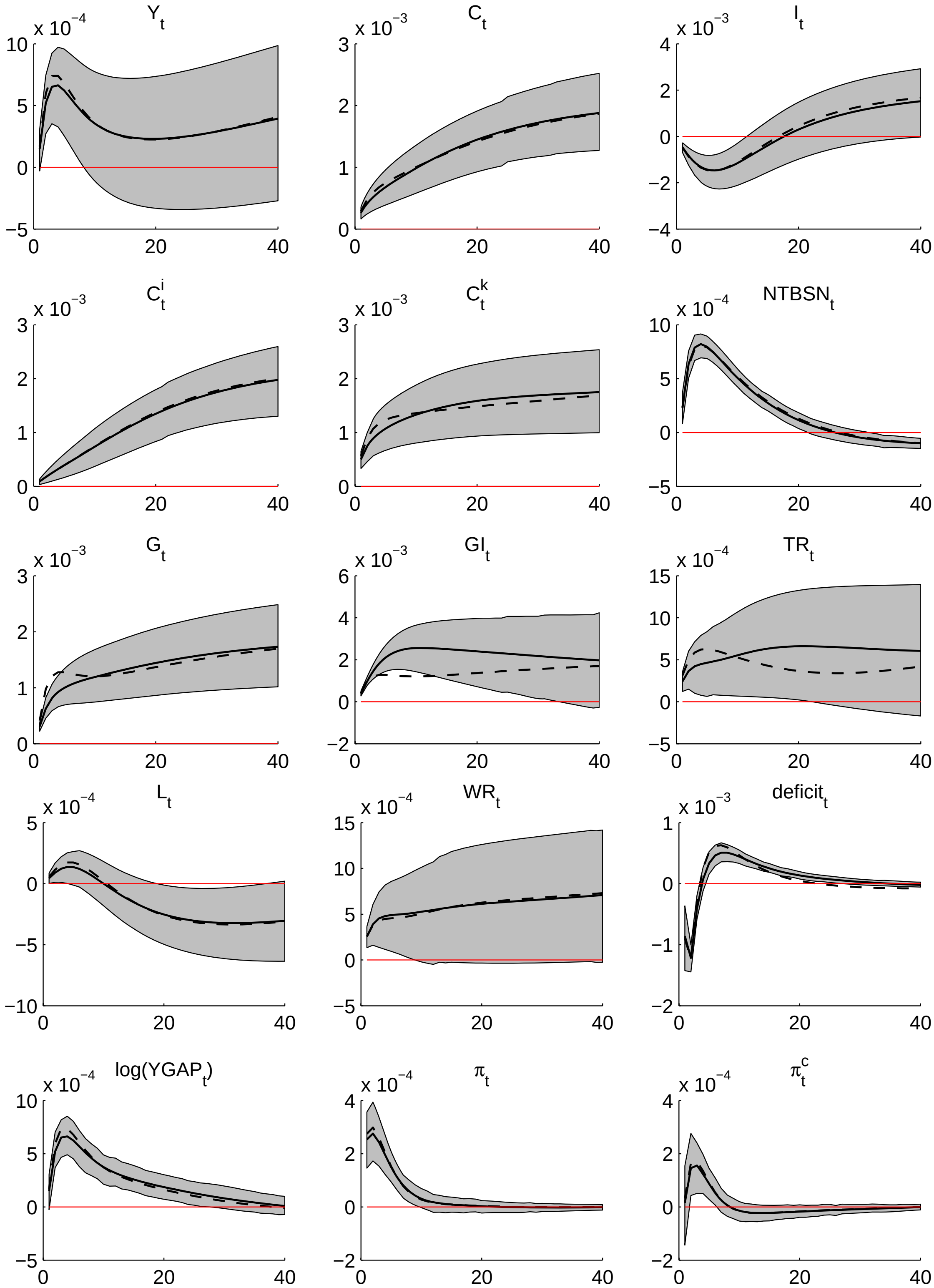
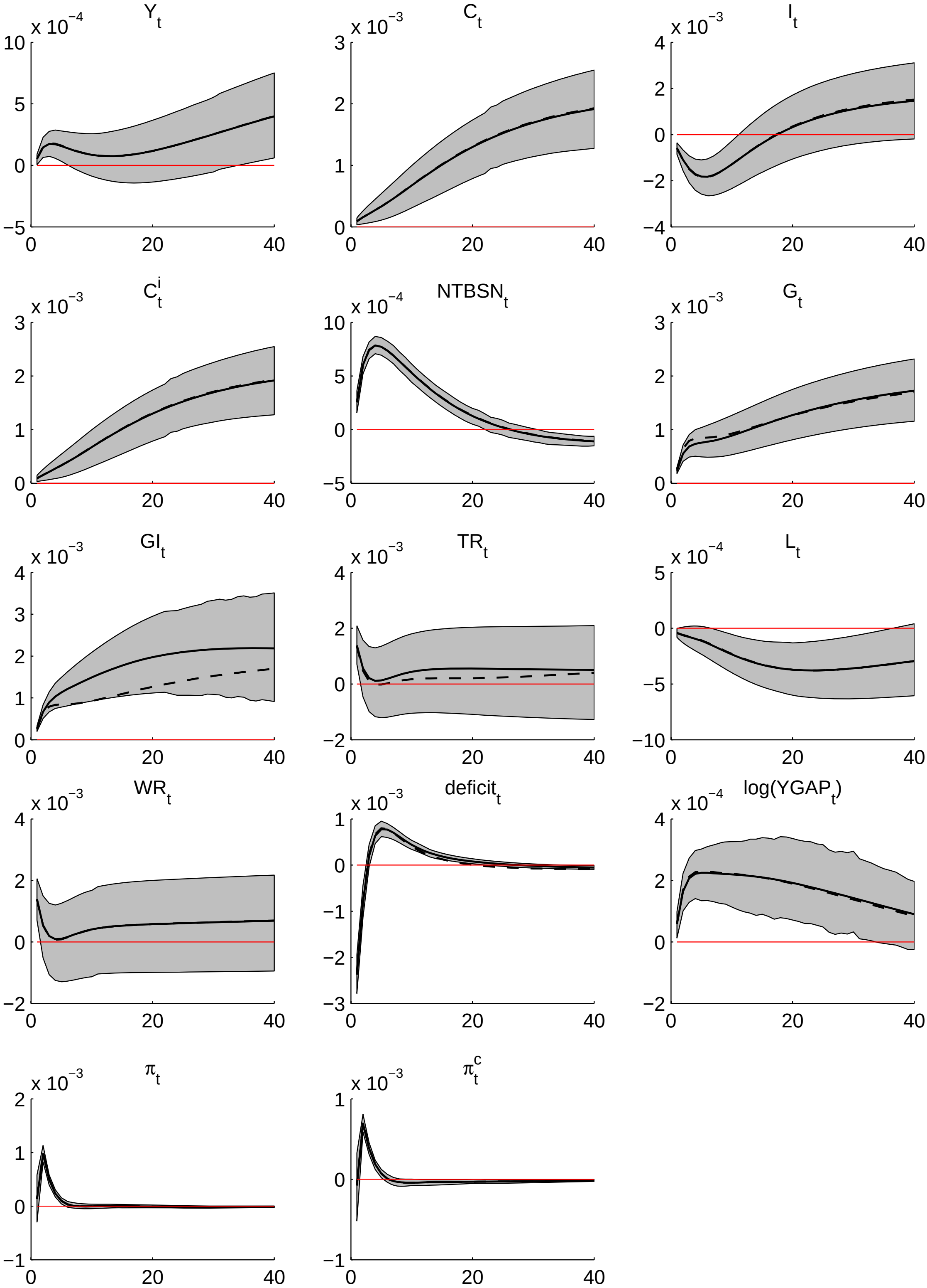


FIGURE 8. IRF's to a shock to world demand (for $slc = \gamma_P = \gamma_{PW} = \gamma_W = 0$)

Solid lines are for the estimated model, dotted lines are the posterior means without fiscal policy reactions



3.2.2 Comparison of standard deviations with and without fiscal policy

We can now turn to a quantitative analysis of the stabilisation power of fiscal policies. This section describes the standard deviations for the main variables we are interested in, as generated by the DSGE model for the two scenarios, *with* and *without* fiscal policy. Table 3.a reports the percentage change in the standard deviations of growth rates of the main economic variables of interest in the model with active stabilisation policy compared to the model without active fiscal policy. The table reports the changes at the infinite horizon and a negative sign indicates a reduction in the standard deviation of the growth rates under that particular policy rule. (Similar conclusions hold for the changes at the first period – details available from the authors) The fiscal rule for government purchases stabilises GDP by 10.3 percent, wage taxes stabilise output by 2.8 percent, while the rules for government investment and transfers play a smaller role in reducing output volatility, each by about 1 percent. In the case of government purchases it is the government consumption aggregate itself which is most stabilised. Notice, however, smoothing government demand helps to reduce employment volatility and thereby the consumption of liquidity-constrained households.[11] Although non liquidity-constrained consumption is destabilised, the stabilising effect on liquidity-constrained consumption is strong enough to stabilise *aggregate* consumption.

All fiscal rules combined yield a reduction in the volatility of GDP of 13.8 percent. Volatility in government consumption is reduced significantly, while government investment, a much smaller component of GDP, is destabilised, as the estimated response parameters were found to be procyclical. Fiscal policy appears to be most effective is stabilising employment (5.7 percent) and liquidity constrained (10.7 percent) consumption. Volatility of aggregate consumption is reduced by 8.7 percent.

[11] We are probably underestimating the effect of automatic stabilisation of transfers since we assume that transfers are given in equal proportions to both types of households.

Table 3.a : Fiscal Stabilisation under alternative specifications.

	Government Consumption rule	Government Transfers rule	Wage tax rule	Government Investment rule	All fiscal rules combined
GDP	-10.31% (2.13%)	-0.81% (0.23%)	-2.76% (1.17%)	-1.37% (0.46%)	-13.80% (2.33%)
Consumption	-0.26% (0.26%)	-5.59% (1.21%)	-3.49% (1.46%)	-0.30% (0.28%)	-8.68% (1.74%)
. Liquidity constrained	-0.47% (0.29%)	-7.13% (1.19%)	-4.52% (1.83%)	0.12% (0.10%)	-10.71% (1.96%)
. Non-liquidity constrained	0.40% (0.74%)	0.56% (0.58%)	0.39% (0.24%)	-1.63% (0.98%)	-0.23% (1.22%)
Investment	0.28% (0.33%)	0.46% (0.33%)	0.09% (0.09%)	-0.59% (0.34%)	0.18% (0.49%)
Government consumption	-32.52% (3.34%)	-0.49% (0.11%)	-1.41% (0.60%)	-0.53% (0.20%)	-32.97% (3.15%)
Transfers	-0.52% (0.48%)	-25.83% (3.89%)	0.22% (0.18%)	0.01% (0.16%)	-25.76% (3.79%)
Government investment	-5.06% (1.09%)	-0.56% (0.13%)	-1.42% (0.61%)	38.73% (12.28%)	31.97% (11.61%)
Employment	-2.25% (0.86%)	-2.27% (0.73%)	-1.80% (0.80%)	0.27% (0.83%)	-5.73% (1.44%)
Inflation	-0.60% (1.01%)	0.15% (0.74%)	-1.30% (0.82%)	1.89% (1.58%)	0.06% (1.59%)
Wage inflation	-0.73% (0.97%)	-0.24% (0.86%)	-1.05% (0.77%)	1.78% (1.51%)	-0.33% (1.60%)
Real wage inflation	0.06% (0.28%)	0.02% (0.26%)	0.40% (0.21%)	-0.06% (0.16%)	0.33% (0.51%)

Note: Posterior mean of the percentage change of standard deviation of growth rates, relative to model with no active fiscal policy response. In brackets we show standard error of the effect.

Fiscal policy is effective in stabilising output and employment fluctuations because of nominal rigidities in goods and labour markets and because of financial market imperfections. This is shown in Table 3.b. The first column repeats the changes in volatility for the estimated model, while the second and third columns show the stabilising role of fiscal policy changes when we remove these market imperfections. We start with credit constraints and look at fiscal policy in a model economy which is identical in all respects to the economy as estimated except for the absence of liquidity constraints (*slc=0*). This modification has a small effect on the stabilising potential of government consumption w.r.t. GDP. Without liquidity-constrained consumers there is no role for transfers any longer to stabilise private consumption and the transfer rule remains completely ineffective for reducing the volatility of private consumption and GDP. Ricardian consumers offset any movement in transfers with private borrowing and lending. Without liquidity constraints, the wage tax rule has also less stabilising effect on GDP. When all fiscal rules are combined the stabilisation achieved in the model without liquidity constraints is falling from 13.8 to 10.8 percent. There is still a reduction in the volatility of employment, as well as in the volatility of aggregate consumption.

Eliminating all market imperfections substantially reduces the stabilising power of fiscal policy. With flexible prices ($\gamma_p=\gamma_w=0$) and no liquidity constraints ($slc=0$), the estimated government consumption rule can reduce output fluctuations only by a 3 percent and it increases the volatility of private consumption (2.1 percent) and private investment (1.4 percent). Similar increases in volatility are found when all fiscal rules are combined. Volatility of GDP is reduced by only 3.2 percent, while that of aggregate consumption is increased by 0.9 percent. The reduction in the volatility of employment (by 0.5 percent) is small and not significant in the case of government consumption. Obviously, progressive wage taxes have a significant stabilising impact on employment in the unconstrained economy. While progressive wage taxation helps to stabilise the consumption of liquidity constrained households and may therefore be welfare improving in a constrained economy, stabilisation does not play a beneficial role in the unconstrained economy. The smaller degree of stabilisation results from three sources. First, because of rapid price adjustments the output and employment gaps are smaller and prompt a smaller fiscal response to exogenous shocks. Second, forward looking households and firms strongly offset changes in government consumption. And third, in the absence of liquidity constraints there is no stabilising role for public transfers.

This shows that the extent of fiscal stabilisation is intimately linked to the degree of market imperfections.

Table 3.b : Fiscal Stabilisation under alternative specifications.

	Estimated Model [a] (I)	No liquidity constraints SLC=0 [b] (II)	No liquidity constraints, SLC=0 [c] Flexible prices/wages $\gamma_P = \gamma_W = 0$ (III)
Percentage change of standard deviation of growth rates			
Government Consumption rule:			
GDP	-10.31% (2.13%)	-9.79% (2.01%)	-2.98% (0.93%)
Priv. Consumption	-0.26% (0.26%)	0.55% (0.69%)	2.15% (1.32%)
-Liq. constrained	-0.47% (0.29%)	-	-
-Ricardian	0.40% (0.74%)	0.55% (0.69%)	2.15% (1.32%)
Investment	0.28% (0.33%)	0.11% (0.27%)	1.45% (0.94%)
Gov. Consumption	-32.52% (3.34%)	-31.17% (2.92%)	-20.17% (24.74%)
Transfers	-0.52% (0.48%)	-0.36% (0.32%)	2.85% (1.61%)
Gov. Investment	-5.06% (1.09%)	-4.45% (0.97%)	-12.88% (4.84%)
Employment	-2.25% (0.86%)	-1.80% (0.71%)	-0.50% (0.43%)
Inflation	-0.60% (1.01%)	-0.57% (0.65%)	9.01% (2.58%)
Wage inflation	-0.73% (0.97%)	-0.63% (0.64%)	-0.07% (0.21%)
Real Wage inflation	0.06% (0.28%)	-0.00% (0.15%)	2.85% (1.62%)
Government Transfer Rule:			
GDP	-0.81% (0.23%)	0.00% (0.00%)	-0.00% (0.00%)
Priv. Consumption	-5.59% (1.21%)	0.00% (0.00%)	0.00% (0.00%)
-Liq. constrained	-7.13% (1.19%)	-	-
-Ricardian	0.56% (0.58%)	0.00% (0.00%)	0.00% (0.00%)
Investment	0.46% (0.33%)	0.00% (0.00%)	0.00% (0.00%)
Gov. Consumption	-0.49% (0.11%)	0.00% (0.00%)	-0.00% (0.00%)
Transfers	-25.83% (3.89%)	-22.46% (3.72%)	-0.44% (0.18%)
Gov. Investment	-0.56% (0.13%)	0.00% (0.00%)	-0.00% (0.00%)
Employment	-2.27% (0.73%)	-0.00% (0.00%)	0.00% (0.00%)
Inflation	0.15% (0.74%)	0.00% (0.00%)	0.00% (0.00%)
Wage inflation	-0.24% (0.86%)	0.00% (0.00%)	0.00% (0.00%)
Real Wage inflation	0.02% (0.26%)	0.00% (0.00%)	0.00% (0.00%)
Government Investment rule:			
GDP	-1.37% (0.46%)	-1.18% (0.39%)	-0.20% (0.06%)
Priv. Consumption	-0.30% (0.28%)	-1.48% (0.82%)	-1.11% (0.63%)
-Liq. constrained	0.12% (0.10%)	-	-
-Ricardian	-1.63% (0.98%)	-1.48% (0.82%)	-1.11% (0.63%)
Investment	-0.59% (0.34%)	-0.51% (0.30%)	-0.57% (0.29%)
Gov. Consumption	-0.53% (0.20%)	-0.45% (0.16%)	-0.76% (0.27%)
Transfers	0.01% (0.16%)	0.07% (0.09%)	0.27% (0.15%)
Gov. Investment	38.73% (12.28%)	41.54% (13.62%)	19.52% (15.75%)
Employment	0.27% (0.83%)	0.73% (0.61%)	0.57% (0.38%)

Inflation	1.89% (1.58%)	1.14% (1.07%)	0.75% (0.23%)
Wage inflation	1.78% (1.51%)	1.13% (1.01%)	0.02% (0.03%)
Real Wage inflation	-0.06% (0.16%)	0.01% (0.10%)	0.27% (0.15%)
Wage Tax rule:			
GDP	-2.76% (1.17%)	-0.18% (0.09%)	-0.09% (0.04%)
Priv. Consumption	-3.49% (1.46%)	-0.30% (0.19%)	-0.24% (0.14%)
-Liq. constrained	-4.52% (1.83%)	-	-
-Ricardian	0.39% (0.24%)	-0.30% (0.19%)	-0.24% (0.14%)
Investment	0.09% (0.09%)	-0.18% (0.12%)	-0.21% (0.14%)
Gov. Consumption	-1.41% (0.60%)	-0.06% (0.03%)	-0.09% (0.05%)
Transfers	0.22% (0.18%)	0.27% (0.18%)	1.46% (1.01%)
Gov. Investment	-1.42% (0.61%)	-0.08% (0.04%)	-0.10% (0.05%)
Employment	-1.80% (0.80%)	-1.04% (0.46%)	-0.81% (0.47%)
Inflation	-1.30% (0.82%)	-0.45% (0.35%)	-0.07% (0.04%)
Wage inflation	-1.05% (0.77%)	-0.28% (0.30%)	0.68% (0.69%)
Real Wage inflation	0.40% (0.21%)	0.23% (0.16%)	1.46% (1.02%)
All fiscal rules combined:			
GDP	-13.80% (2.33%)	-10.82% (2.09%)	-3.25% (0.96%)
Priv. Consumption	-8.68% (1.74%)	-1.19% (1.02%)	0.86% (1.54%)
-Liq. constrained	-10.71% (1.96%)	-	-
-Ricardian	-0.23% (1.22%)	-1.19% (1.02%)	0.86% (1.54%)
Investment	0.18% (0.49%)	-0.54% (0.44%)	0.70% (0.92%)
Gov. Consumption	-32.97% (3.15%)	-31.22% (2.88%)	-19.51% (24.90%)
Transfers	-25.76% (3.79%)	-22.34% (3.64%)	4.20% (2.54%)
Gov. Investment	31.97% (11.61%)	37.47% (13.21%)	16.12% (17.54%)
Employment	-5.73% (1.44%)	-2.15% (1.13%)	-0.68% (0.70%)
Inflation	0.06% (1.59%)	0.06% (0.90%)	9.65% (2.65%)
Wage inflation	-0.33% (1.60%)	0.14% (0.85%)	0.60% (0.74%)
Real Wage inflation	-13.80% (2.33%)	0.21% (0.19%)	4.57% (2.50%)

a) DSGE model with estimated parameters shown in Table 2.

b) DSGE model with the share of liquidity constrained consumers set to zero.

c) DSGE model with the share of liquidity constrained consumers and adjustment costs for wage and price setters set to zero

4 Conclusions

This paper uses an estimated DSGE model for the euro area to study the effects of fiscal stabilisation policies. So far empirical work on fiscal policy has concentrated mainly on the effects of government spending shocks. This paper extends this literature by focussing on an analysis of the magnitude of fiscal stabilisation in the euro area at an aggregate level.

There are at least two interesting features of the euro area economy. First, there are nominal rigidities in goods and labour markets, and there are financial market frictions with a significant share of liquidity constrained households. Second, the government is a major sector of the euro area economy. We considered fiscal stabilisation via government consumption, investment, transfers and wage taxes. Our main findings can be summarised as follows. We find empirical evidence for systematic countercyclical fiscal policy. Consistent with previous findings, there is a positive fiscal multiplier in the case of transitory fiscal shocks as required for stabilisation policies. However, the multiplier is smaller than one. Given the estimated fiscal rule we find that fiscal policy is effective in stabilising GDP. It stabilises aggregate demand and thereby counterbalance the demand externality arising from nominal rigidities. In addition automatic stabilisation via government transfers helps to smooth consumption of liquidity constrained household. Fiscal policy partly compensates the financial market distortion. With distorted goods labour and financial markets we find that the estimated fiscal policy rules reduce fluctuations in euro area GDP by about 14 percent. In a non-distorted economy, the volatility of GDP would be reduced by 3 percent.

In future research we will extend this analysis in various directions. It would be interesting to explore how the stabilising properties of the estimated rules compare to simple optimal rules. We have also disregarded automatic stabilisation from other revenue components. This requires a more careful analysis of various tax rules. In future research, more attention will have to be devoted to fiscal stabilisation at the level of euro area member states.

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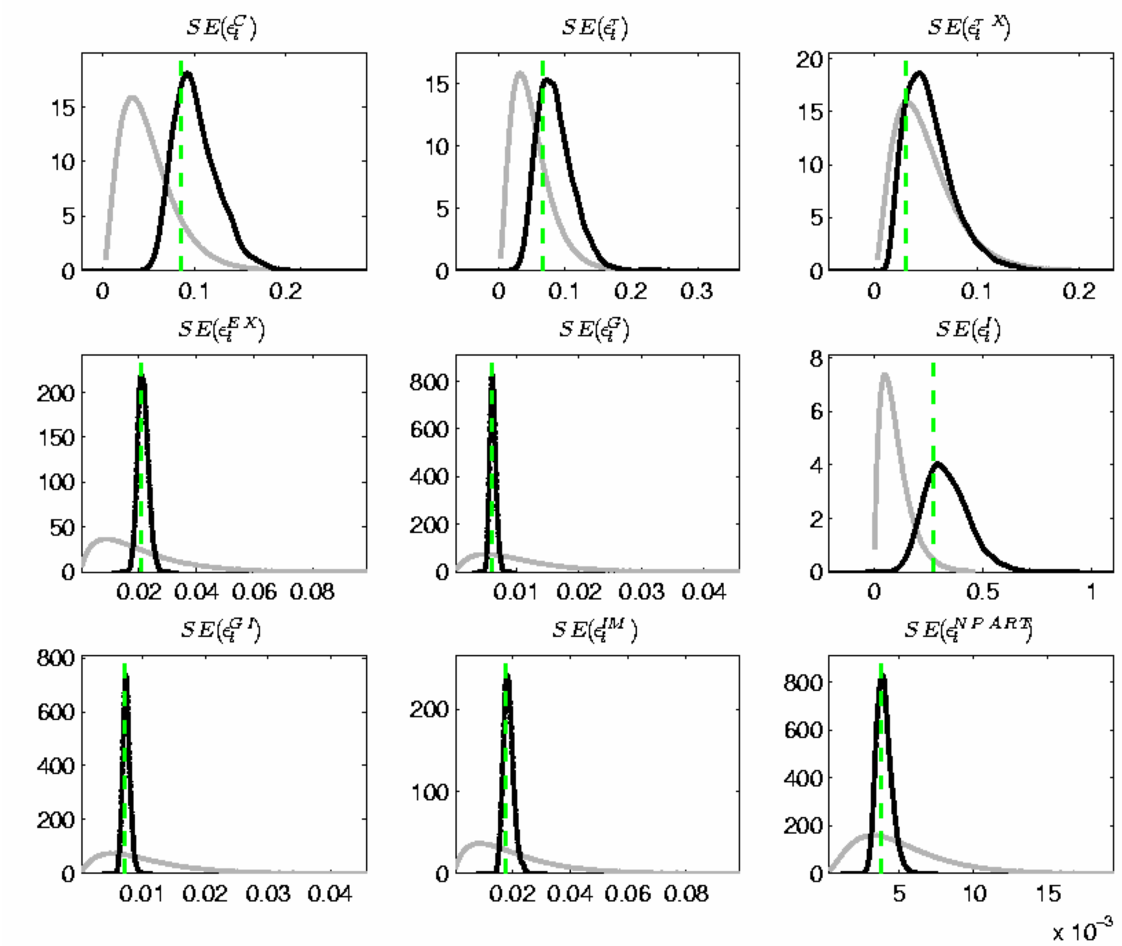
ANNEX 1

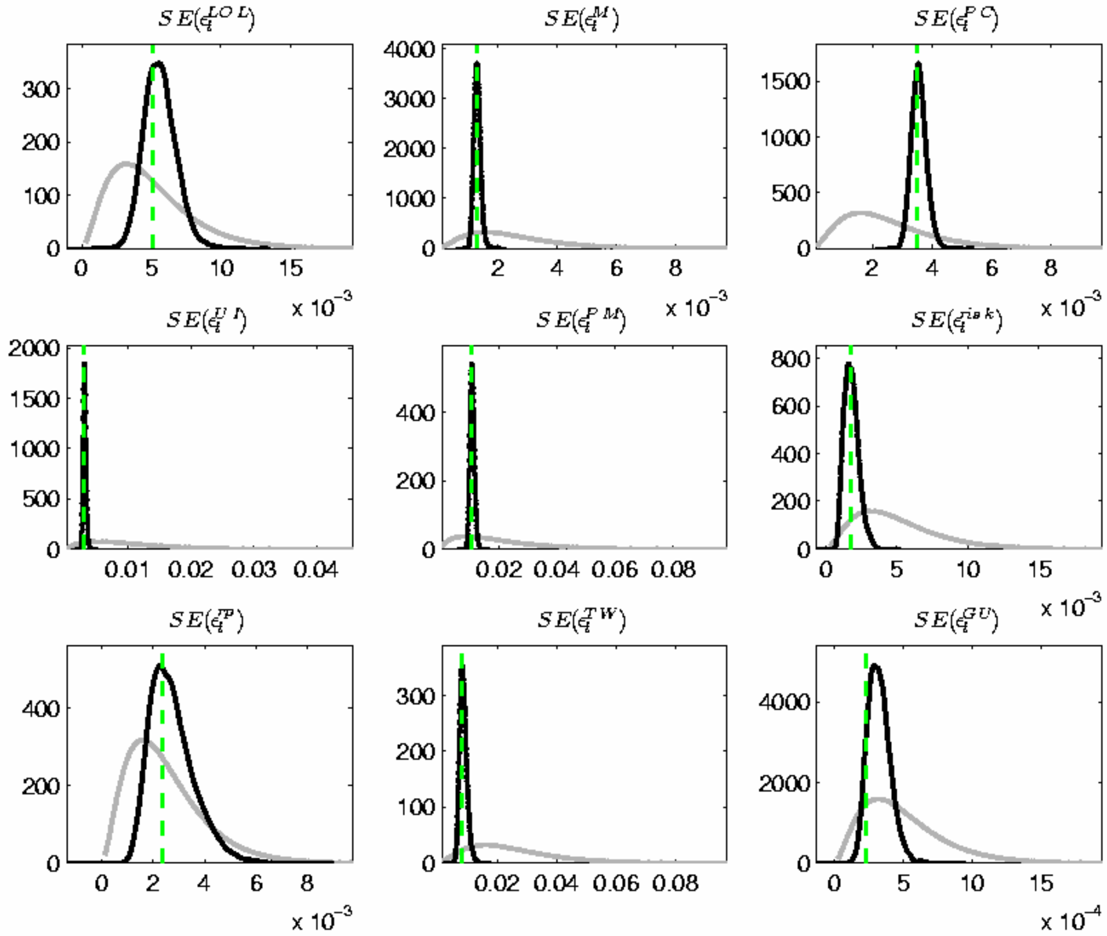
TABLE A1: Estimation Results: Shocks

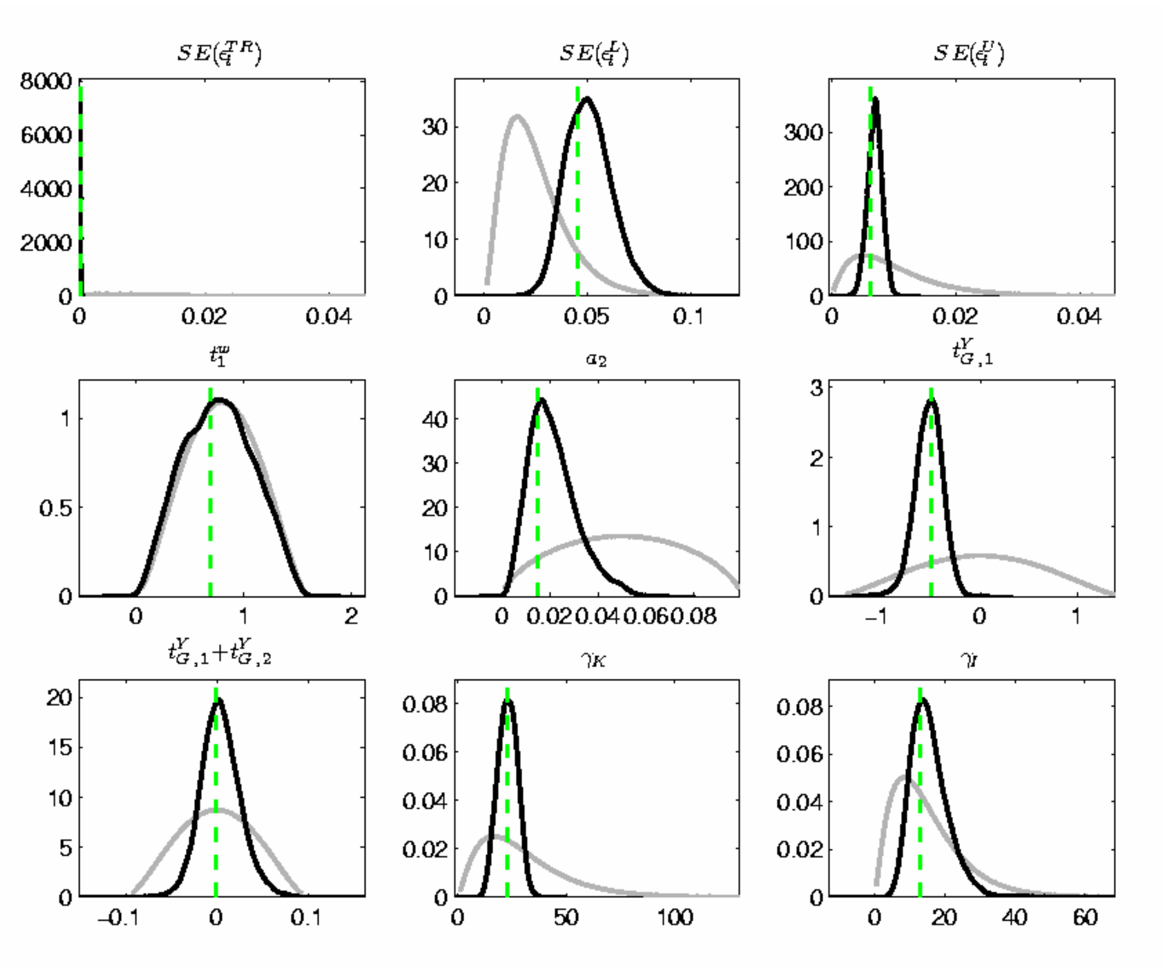
Parameter name		**Prior**			**posterior**	
		distrib	**mean**	**std**	**mean**	**std**
σ^{C}	E_EPS_C	gamma	0.05	0.03	0.1016	0.024292
σ^{τ}	E_EPS_ETA	gamma	0.05	0.03	0.085	0.027609
$\sigma^{\tau X}$	E_EPS_ETAX	gamma	0.05	0.03	0.0534	0.02351
σ^{EX}	E_EPS_EX	gamma	0.02	0.015	0.0215	0.00178
σ^{G}	E_EPS_G	gamma	0.01	0.007	0.0062	0.000486
σ^{I}	E_EPS_I	gamma	0.1	0.07	0.3351	0.102453
σ^{IG}	E_EPS_IG	gamma	0.01	0.007	0.0074	0.000574
σ^{IM}	E_EPS_IM	gamma	0.02	0.015	0.0186	0.001716
σ^{NPART}	E_EPS_L	gamma	0.005	0.003	0.0039	0.000503
σ^{LOL}	E_EPS_LOL	gamma	0.005	0.003	0.0056	0.001135
σ^{M}	E_EPS_M	gamma	0.003	0.0015	0.0013	0.000111
σ^{PC}	E_EPS_PC	gamma	0.003	0.0015	0.0036	0.00025
σ^{UI}	E_EPS_PCPI	gamma	0.01	0.007	0.003	0.00022
σ^{PM}	E_EPS_PM	gamma	0.02	0.015	0.0108	0.000743
σ^{RPE}	E_EPS_RPREME	gamma	0.005	0.003	0.0018	0.000502
σ^{rp}	E_EPS_RPREMK	gamma	0.003	0.0015	0.0027	0.000852
σ^{TW}	E_EPS_TW	gamma	0.025	0.015	0.0086	0.001208
σ^{GU}	E_EPS_TFP	gamma	0.001	0.0003	0.0003	8E-05
σ^{TR}	E_EPS_TR	gamma	0.01	0.007	0.0001	5.67E-05
σ^{W}	E_EPS_W	gamma	0.025	0.015	0.0507	0.011195
σ^{UP}	E_EPS_Y	gamma	0.01	0.007	0.0069	0.001161
ρ^{C}	RHOCE	beta	0.85	0.075	0.9616	0.026278
ρ^{τ}	RHOETA	beta	0.5	0.2	0.1045	0.056776
$\rho^{\tau X}$	RHOETAX	beta	0.85	0.075	0.8556	0.049693
ρ^{EX}	RHOEXE	beta	0.85	0.075	0.9647	0.008725
ρ^{GI}	RHOIG	beta	0.85	0.075	0.9423	0.041038
ρ^{IM}	RHOIME	beta	0.85	0.075	0.9737	0.007616
ρ^{NPART}	RHOLE	beta	0.85	0.075	0.977	0.008225
ρ^{Lss}	RHOL0	beta	0.97	0.015	0.9698	0.012736
ρ^{LOL}	RHOLOL	beta	0.85	0.075	0.9747	0.006466
ρ^{M}	RHOME	beta	0.5	0.2	0.2234	0.064486
ρ^{PC}	RHOPCE	beta	0.85	0.075	0.9754	0.010131
ρ^{UI}	RHOPCPI	beta	0.5	0.2	0.2351	0.079813
ρ^{PM}	RHOPME	beta	0.85	0.075	0.9325	0.022655

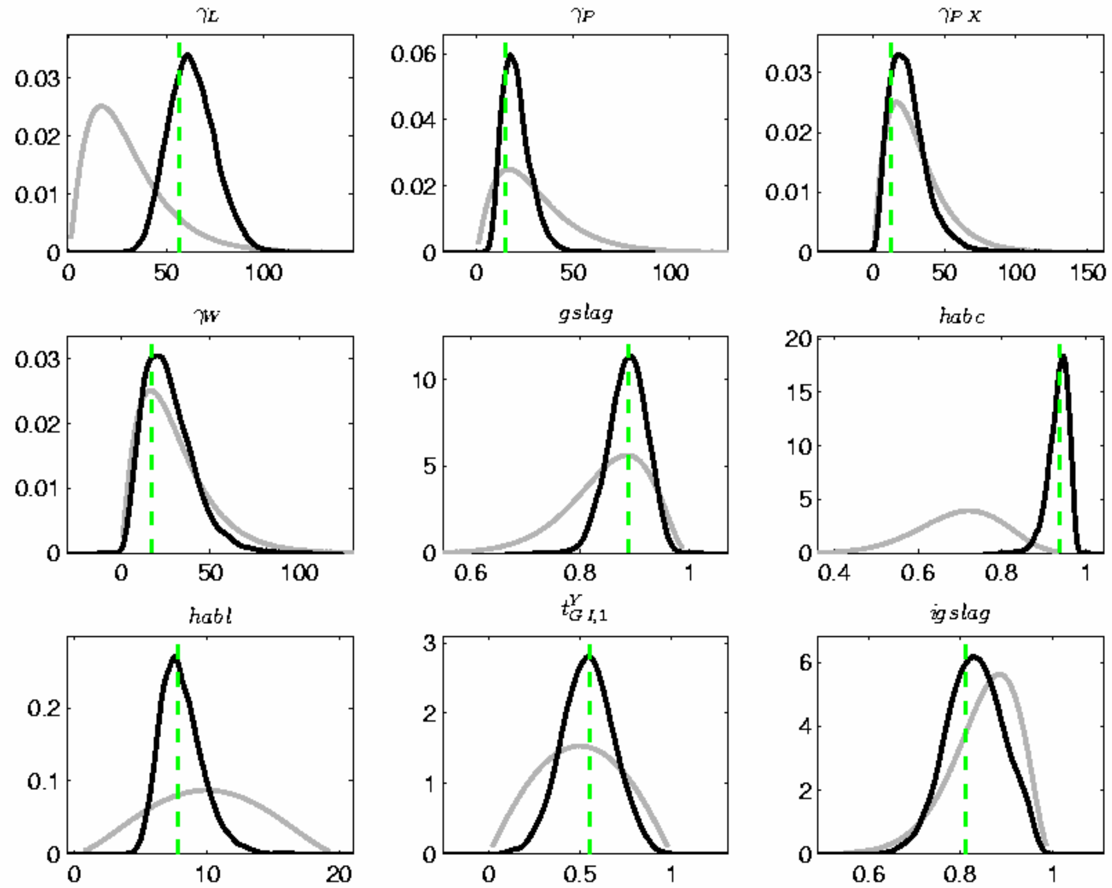
ρ^{RPE}	RHORPE	beta	0.85	0.075	0.9344	0.032867
ρ^{rp}	RHORPK	beta	0.85	0.075	0.9375	0.019573
ρ^{TR}	RHOTR	beta	0.85	0.075	0.8599	0.07351
ρ^{TW}	RHOTW	beta	0.5	0.2	0.5443	0.139158
ρ^{GU}	RHOTFP	beta	0.85	0.06	0.9918	0.004761

Figure A1. Prior distributions (grey lines), posterior distributions (black lines) and posterior mode (dotted lines) of the estimated parameters.

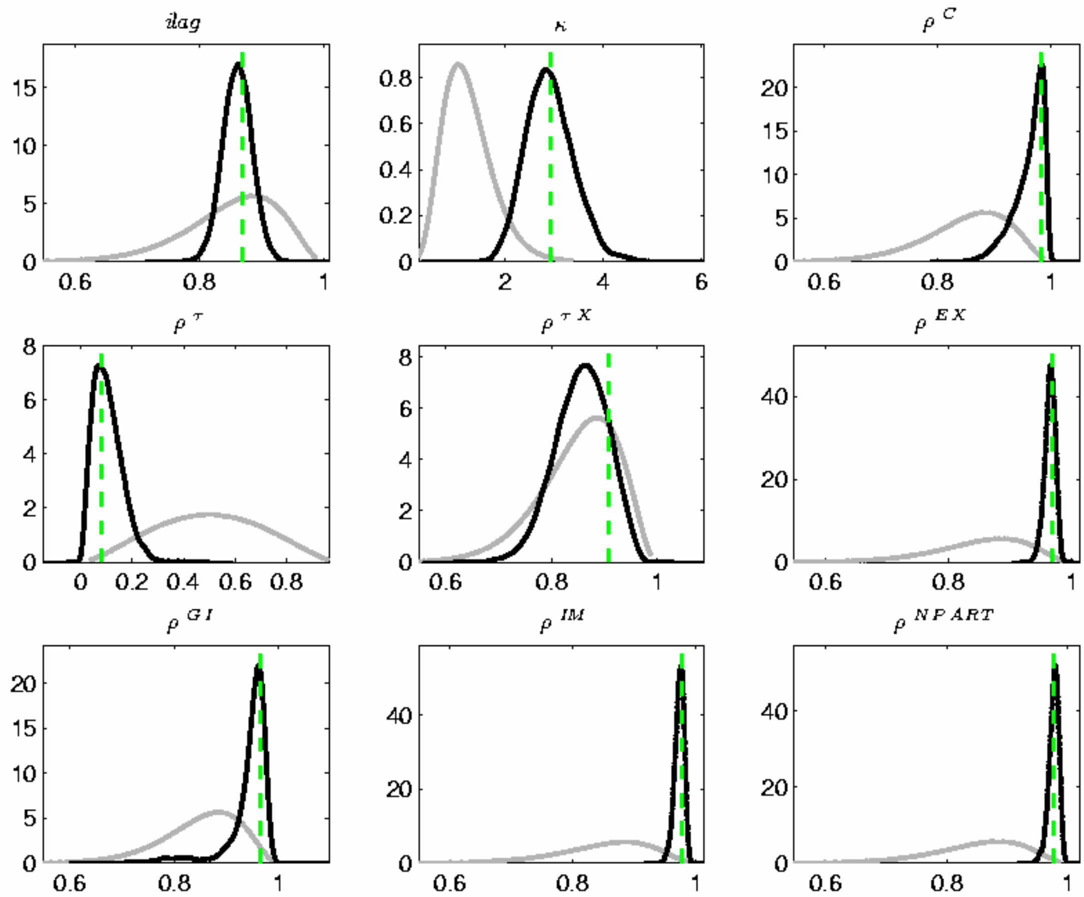



$SE(\epsilon_i^{LOL})$
$SE(\epsilon_i^{M})$
$SE(\epsilon_i^{PC})$
$SE(\epsilon_i^{UI})$
$SE(\epsilon_i^{PM})$
$SE(\epsilon_i^{risk})$
$SE(\epsilon_i^{JP})$
$SE(\epsilon_i^{TW})$
$SE(\epsilon_i^{GU})$
x 10^{-3}
x 10^{-4}

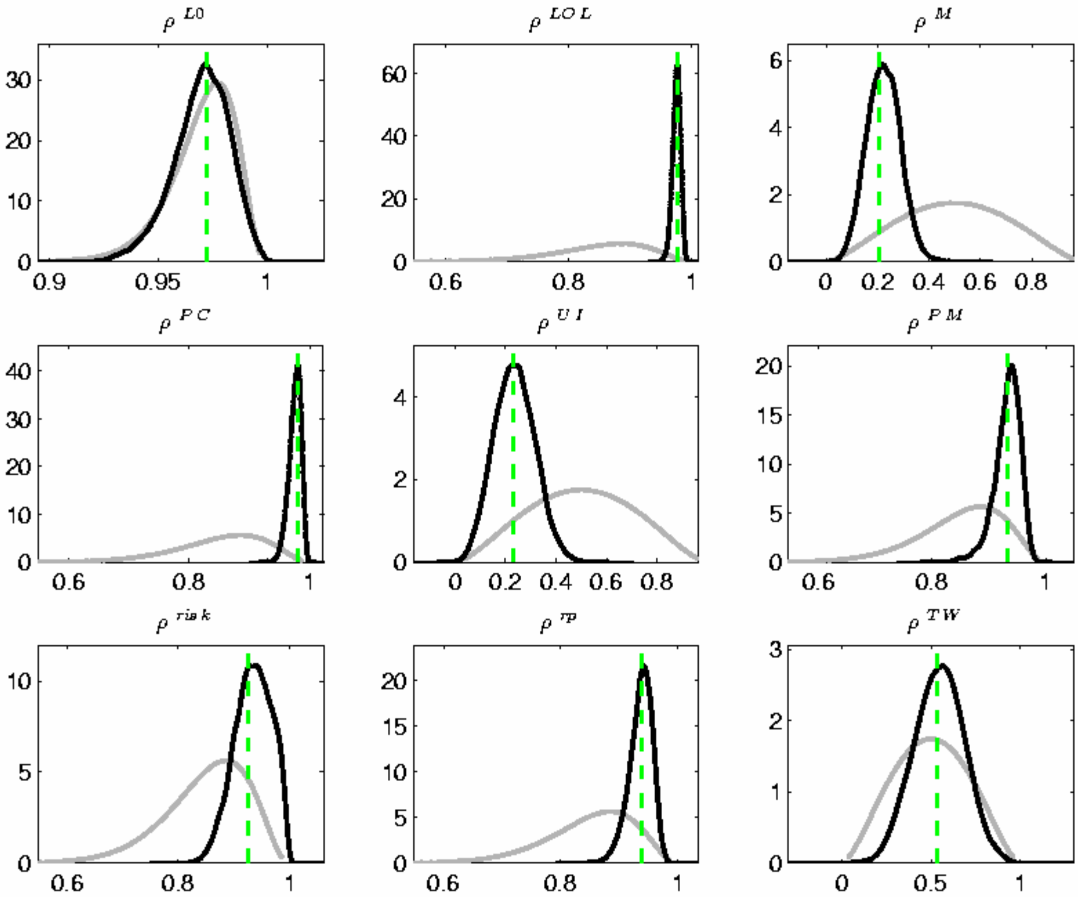

$SE(\epsilon_t^{TR})$
$SE(\epsilon_t^{L})$
$SE(\epsilon_t^{U})$
t_1^w
a_2
$t_{G,1}^Y$
$t_{G,1}^Y+t_{G,2}^Y$
γ_K
γ_I
8000 6000 4000 2000 0
0 0.02 0.04
30 20 10 0
0 0.05 0.1
300 200 100 0
0 0.02 0.04
1 0.5 0
0 1 2
40 30 20 10 0
0 0.02 0.04 0.06 0.08
3 2 1 0
−1 0 1
20 15 10 5 0
−0.1 0 0.1
0.08 0.06 0.04 0.02 0
0 50 100
0.08 0.06 0.04 0.02 0
0 20 40 60



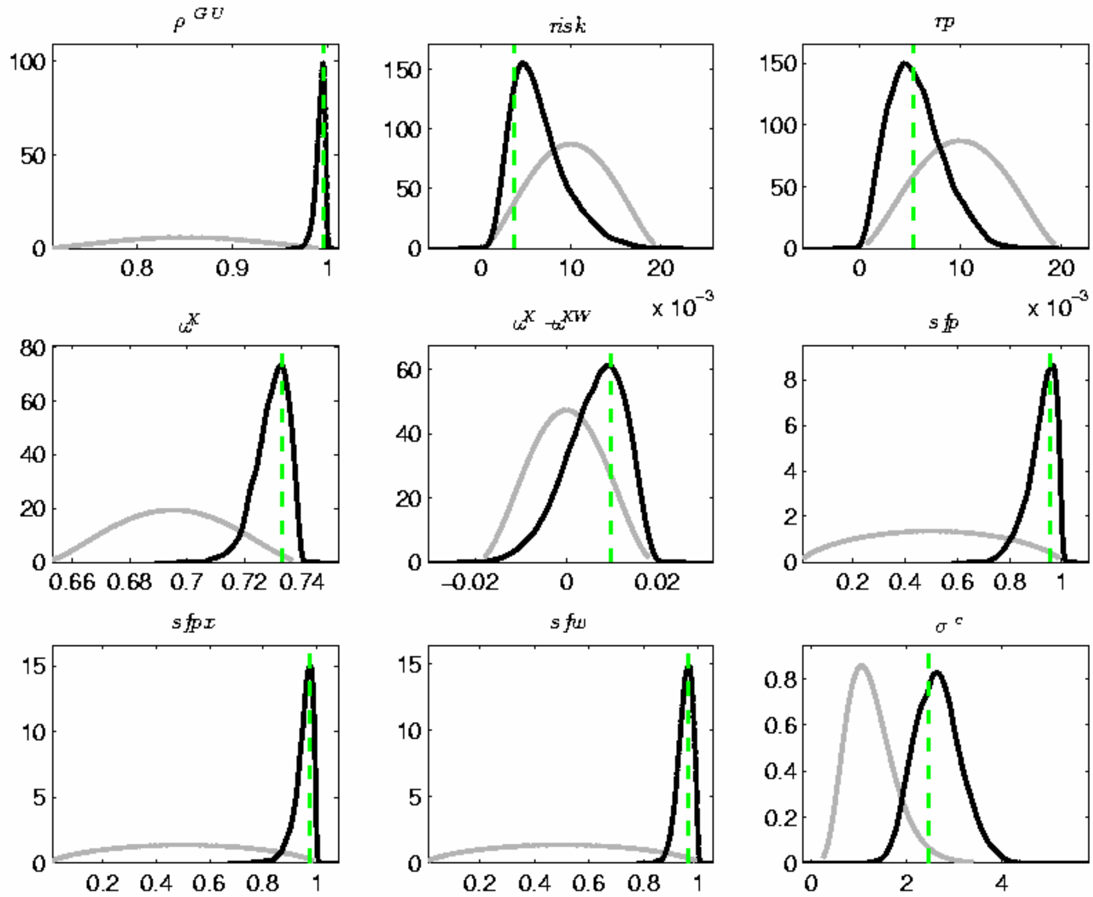
γ_L
γ_P
γ_{PX}
γ_W
gslag
habc
habl
$t^{Y}_{GI,1}$
igslag



ilag
κ
ρ C
ρ τ
ρ τX
ρ EX
ρ GI
ρ IM
ρ NPART



ρ^{L0}
ρ^{LOL}
ρ^{M}
ρ^{PC}
ρ^{UI}
ρ^{PM}
ρ^{risk}
ρ^{rp}
ρ^{TW}



risk
x 10^-3
x 10^-3
sfp
sfpx
sfw

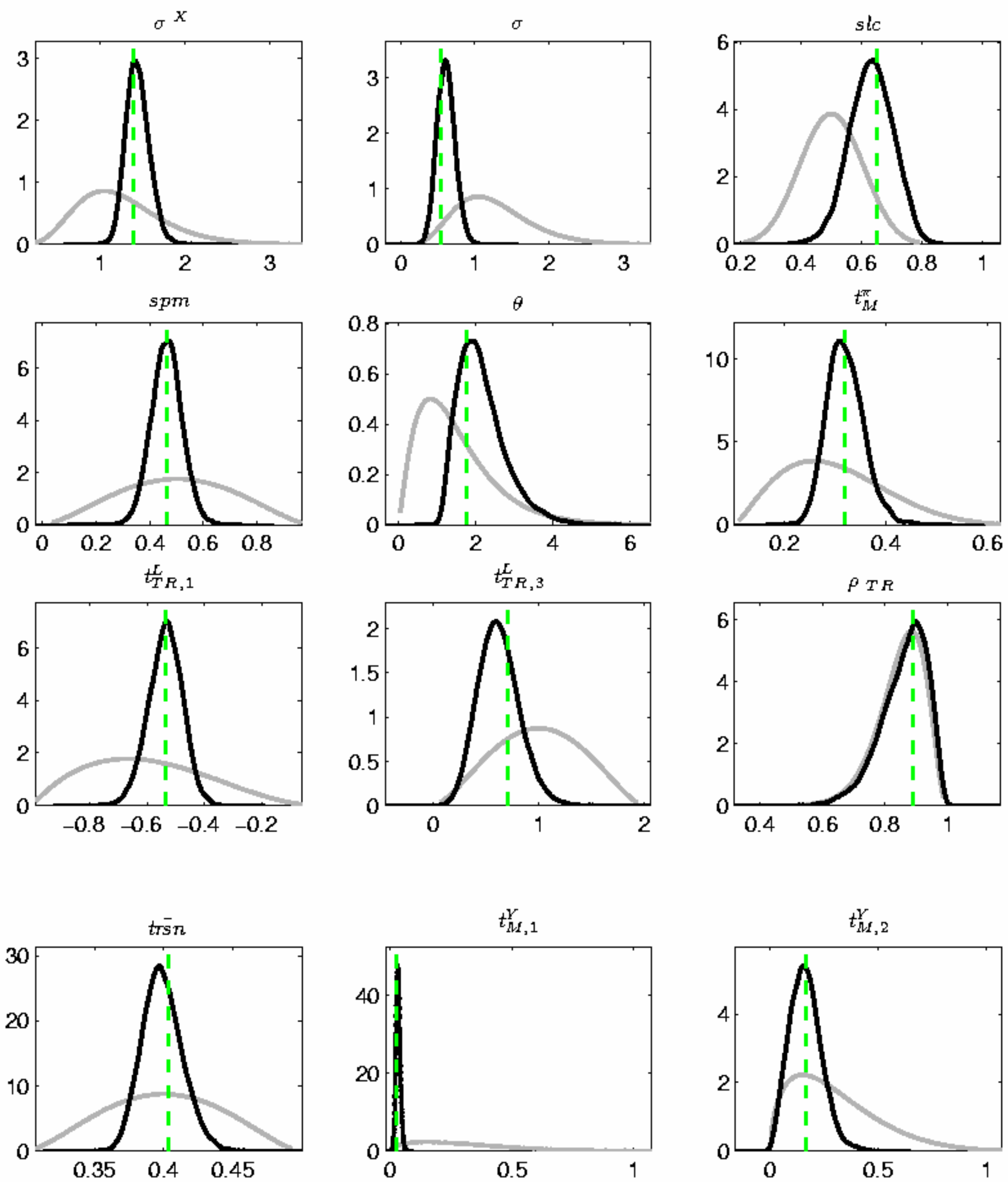
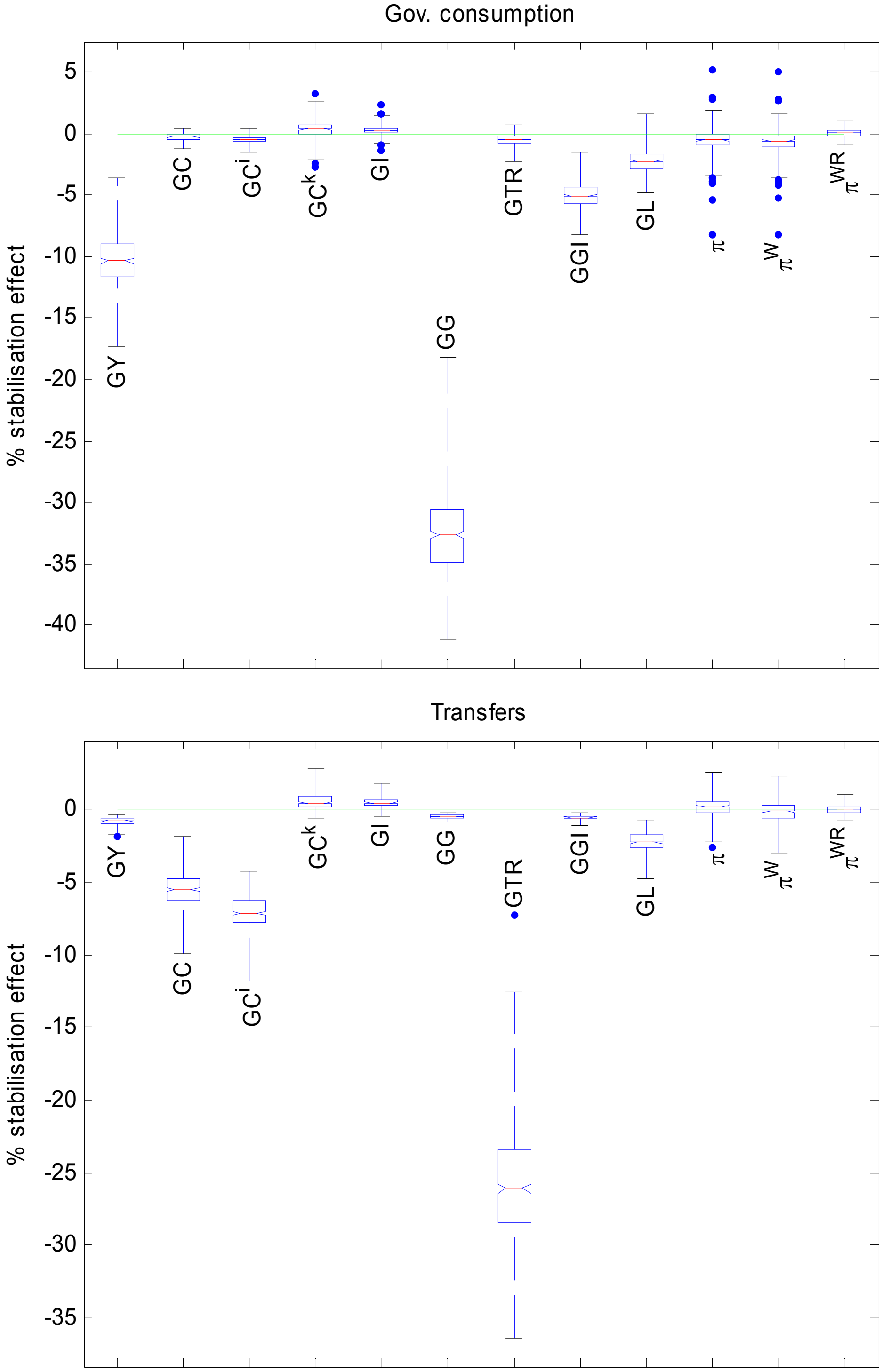
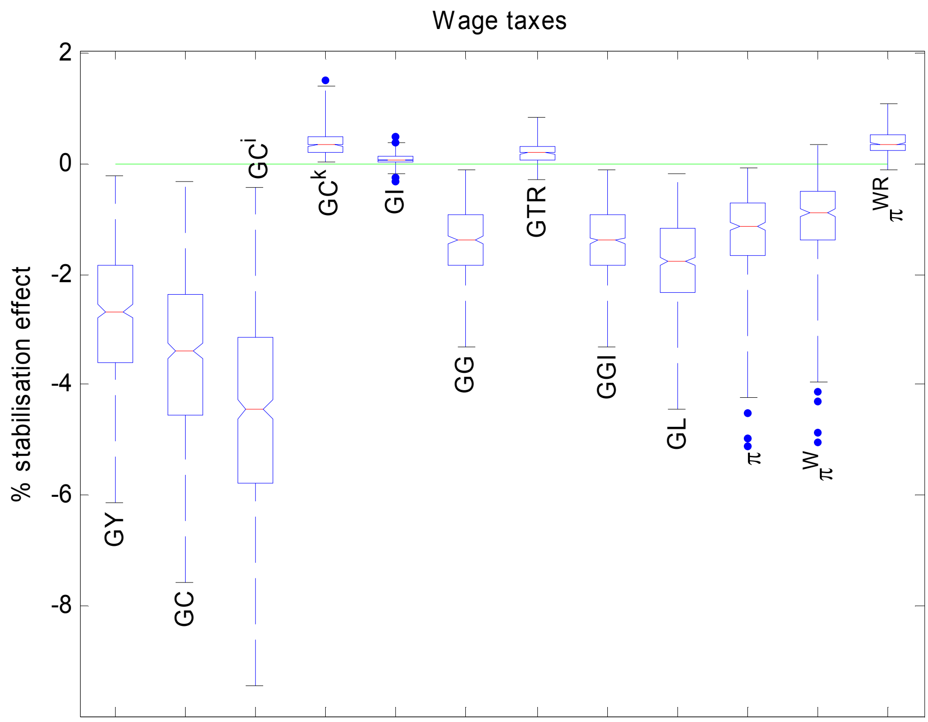
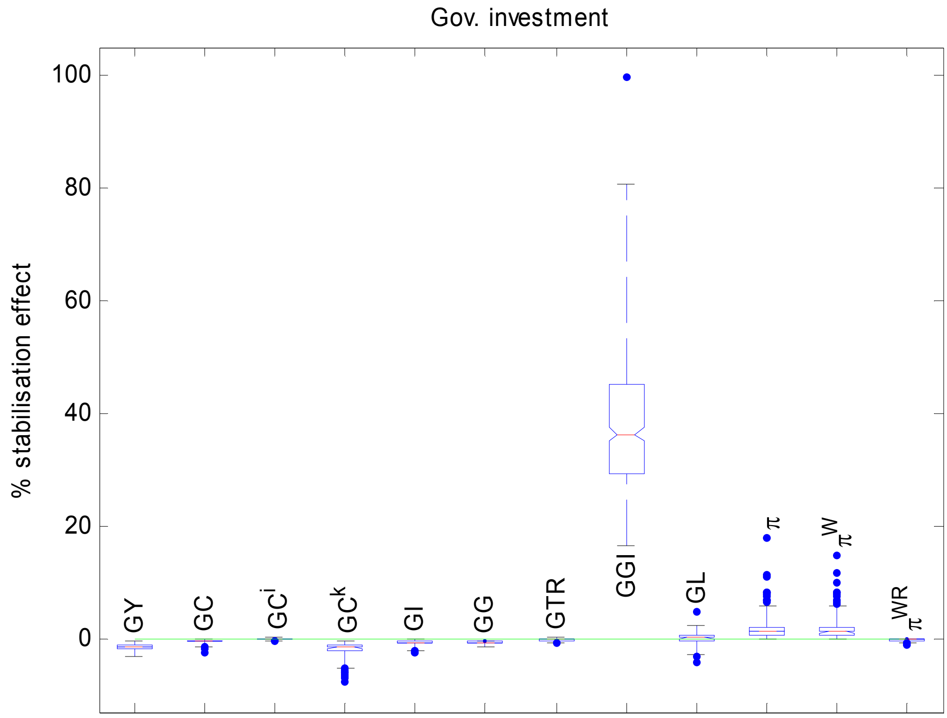

σ^X
σ
slc
spm
θ
t^{π}_{M}
$t^{L}_{TR,1}$
$t^{L}_{TR,3}$
ρ_{TR}
$\bar{trsn}$
$t^{Y}_{M,1}$
$t^{Y}_{M,2}$

Figure A2. Boxplots of the posterior distributions of the fiscal stabilisation effects for the base model. (Inf-ahead horizon)

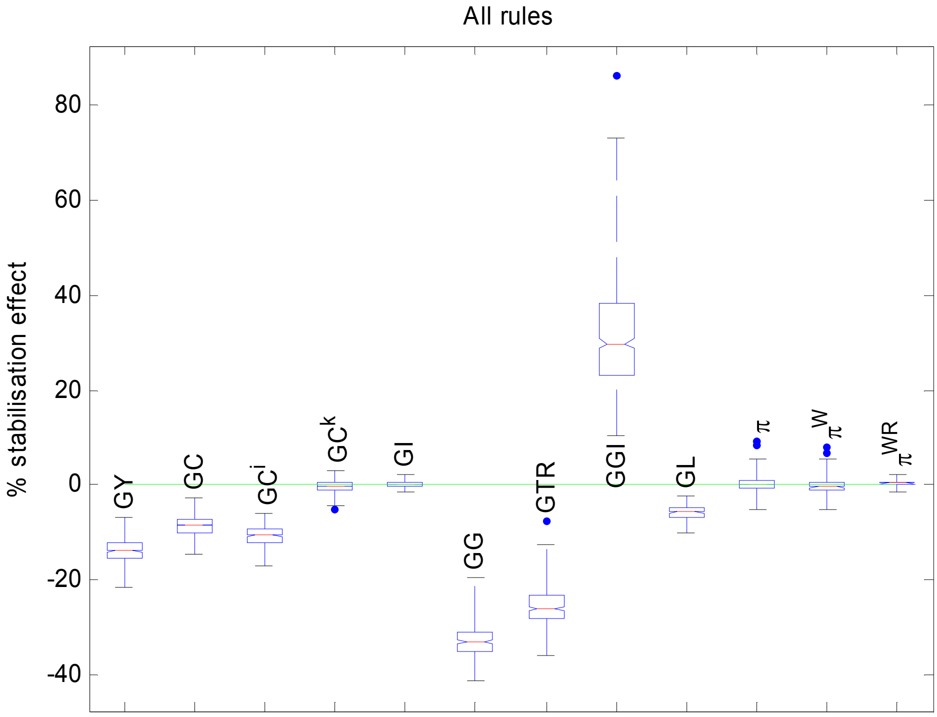




Wage taxes
% stabilisation effect
2
0
-2
-4
-6
-8
GY
GC
GC^i
GC^k
GI
GG
GTR
GGI
GL
π
π^W
π^WR



Gov. investment
% stabilisation effect
100
80
60
40
20
0
GY
GC
GC^i
GC^k
GI
GG
GTR
GGI
GL
π
π^W
π^WR



All rules
% stabilisation effect
80
60
40
20
0
-20
-40
GY
GC
GC^i
GC^k
GI
GG
GTR
GGI
GL
π
π^W
π^WR

ANNEX 2 Comparison with model with exogenous fiscal policy

Comparing the posterior mean in the two model specifications (see Table A.2), we can see that the model with exogenous rules need larger degree of persistence for government consumption and investment (*gslag* and *igslag*), and for transfers the persistency moves from *trslag*=0 in our base specification to 0.947 in the exogenous TR rule. As far as other structural parameters are concerned, major changes concern θ (from 2.14 to 1.8), *slc* (drops from 0.63 to 0.56), *risk* (falls from 0.0063 to 0.0056), *rp* (rises from 0.0056 to 0.0075), κ (falls from 2.9 to 2.5), *habc* (from 0,93 to 0.9).

Table A2. Estimation results for the base model and for the model with exogenous rules for nominal shares of government consumption, investment, transfers.

Parameter name		**Posterior mean**	
		Base	**Exog. rules**
a_2	A2E	0.0212	0.0276
$t^Y_{G,0}$	G1E	-0.5339	0
$t^Y_{G,1}$	G2E	0.53807	0
$t^Y_{G,0}+t^Y_{G,1}$	GSUM	0.0041	0
γ_K	GAMIE	22.9549	20.98
γ_I	GAMI2E	15.6589	11.2478
γ_L	GAMLE	63.1248	59.7933
γ_P	GAMPE	20.6431	21.431
γ_{PX}	GAMPXE	24.411	24.2975
γ_W	GAMWE	26.5775	20.0595
gslag	GSLAG	0.8865	0.907
habc	HABE	0.9352	0.9049
habl	HABLE	8.1037	4.4887
$t^Y_{IG,1}$	IG1E	0.5424	0
igslag	IGSLAG	0.8318	0.9074
ilag	ILAGE	0.8597	0.8388
κ	KAPPAE	2.9125	2.4845
risk	RPREME	0.0063	0.0056
rp	RPREMK	0.0056	0.0075
ω^X	SE	0.7295	0.728
ω^{XW}	SWE	0.723305	0.7199
$\omega^X-\omega^{XW}$	SEDIFF	0.0062	0.0081
sfp	SFPE	0.9218	0.8956
sfpx	SFPXE	0.9539	0.9481
sfw	SFWE	0.9523	0.9355
σ^C	SIGC	2.64	2.3667
σ^X	SIGEXE	1.4431	1.2812
σ	SIGIME	0.6116	0.5441

slc	SLC	0.6312	0.5564
spm	SPM	0.4615	0.4204
θ	THETAE	2.1465	1.8003
t_M^{π}	TINFE	0.32	0.29
$t_{M,1}^{Y}$	TYE1	0.0326	0.0135
$t_{M,2}^{Y}$	TYE2	0.1627	0.1194
t_1^{w}	TW1	0.7661	0
t_{TR}^{L}	TR1E	-0.5367	0
t_{TR}^{dep}	TR3E	0.6178	0.0449
$trslag$	TRSLAG	0	0.9471
$\overline{trsn}$	TRSN	0.3988	0.4099