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Abstract

The objective of this paper is to investigate the optimality of EMU fiscal rules from a welfare perspective. We compute welfare-maximizing feedback coefficients for monetary and fiscal rules in a NK-DSGE with a high number of nominal and real distortions, calibrated on the Euro-area data. The framework includes imperfect competition, costly capital accumulation, consumption habits, price and wage stickiness, distortionary taxation on consumption, labor and capital income. Fiscal policy responds, alternatively, to total deficit, total government liabilities, and a linear combination of both targets. We show that the liabilities rule is welfare superior, but it does not provide enough output stabilization if not coupled with a non-zero response of monetary policy to output; optimal feedback coefficient are larger under debt targeting rather than deficit; under the current specification, a SGP-like rule seems highly suboptimal.

JEL Classification: E32, E52,E62.

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1. Introduction

This paper presents a Dynamic Stochastic General Equilibrium model with a large number of distortions, where fiscal and monetary policy react to aggregate variables according to specific policy rules. Our objective is to analyze if and how fiscal rules that have been in place in Europe since EMU creation are suboptimal from a welfare perspective; also, we check the welfare properties of other rules that are often proposed as better solution for the conduct of fiscal policy. Our main finding is that in particular one of these rules - a debt-pegging tax rate - appears the be the least suboptimal configuration, if monetary policy response to output is not mute. We also provide a complete welfare ranking of alternative fiscal rules and the economy's response to stochastic shocks under each of them.

The policy debate on the best specification of fiscal rules has been particularly stimulated by the introduction of the EMU. Maastricht convergence criteria (1992) and the Stability and Growth Pact (1997 followed by 2005 reform) provided the opportunity for a lively discussion among economists and policy makers which is still far from being settled. While the importance of maintaining sound public finance in order to guarantee macroeconomic stability seems to be now widely accepted, there is still no widespread consensus on the macroeconomic variable(s) that fiscal policy should target and the desirable extent of the reaction.

Macroeconomic theory has lately devoted particular attention to the issue, making wide use of the most recent wave of DSGE models with nominal rigidities. Smets and Wouters (2003), Christiano *et al* (2005) and Schmitt-Grohè and Uribe (2006) are probably the reference papers of some of the most advanced contributions on the analysis of stabilization policies in highly distorted stochastic environments. Some of the above studies focused on the enrichment of the amount of real and nominal rigidities (like Christiano e*t al),* some on Bayesian estimation of structural parameters (Smets and Wouters) and some on welfare analysis of the policy interactions (Schmitt-Grohè and Uribe).

However, we feel that the welfare analysis of alternative and realistic fiscal policy rules in highly distorted economies might still be subject to further investigation. Our ultimate driving motivation is the desire to build an analytical framework within which we could legitimately draw policy conclusions on the desiderability of different fiscal policy rules, with particular reference to the constraints currently in place in the European integration process.

In order to accomplish this task, we build a model with two sources of nominal rigidities - price and wage adjustment costs - and three sources of real rigidities - investment adjustment costs, consumption habit formation and imperfect competition in product and labor markets. The fiscal authority has three distortionary tax rates as policy instruments, which are set according to three alternative policy rules responding to different public finance aggregates: total deficit, total stock of government liabilities, and a linear combination of both. All the properties of the model are checked under these three alternatives fiscal policy specifications, in the attempt to investigate the general equilibrium and welfare effects of the adoption of different rules. From a technical point of view, the model is solved via an Accurate Second Order Solution as shown by Kim e*t al* (2003), so to obtain appropriate welfare comparisons across alternative policies. We then use a measure conditional to the non-stochastic steady state in order to be able to capture transitional welfare effects.

Our analysis show some remarkable results. First, a tax rule responding to total government liabilities is welfare-superior to other specifications; nevertheless, monetary policy's response to output must not be mute, otherwise the deficit rule is preferable, since it provides a more aggressive output stabilization via the effect on aggregate demand. The "mixed" feedback rule, on the other hand, seems to be largely suboptimal, although providing the best smoothing response after a shock. Second, within the liabilities rule, optimality implies a response of the tax rates on capital and labor equal, respectively, to 1.39 and 1.01, a result which seems robust to a wide range of stress tests; within the deficit rule, the optimal responses are 0.93 and zero. We interpret this result as a confirmation of the optimality of an "active" response to the stock of debt, whereas when fiscal policy targets deficit the response must be softer, in order not to boost volatility. Third, under any specifications it seems optimal to tax capital income more than labor income, as the former is subject to a quantity rigidity and it is predetermined, whereas the latter is featured by rigidity on its own price and, given its differentiated nature, can be subject to increased dispersions and volatility which is welfare-damaging. Optimal response of the tax rate on consumption, on the other hand, seems to be rather small.

The paper is organized as follows. Section 2 presents the set-up of the model, with the separate characterization of the households and firms sectors, the policy environment and the steady-state. Section 3 deals with calibration issues, using quarterly data on the Euro area from 1958 to 2008. Section 4 performs the welfare analysis, looking for the utility-maximizing fiscal policy parameters under the three alternative feedback rules, and dealing with a careful robustness checking procedure. Section 5 presents the reaction of the model economy to three stochastic shocks (productivity, monetary policy and government expenditure), by comparing impulse response functions under different fiscal policy specification. Section 6 concludes and discusses possible policy implications.

2.The model

The framework is a New Keynesian DSGE model with costly capital accumulation, imperfect competition, internal consumption habits, price and wage rigidities introduced via quadratic adjustment costs. Policy authorities conduct monetary and fiscal policies via, respectively, Taylor rule and tax rates responding to alternative public finance aggregates.

Households are indexed by $i \in [0,1]$. They define their optimal plans by maximizing an intertemporal strongly separable utility function; they sell capital stock and their labor to intermediate firms at rate respectively, Z_{it} and W_{it} ,on which they are taxed with distortionary rates τ^k and τ^w .They allocate their resulting income across consumption (C_{it}, taxed at rate τ^c),investment (I_t,augmented by adjustment costs), and financial assets (made of interest bearing government bonds B_{it} and unfruitful money holding M_{it}). Intermediate sector firms are indexed by $j \in [0,1]$. They operate under monopolistic competition, hire labor and capital by households in order to produce (subject to total factor productivity shock and fixed-cost shock) intermediate inputs Y_{jt} then used by final goods firms, under perfect competition, to produce a final homogenous good Y_t. Monetary policy is driven by standard Taylor rule subject to cost-push shock, whereas the government conducts fiscal policy by manoeuvring the distortionary tax rates τ^i (with $i = c,w,k$) with a feedback rule responding, alternatively, to total deficit, total liabilities and a linear combination of the two.
We now proceed with the separate modelling of households, firms and policy behaviour.

2.1. Households

The model economy is populated by an infinite number of agents indexed on the real line between 0 and 1, who formulate preferences over consumption, labor efforts and money balances according to the following intertemporal utility function for the i^{th} household:

$$U_{i0} = E_0 \beta^t \sum_{t=0}^{\infty} u(C_{it}, N_{it}, M_{it}) \tag{1}$$

Functional form assumptions for the instantaneous utility function are as follows:

$$u(N_{it}) = -\frac{a_n}{1+\gamma_n} N_{it}^{\ 1+\gamma_n} \tag{2}$$

$$u(C_{it}) = \frac{(C_{it} - \varphi C_{i,t-1})^{1-\sigma}}{1-\sigma} \tag{3}$$

$$u(M_{it}) = \chi \frac{m_{it}^{\ 1-\sigma_m}}{1-\sigma_m} \tag{4}$$

Utility depends positively on private consumption C_{it} (with the parameter $0 < \vartheta < 1$ determining the degree of internal habit persistence) and on real money balances m_{it} (with σ_m being the inverse of the elasticity of money holdings with respect to the interest rate). It depends negatively on labor supply N_{it} (with γ_n the inverse of the elasticity of work with respect to the real wage).

Budget constraint in real terms can be expressed so to make clear the equality between total income (LHS) and total expenditures (RHS):

$$Y_{it} + R_{t-1}\frac{b_{t-1}}{\pi_t} + \frac{m_{t-1}}{\pi_t} = (1+\tau_t^c)C_t + I_t(1+AC^k) + AC^p + AC^w + b_t + m_t \tag{5}$$

with Y_t being net real income stemming from ownership of production factors, m_{t-1} last period real cash balances, and $R_{t-1}\frac{b_{t-1}}{\pi_t}$ the gross return from last period government bonds holding (R and π are gross indicators of interest rate and inflation). RHS include gross consumption, gross investment, adjustment costs for prices and nominal wages, and accumulation of period t financial assets.

Households net total income is given by:

$$Y_{it} = (1-\tau_t^w)W_{it}N_{it} - T_{it} + \Pi_{it} + (1-\tau_t^k)Z_tK_{it} \tag{6}$$

with Z_t being the rental rate of capital, W_{it} the real wage of the individual supplier, Π_{it} the profits deriving from firms' ownership, T_{it} the lump-sum tax (transfer) to be paid (received) to (by) the government, and τ_t^i (with $i = w, k, c$) being the tax rates on, respectively, wage and capital income, and consumption.

Adjustment costs AC^i (with $i = k,p,w)$ display the usual quadratic functional form, originally pioneered by Rotemberg (1982):

$$AC^k = \frac{\phi_k}{2}\left(\frac{I_{it}}{K_{it}}\right)^2 I_{it} \tag{7}$$

$$AC^p = \frac{\phi_p}{2}\left(\frac{P_{it}}{P_{i,t-1}} - \overline{\pi}\right)^2 Y_{it} \tag{8}$$

$$AC^w = \frac{\phi_w}{2}\left(\frac{W_{it}}{W_{i,t-1}} - \overline{\pi^w}\right)^2 W_{it} \tag{9}$$

Equation (7), where ϕ_k represents the adjustment scale cost for capital, indicates that one unit of investment I_{it} is actually transformed into one unit of capital K_{it} at the costs of $\frac{\phi_k}{2}\left(\frac{I_t}{K_t}\right)^2 I_{it}$ extra-amount of real resources for the investor. As usual, it is important to remember that the presence of adjustment costs makes current investment depend on the future via the expectations mechanism and helps smoothing the otherwise excessively strong reaction of the real interest rate after a technological shock. Also, a functional form as in (7) produces positive steady-state adjustment costs[1].

In (8) and (9) ϕ_p and ϕ_w indicate the degree of rigidities in the adjustment of prices and wages. This way to rationalize nominal variables stickiness is alternative to the Calvo mechanism (Erceg *et al* 2000, Christiano e*t al* 2003, Sbordone 2001) and to the staggered wage contracts approach (Cho and Cooley 1995, Chari e*t al* 2000). It is, instead, in line with contributions such Kim (2000) and Marzo (2005), and represents a tractable way to rationalize all the information costs associated with raising prices and wages above the steady-state inflation rates (respectively, $\bar{\pi}$ and $\bar{\pi}^W$, which in turn can be interpreted, following Woodford 2003, a measure of wage inflation). Following what has become a standard assumption in the literature (Christiano e*t al* 2005*,* Smets and Wouters 2003), we assume the existence of state-contingent securities whose role is to ensure households againts variations in specific labor income $W_{it}N_{it}$. As a result, individual labor will be equal to aggregate labor income W_tN_t , and

[1]As pointed out in Kim (2000), in order to produce zero steady-state adjustment costs we would need to make them function of net investment, according to $\frac{\phi_k}{2}\left(\frac{I_{i,k}}{K_{i,k}} - \delta\right)I_{it}$.

thus the marginal utility of wealth will be identical across different types of households.

Total amount of labour supplied in the economy, in fact, is a CES aggregator of individual labor effort:

$$N_t = \left[\int_0^1 N_{it}^{\frac{\psi-1}{\psi}} di \right]^{\frac{\psi}{\psi-1}} \tag{10}$$

with $\psi > 1$ being the elasticity of substitution among individual different kinds of labor. As usual, we assume that it is N_t to be employed in the production of intermediate goods, which therefore require all types of labor. In analogy to the final good sector, the demand for differentiated labor inputs N_{it} is:

$$\frac{N_{it}}{N_t} = \left(\frac{W_{it}}{W_t} \right)^{-\psi} \tag{11}$$

and the aggregate wage index:

$$W_t = \left[\int_0^1 W_{it}^{1-\psi} di \right]^{\frac{1}{1-\psi}} \tag{12}$$

Capital stock evolves according to the standard:

$$K_{it} = (1-\delta)K_{i,t-1} + I_{it} \tag{13}$$

where $0 < \delta < 1$ is the constant depreciation rate.

The representative household's problem is to choose the optimal combination of consumption, labor supply, real money holdings, government bonds, capital and investment (the vector $[C_{it}, N_{it}, m_{it}, b_{it}, K_{it}, I_{it}]$) taking as given the aggregate price level (P_t), the aggregate wage index (W_t) and the rental rate of capital (Z_t). In order to do that she maximizes (1)-(4) subject to (5)-(13) and the usual no-Ponzi-game borrowing condition. The corresponding FOCs are:

$$(C_{it} - \vartheta C_{i,t-1})^{-\sigma} - \beta\vartheta(C_{i,t+1} - \vartheta C_{i,t})^{-\sigma} = \lambda_t(1+\tau_t^c) \tag{14}$$

$$a_n N_{it}^{\gamma_n} = \lambda_t(1-\tau_t^w)\left(1 - \frac{1}{e^W}\right) W_{it} \tag{15}$$

$$\chi m^{-\sigma_m} = \lambda_t \left[\frac{R_t - 1}{R_t} \right] \tag{16}$$

$$\lambda_t = \beta E_t \lambda_{t+1} R_t \frac{P_t}{P_{t+1}} \tag{17}$$

$$\mu_t = \lambda_t \left[(1 - \tau_t^k) Z_t + \phi_k \left(\frac{I_{it}}{K_{it}} \right)^3 \right] + \beta E \mu_{t+1} (1 - \delta) \tag{18}$$

$$\beta E_t \mu_{t+1} = \lambda_t \left[1 + \frac{3}{2} \phi_k \left(\frac{I_{it}}{K_{it}} \right)^2 \right] \tag{19}$$

where λ_t and μ_t are Lagrange multipliers on, respectively, households' budget constraint and capital accumulation equation. As usual, they indicate the price of consuming and investing in utility terms.

Equation (14) equates the marginal utility of consumption (augmented by habit formation) to the Lagrange multiplier on the budget constraint (marginal cost of consuming), corrected for the distortionary tax rate on consumption.

Equation (15) equates the marginal disutility of working with the utility value of net real wage. The term e_{it}^W, almost identical to Kim (1998) and Marzo (2005), denotes the elasticity of labor demand to the real wage, augmented by the wage adjustment costs, and it is given by the expression[2]:

$$\frac{1}{e^w} = \frac{1}{\psi} \left[\begin{array}{c} 1 - \frac{\phi_w}{(1-\tau_t^w) N_{it}} W_t \left(\frac{P_t W_{it}}{P_{t-1} W_{i,t-1}} - \bar{\pi}^w \right) \frac{P_t}{P_{t-1} W_{i,t-1}} + \\ \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\phi_w}{(1-\tau_t^w) N_{it}} W_{t+1} \left(\frac{P_{t+1} W_{i,t+1}}{P_t W_{it}} - \bar{\pi}^w \right) \frac{P_{t+1} W_{i,t+1}}{P_t W_{it}^2} \end{array} \right] \tag{20}$$

With respect to the above-mentioned contributions, in our framework the elasticity e^W is affected by the tax rate on wage income, which makes labor demand more rigid.

We can check that in steady-state (or when the scale parameter $\phi^w = 0$, namely there are no wage

[2]Equation (20) is derived by taking account of equations (9) and (11) in the maximization for N_{it}.

adjustment costs) the elasticity is constant at the level ψ. .Outside the steady-state, or in the presence of positive costs, wage rigidities plays a role in the optimal labor supply in equation (15), by creating a second wedge (the other being the distortionary tax rate τ^w) between the real wage and the labor/leisure marginal rate of substitution.
Equation (16) equates the marginal utility of holding money with the utility costs of alternative uses of that additional unit of income (consumption or bond holdings); analogously, equation (17) defines optimal bond allocation, by equating the marginal cost of bond holding (i.e. the marginal utility of foregone consumption) to the marginal utility of increased consumption the next period.
Optimal capital accumulation involves two efficiency conditions. Equation (18) states that the marginal utility of capital is equal to the sum of three marginal utilities: the one from the net-of-taxes rental rate ($\lambda_t(1-\tau_t^k)Z_t$), the one from the gain in adjustment costs ($\lambda_t\phi_k\left(\frac{I_t}{K_t}\right)^3$), and the one (discounted and depreciated) from next period's capital ($\beta E\mu_{t+1}(1-\delta)$).
Equation (19) equates marginal benefit of investing (the discounted future marginal value of capital) with its marginal cost (the marginal utility of foregone consumption augmented by adjustment costs).

2.2 Firms

We assume the existence of a large number of intermediate firms indexed by $j \in [0,1]$, each producing a single variety j , then demanded by final good firms according to the following demand schedule:

$$Y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon} Y_t \tag{21}$$

Final good firms assemble inputs, under perfect competition, according to a Constant Elasticity of Substitution (CES) production function:

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}}\,dj\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{22}$$

with $\varepsilon > 1$ being the elasticity of substitution between intermediate goods (and the price elasticity of demand)

Intermediate good firms are monopolistically competitive and therefore enjoy market power over their particular variety i ; production takes place through the following Cobb Douglas production function:

$$Y_{jt} = A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha} - \Phi_t \tag{23}$$

where K_{jt} and N_{jt} ,respectively, indicate the amount of capital stock and labor employed in the production process. Moreover, A_t is a technological shock, common to all firms and Φ_t is a fixed cost shock. The presence of Φ_t can be justified on the ground of a pure cost necessary to start up with the business, and implies increasing returns to scale. From the technical point of view - as indicated by Kim (2000) and Christiano et al. (2001) - Φ_t allows to restore the zero profit condition at the steady state, after a proper calibration, provided that it is nonnegative. The presence of Φ_t obeys also to another principle: the need to insert shocks not directly hitting the real interest rate, which, instead, would respond as a second round effect to that shock. In this way, we eliminate the problem of interpreting changes in the real interest rate as only depending on technological shock. The evolution of A_t and Φ_t is assumed to follow an AR(1) process, described as:

$$\log A_t = (1-\rho_A)\log \overline{A} + \rho_a A_{t-1} + \varepsilon_t^A \tag{24}$$

$$\log \Phi_t = (1-\rho_\Phi)\log \overline{\Phi} + \rho_a \Phi_{t-1} + \varepsilon_t^\Phi \tag{25}$$

with $\varepsilon_t^A \sim N(0,\sigma_A^2)$, $\varepsilon_t^\Phi \sim N(0,\sigma_\Phi^2)$. To simplify, we assume that the two production function shocks are uncorrelated, i.e.: $\sigma_{A\Phi} = 0$.

The presence of quadratic adjustment costs (8) injects an intertemporal dimension into the firm's optimization problem, which is now properly dynamic and thus requires a specific discount factor of future stream of profits, that we call Λ_t.

The j^{th} intermediate firm then maximizes the future stream of nominal profits (discounted at rate Λ_t and given by factor prices and adjustment costs in each period), under the technological and demand constraint. Formally:

$$\max_{P_{jt}} \Pi_{j0} = E_0\left[\sum_{t=0}^{\infty} \Lambda_t P_t \Pi_{jt}\right] \tag{26}$$

where:

$$P_t \Pi_{jt} = P_{jt} Y_{jt} - P_t Z_t K_{jt} - P_t W_t N_{jt} - P_t AC_{jt}^P \tag{27}$$

subject to:

$$\begin{aligned} Y_{jt} &= A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha} - \Phi_t \\ Y_{jt} &= \left(\frac{P_{jt}}{P_t}\right)^{-\varepsilon} Y_t \\ AC_{jt}^P &= \frac{\phi_P}{2}\left[\frac{P_{jt}}{P_{j,t-1}} - \bar{\pi}\right]^2 Y_t \end{aligned}$$

Maximization leads to the following factor prices:

$$Z_t = \alpha(1 - \frac{1}{\varepsilon_{jt}^Y})\left(\frac{Y_{jt} + \Phi_t}{K_{jt}}\right) \tag{28}$$

$$W_t = (1-\alpha)(1 - \frac{1}{\varepsilon_{jt}^Y})\left(\frac{Y_{jt} + \Phi_y}{N_{jt}}\right) \tag{29}$$

with ε_{jt}^Y , analogously to the labor market case (20), being the output demand elasticity:

$$\frac{1}{\varepsilon_{jt}^Y} = \varepsilon^{-1}\left[\begin{array}{c} 1 - \phi_P\left(\frac{P_{jt}}{P_{j,t-1}} - \bar{\pi}\right)\frac{P_t}{P_{j,t-1}}\frac{Y_t}{Y_{jt}} \\ +\beta E_t \phi_P \frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{P_{j,t+1}}{P_{j,t}} - \bar{\pi}\right)\frac{P_{t+1}}{P_{jt}}\frac{P_{j,t+1}}{P_{jt}}\frac{Y_{t+1}}{Y_{jt}} \end{array}\right] \tag{30}$$

With perfect price flexibility $(\phi_P = 0)$ or in steady-state $(\pi_t = \pi_{t+1} = \bar{\pi})$ expression (30) simplifies to $\varepsilon_{jt}^Y = \varepsilon$,so that the mark-up is a decreasing function of the elasticity of substitution across intermediate goods. In such situation, stochastic shocks do not change the mark-up, with the only differences being that technological or fixed-cost shocks affect real variables, whereas demand shocks do not. With price stickiness, mark-up becomes a transmission channel for the business cycle, through its own cyclicality whose direction relies on the source of the shock (Kim 2000): production function shocks leading to a reduction of marginal costs increase output and the mark-up, whereas demand side shocks (shifting upward the profit-maximizing equality between marginal and revenue and marginal costs) increase output but lead to a cut in the mark-up.

2.3. Policy

Monetary policy follows a standard Taylor-rule with inertia:

$$\frac{R_t}{\bar{R}} = \left[\frac{\pi_t}{\bar{\pi}}\right]^{\phi_\pi}\left[\frac{Y_t}{\bar{Y}}\right]^{\phi_y}\left[\frac{R_{t-1}}{\bar{R}}\right]^{\phi_i} + \varepsilon_t^{MP} \tag{31}$$

which in loglinearized form is:

$$\hat{R}_t = \phi_\pi \hat{\pi}_t + \hat{y}_t + \phi_r \hat{R}_{t-1} + \varepsilon_t^{MP} \tag{32}$$

where we also allow for a $i.i.d$ shock to monetary policy $\varepsilon_t^{MP} \sim (0, \sigma_{MP}^2)$.
Government budget constraint in nominal terms is:

$$B_t + M_t - M_{t-1} = R_{t-1}B_{t-1} + P_tG_t - P_tT_{tot} \tag{33}$$

with M_t and B_t being the aggregation of individual nominal assets holdings:

$$M_t = \sum_{i=1}^{I} M_{it},\ \ B_t = \sum_{i=1}^{I} B_{it} \tag{34}$$

T_t^{TOT} is the total tax revenue coming from lump-sum taxation (T_t), and taxation on consumption, and labor and capital income:

$$T_t^{TOT} = T_t + \tau_t^c C_t + \tau_t^w W_t N_t + \tau_t^k Z_t K_t \tag{35}$$

Equation (33) makes clear that each period the government covers its total deficit on the RHS (primary deficit $G_t - T_t^{TOT}$ plus gross interest rate payments $R_{t-1}B_{t-1}$) by printing new money or by issuing new debt (LHS).

As in Schmitt-Grohè and Uribe (2006), we can define total real liabilities l_t as:

$$l_t = R_t b_t + m_t \tag{36}$$

with b_t and m_t being, respectively, bond and money holdings in real terms.

Therefore, in real terms, government budget constraint (33) can be written as:

$$l_t = \frac{R_t}{\pi_t} l_{t-1} + R_t(G_t - T_t^{TOT}) - m_t(R_{t-1}) \tag{37}$$

Primary government expenditure G_t evolves according to:

$$\log G_t = \rho_g \log G_{t-1} + (1-\rho_g)\log \bar{G} + \varepsilon_t^g \tag{38}$$

with $0 < \rho_g < 1$ being the AR(1) coefficient, $\bar{G}$ the steady-state level, and ε_{Gt} $i.i.d. \sim (0, \sigma_g^2)$.

Fiscal policy is conducted by manoeuvring the three distortionary tax rates on consumption, labor income and capital income $(\tau_t^i$ with $i = c, w, k)$, according to feedback policy rules responding to a last period fiscal aggregate X_{t-1} :

$$\log \tau_t^i = \rho^i \log \tau_{t-1} + (1-\rho^i)[\log \bar{\tau} + X_{t-1}] \tag{39}$$

with $i = c, w, k$

We will try different specification of X_{t-1} :

$$X_{t-1} = \left\{ \begin{array}{c} \phi_d^i(\log D_{t-1} - \log \bar{D}) \\ \phi_l^i(\log l_{t-1} - \log \bar{l}) \\ \phi_d^i(\log D_{t-1} - \log \bar{D}) + \phi_l^i(\log l_{t-1} - \log \bar{l}) \end{array} \right\} \tag{40}$$

(40) indicates an automatic response of the tax rate to deficit, to total liabilities, and to a linear combination of deficit and liabilities. Rigorously, the tax rate responds to deviation of the above aggregates from their steady-state level. The motivation behind the design of these alternative rules can be summarized as follows. The first one follows the prescription of the Stability and Growth Pact in the European Monetary Union, which in the short run prevents member states to overcome the 3% deficit / GDP ceiling, and in the medium run pushes towards balanced budget. The second rule (pegging to the stock of government liabilities) is the most recommended policy stance, and represents one of the suggestions for a further reform of EMU fiscal rules. Finally, the third one is an hybrid of the former

two rules, and can be considered the one leading the fiscal consolidation process of EU states during the run-up to the single currency in the mid-Nineties[3].

In the remaining of the paper, we will examine how the adoption of different fiscal target as in (40) affects the response of the economy to a variety of shocks, and which policy specification yield the highest level of conditional and unconditional welfare.

2.4. Equilibrium and steady-state

In order to make the model economy tractable, we impose ex-post symmetry on agents' behaviour, so we drop all the i and j indexes. Furthermore, we assume equality between households and firms stochastic discount factors:

$$\beta\frac{\lambda_{t+1}}{\lambda_t} = \frac{\Lambda_{t+1}}{\Lambda_t} \tag{45}$$

As standard in the literature, we rationalize (45), which states that firms discount their future profits the same way household discount future consumption flows, by assuming that there is a complete and competitive market for contingent claims that each agents has access to.

The final goods market is in equilibrium when total production equals total demand, augmented by adjustment costs:

$$Y_t = G_t + C_t + I_t(1 + AC^k) + AC^p + AC^w \tag{46}$$

The capital rental market is in equilibrium when the demand for capital by intermediate goods producers equals the quantity supplied by households. The labor market is in equilibrium if firms' demand for labor is equal to the amount of labor supplied at the wage level set by households. The bond market is in equilibrium when government debt is held by investors at the interest rate R_t, whose level is determined by monetary policy. The complete model can be found in Appendix A .

3. Calibration

We calibrate the model on the Euro area economy with quarterly data from 1958 to 2008.

[3]Maastricht convergence criteria obliged perspective member states to comply to both the deficit (3% ceiling) and the debt (60% of GDP) parameters.

We assume that the economy is operating in the deterministic steady-state of a competitive equilibrium in which the inflation rate (computed using GDP deflator) is 4.31 per cent per annum, and the nominal interest rate (measured by the three months interbank rate) is 5.30 per cent. The share of steady-state private consumption over output is 57 per cent, while for gross private investments are calibrated at 14.5 per cent; government expenditure is determined residually using the aggregate resource constraint and it is found equal to 27.08 per cent of national product. Steady-state government debt is calibrated at 60 per cent of GDP, in line with the EMU fiscal constraints. The amount of labor effort $(L = 0.33)$ is calibrated by using the empirically observed ratio of market activities over the total time endowment, equal to approximately one third. Steady-state tax rates on consumption, labor and capital are calibrated at, respectively, 20, 40 and 25 per cent as estimated by Forni e*t al* (2006) for the Euro area.

The calibration of deep parameters is summarized in Table 1:

Table 1

Parameter	**Value**	**Description**
β	0.9961	households' discount factor
δ	0.025	capital depreciation rate
α	0.33	capital share of income
θ	6	elasticity of substitution between goods
γ_n	1.5	inverse of labor supply elasticity
σ	2	risk adversion
ϑ	0.7	habit formation
σ_m	10.62	utility function parameter (money)
ϕ_k	314	investment adjustment cost
ϕ_p	60	price adjustment cost
ϕ_w	100	wage adjustment cost

The capital stock share α is set at $0.33;$ the capital/output ratio implied by the model is $K/Y = \alpha/Z = 10.44$,very close to the value reported by Christiano 1991, equal to 10.33). The elasticity of substitution across differentiated goods is calibrated at $\theta = 6,$ so to generate a mark-up equal to 1.2; on the other hand, the elasticity of substitution among individual labor varieties is taken to be $\psi = 12$ in analogy with the value obtained in the estimation by Kim (2000). The risk adversion

parameter is calibrated at the standard value of $\sigma = 2$ (Prescott 1986). The calibration of the structural parameter referring to the presence of money in the utility function relies on Christiano, Eichenbaum, and Evans (2005): we chose the parameter $\sigma_m = 10.62$ and we use their value of money velocity (0.44) to calibrate the steady-state value of money to the GDP. The parameter for price adjustment ϕ_p has been set equal to 60 as in Ireland (2002), while an higher value has been chosen for the wage adjustment equation ($\phi_w = 100$) , so to reflect the relatively higher rigidity of labor market.
Table 2 summarizes the calibration of stochastic moments.

Table 2

Parameter	Value	Description
ρ_A	0.95	AR(1) parameter for productivity
ρ_G	0.9	AR(1) parameter for gov.expenditure
ρ_Φ	0.911	AR(1) parameter for fixed cost
σ_A	0.07	Standard deviation of productivity innovation
σ_{MP}	0.03	Standard deviation of monetary policy innovation
σ_G	0.01	Standard deviation of gov. expenditure innovation
σ_Φ	0.14	Standard deviation of fixed cost innovation

Fiscal policy parameters are left free to vary, whereas for monetary policy we use in the benchmark the standard parameters configuration ($\phi_\pi = 1.2, \phi_y = 0.5$), but we vary them considerably when dealing with robustness analysis.

4. Welfare analysis

In this section we perform policy evaluations by computing the welfare cost of different specifications of the fiscal rules and, within each of them, different values of the feedback coefficient relating tax rates and fiscal aggregates. In order to do so (following contributions such as Schmitt-Grohé-Uribe 2006 and Marzo 2005) we solve the full model up to second order approximation of the policy function, and use it in the calculation of the second order expansion of the utility function around the deterministic steady-state. After that, we compute the welfare costs associated with the adoption of a particular fiscal policy rule, with respect to the second-order approximation of the utility function at the steady-state. Welfare costs are computed in terms of fraction of consumption that a household has to give up in order to attain the same welfare under alternative policy regimes.

In particular, we look for policy parameters that minimize the difference $E[V^{SS}]-E[V^{F}]$, where:

$$E\left[V^{SS}\right]=E_0\sum_{t=0}^{\infty}\beta^t u\left(C^{SS},L^{SS},M^{SS}\right) \tag{47}$$

$$E\left[V^{F^i}\right]=E_0\sum_{t=0}^{\infty}\beta^t u\left(C^{F^i},L^{F^i},M^{F^i}\right) \tag{48}$$

Equation (47) refers to the second order approximation of the utility function calculated at the steady-state, whereas equation (48) indicates the same measure under a specific fiscal policy regime F^i with i indicating one of the three fiscal policy rules.

As standard now, we define ξ as the fraction of consumption that a household has to give up to maintain the same second-order welfare as in the steady-state, when the economy adopts a particular fiscal policy regime F^i. Formally:

$$E\left[V^{F^i}\right] = E_0\sum_{t=0}^{\infty}\beta^t u((1-\xi)(1-\vartheta)C^{SS},L^{SS},M^{SS}) \tag{49}$$

Considering the functional form adopted, we can derive an analytical expression for ξ as in Schmitt-Grohé and Uribe (2006):

$$\xi = \left[1-\left(\frac{(1-\sigma)V^{F^i}+(1-\beta)^{-1}}{(1-\sigma)V^{SS}+(1-\beta)^{-1}}\right)^{\frac{1}{1-\sigma}}\right] \tag{50}$$

Welfare costs, measuring the percentage of consumption needed in order to switch from steady-state configuration to a given policy regime F^i is then given by:

$$\omega = \xi \times 100$$

The following table reports the optimal fiscal policy based on conditional welfare measure under the three alternative fiscal regimes. The results have been obtained after a grid search within the interval $[-2, 2]$ for each fiscal policy parameter, and with the following specification of monetary policy parameters $[\phi_\pi = 1.2, \phi_y = 0.5, \phi_r = 0.7]$. Under all the following experiments, consumption tax rate's response will be kept at a conventional value of 0.3, which has been found to be optimal in that respect.

Table 3

Fiscal target	ϕ_D^k	ϕ_D^L	ϕ_l^K	ϕ_l^L	ω
liabilities	-	-	1.39	1.01	-9.0369
deficit	0.93	0	-	-	-10.9841
both	0.85	0	0.95	0	-203.89

What Table 3 tells us is that under standard monetary policy with a considerable degree of inertia, the optimal fiscal policy is the one where both tax rates on capital and labor respond more than proportionally to the total stock of government liabilities. Under the deficit rule, optimal fiscal policy responds less than proportionally with the capital tax instrument, and does not respond with the labor tax. No taxation on labor is confirmed in the "mixed" rule, which delivers a heavier response on the liabilities side, but nonetheless is much less suboptimal that the previous two.

We now ask ourselves whether the above results are robust to alternative monetary policy specifications. Table 4 shows the robustness of the above results (relative to the debt and deficit rule) under different monetary policies. The first three columns indicate the monetary stance towards inflation, output and lagged interest rate; the fourth and fifth columns report the corresponding optimal feedback parameter for the liabilities rule, with the relative welfare cost (ω_l). The last columns show the corresponding feedback parameters (to capital and labor income) under deficit targeting, with the corresponding costs (ω_d).

Table 4

ϕ_π	ϕ_y	ϕ_r	ϕ_l^K	ϕ_l^L	ω_l	ϕ_d^K	ϕ_d^L	ω_d
0.7	0	0	1.37	1.03	–64.5829	0.93	0	–13.3424
0.7	0.5	0	1.38	1.01	–9.0251	0.93	0	–12.5625
0.7	0.5	0.7	1.39	1.01	–9.0369	0.93	0	–11.4355
0.7	0	0.7	1.39	1.01	–85.355	0.93	0	–13.8459
1.2	0	0	1.37	1.02	–64.76	0.93	0	–10.9841
1.2	0.5	0	1.38	1.01	–9.0251	0.93	0	–10.9945
1.2	0	0.7	1.39	1.01	–85.35	0.93	0	–11.0862
3	0	0	1.37	1.02	–64.76	0.93	0	–10.9841
3	0	0.7	1.39	1.01	–85.35	0.93	0	–11.0013
3	0	0.7	1.39	1.01	–85.35	0.93	0	–11.5623
3	0.5	0.7	1.39	1.01	–9.03	0.93	0	–12.4111
3	0.5	0	1.38	1.01	–9.02	0.93	0	–10.9841
10	0	0	1.37	1.02	–64.76	0.93	0	–10.9841
10	0	0.7	1.39	1.01	–85.35	0.93	0	–10.9841

Therefore, the fiscal rule on debt is preferable to the one on deficit only if the monetary policy's response to output is not mute. We believe that the interpretation of this crucial result lies in the high degree of distortions in our model economy. A fiscal rule on debt is optimal because of its stabilizing properties, but given the number of imperfections an active output stabilization role is also needed from the monetary policy arm. Otherwise, the fiscal rule on debt is not enough to offset the inflationary pressures coming from output distortions, and then it is more desirable to switch towards an aggressive response to deficit (a flow rather than a stock variable, and therefore potentially causling more volatility). In that case, however, the optimal coefficients are smaller. Given the more aggressive nature of a fiscal rule on deficit, feedback coefficients must be lower ($\phi_d^K = 0.93$ and $\phi_d^L = 0$), in order not too boost volatility; in particular, labor tax response should be zero. Note that under the deficit rule the conditional welfare loss is much less dependant on the monetary policy stance, as the fiscal rule provides the highest possible contribution to fight inflation.

The last result to comment is the higher value of the feedback coefficients (under all types of fiscal rules) on capital relative to the ones on labor income. This stems from the fact that capital is predetermined and subject to quantity rigidities, whereas labor has price rigidities.

5. Response to shocks

In this section we present the response of the model economy to different shocks originating from three alternative sources: productivity, fiscal and monetary sides. Impulse response functions are computed under the three alternative fiscal policy rules, and are shown in Appendix B. As it can be seen, the stabilizing properties of a debt-pegging tax rule are confirmed, as response to shocks is smoother under that particular specification.

6. Conclusions

This paper presented a New Keynesian Dynamic Stochastic General Equilibrium model featured by a considerable number of nominal and real rigidities. Our main goal was to investigate the behaviour of the economy - in terms of reaction to stochastic shocks and welfare analysis - under three alternative fiscal policy rules defining the response of the three distortionary tax rates (on consumption, wage and capital income) to - respectively- total government liabilities, total deficit and a linear combination of the two fiscal aggregates.

Our results can be summarized as follows:

- a fiscal rule where the main policy instruments are tax rates on labor and capital income responding to the past stock of real liabilities is the best configuration from a welfare point of view. Taxation on consumption should be kept rather small, and the feedback coefficient on labor and capital tax should be, respectively, 1.01 and 1.39. Fiscal rules responding to deficit and, to a greater extent, to a linear combination of fiscal aggregates, are welfare inferior.
- the above welfare ranking is conditional on monetary policy's response to output not being mute, otherwise the fiscal rule responding to deficit becomes the optimal one.
- all the configurations deliver the same result in terms of the relative burden of taxation, which should be on capital more than on labor.

- a fiscal rule targeting the stock of real liabilities seems to result in the best smoothing response after a shock.

From a policy point of view, this paper seems to strengthen the position calling for a greater emphasis of EMU fiscal rules on public debt stabilization, provided that monetary policy does not give up on output stabilization. The strong suboptimality of SGP-like fiscal rule is no doubt a strong conclusion; nevertheless, we should maybe remember that the main economic rationale of the SGP has never been the choice of a welfare maximizing fiscal stance. Instead, EMU fiscal rules have been designed in order to prevent the arising of negative externalities which would damage the correct functioning of a monetary union. If and when the European integration process heads towards a more centralized fiscal framework that can overcome the need of national fiscal policies' coordination, then maybe the conduct of fiscal policy can more legitimately focus on rules that seem to have a better welfare enhancing perspective.

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Appendix A :Model equations

$$(C_{it} - bC_{i,t-1})^{-\sigma} - \beta b(C_{i,t+1} - bC_{i,t})^{-\sigma} = \lambda_t(1 + \tau_t^c)$$

$$a_n N_{it}^{\gamma_n} = \lambda_t(1 - \tau_t^w)\left(1 - \frac{1}{e^W}\right)W_{it}$$

$$Z_t = \alpha(1 - \frac{1}{\varepsilon_{jt}^Y})\left(\frac{Y_{jt} + \Phi_t}{K_{jt}}\right)$$

$$\frac{W_t}{P_t} = (1-\alpha)(1 - \frac{1}{\varepsilon_{jt}^Y})\left(\frac{Y_{jt} + \Phi_y}{N_{jt}}\right)$$

$$Y_{jt} = A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha} - \Phi_t$$

$$l_t = R_t b_t + m_t$$

$$T_t^{TOT} = -T_t^{ls} + \tau_t^c C_t + \tau_t^w \frac{W_t}{P_t} N_t + \tau_t^k Z_t K_t$$

$$\frac{R_t}{\bar{R}} = \left[\frac{\pi_t}{\bar{\pi}}\right]^{\phi_\pi}\left[\frac{Y_t}{\bar{Y}}\right]^{\phi_y}\left[\frac{R_{t-1}}{\bar{R}}\right]^{\phi_i} + \varepsilon_t^{MP}$$

$$\log A_t = (1-\rho_a)\log\bar{A} + \rho_a \log A_{t-1} + \varepsilon_t^A$$

$$\log\Phi_t = (1-\rho_\Phi)\log\bar{\Phi} + \rho_\Phi \log\Phi_{t-1} + \varepsilon_t^\Phi$$

$$\log G_t = \rho_g \log G_{t-1} + (1-\rho_g)\log \bar{G} + \varepsilon_t^g$$

$$\log T_t^{LS} = (1-\rho_{ls})\log T^{LS} + \rho_{LS}\log T_{t-1}^{LS} + \varepsilon_t^{LS}$$

$$b_t + m_t - \frac{R_{t-1}}{\pi_t}b_{t-1} - \frac{m_{t-1}}{\pi_t} + C_t + I_t(1+AC^k) + T_t^{TOT} + AC^w + AC^p - Y$$

$$K_{it} = (1-\delta)K_{i,t-1} + I_{it}$$

$$\log \tau_t^C = \rho^C \log \tau_{t-1} + (1-\rho^C)[\log \bar{\tau}^C + \phi^C(\log l_{t-1} - \log \bar{l})]$$

$$\log \tau_t^K = \rho^K \log \tau_{t-1} + (1-\rho^K)[\log \bar{\tau}^K + \phi^K(\log l_{t-1} - \log \bar{l})]$$

$$\log \tau_t^W = \rho^W \log \tau_{t-1} + (1-\rho^W)[\log \bar{\tau}^W + \phi^W(\log l_{t-1} - \log \bar{l})]$$

$$D_t = R_{t-1}B_{t-1} + G - T^{tot}$$

$$l_t = \frac{R_t}{\pi_t}l_{t-1} + R_t(G_t - T_t^{TOT}) - m_t(R_t - 1)$$

$$\chi m^{-\vartheta} + \beta\frac{\lambda_{t+1}}{\pi_t} = \lambda_t$$

$$\frac{1}{\varepsilon_{jt}^Y} = \varepsilon^{-1}\left[\begin{array}{c} 1 - \phi_p\left(\frac{P_{jt}}{P_{j,t-1}} - \bar{\pi}\right)\frac{P_t}{P_{j,t-1}}\frac{Y_t}{Y_{jt}} \\ +\beta E_t \phi_p \frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{P_{j,t+1}}{P_{j,t}} - \bar{\pi}\right)\frac{P_{t+1}}{P_{jt}}\frac{P_{j,t+1}}{P_{jt}}\frac{Y_{t+1}}{Y_{jt}} \end{array}\right]$$

$$\frac{1}{e^w} = \frac{1}{\psi}\left[\begin{array}{c} 1 - \frac{\phi_w}{(1-\tau_t^w)N_{it}} W_t \left(\frac{P_t W_{it}}{P_{t-1} W_{i,t-1}} - \bar{\pi}^w \right) \frac{P_t}{P_{t-1} W_{i,t-1}} + \\ \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\phi_w}{(1-\tau_t^w)N_{it}} W_{t+1} \left(\frac{P_{t+1} W_{i,t+1}}{P_t W_{it}} - \bar{\pi}^w \right) \frac{P_{t+1} W_{i,t+1}}{P_t W_{it}^2} \end{array}\right]$$

$$\beta E_t \mu_{t+1} = \lambda_t \left[1 + \frac{3}{2}\phi_k \left(\frac{I_{it}}{K_{it}} \right)^2 \right]$$

$$\mu_t = \lambda_t \left[(1 - \tau_t^k) Z_t + \phi_k \left(\frac{I_{it}}{K_{it}} \right)^3 \right] + \beta E \mu_{t+1} (1 - \delta)$$

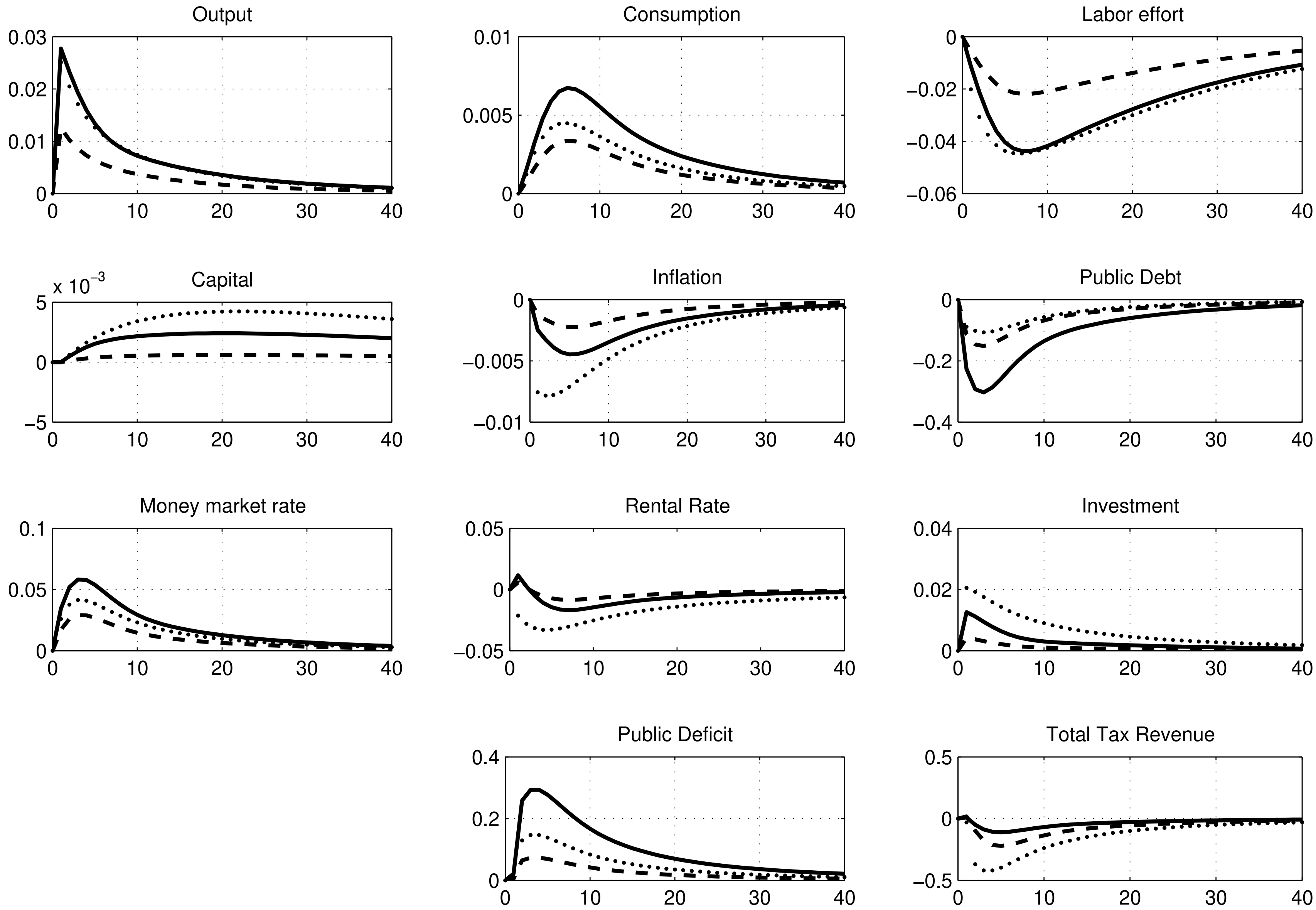
$$\lambda_t = \beta E_t \lambda_{t+1} R_t \frac{P_t}{P_{t+1}}$$

Appendix B : Impulse Response Function

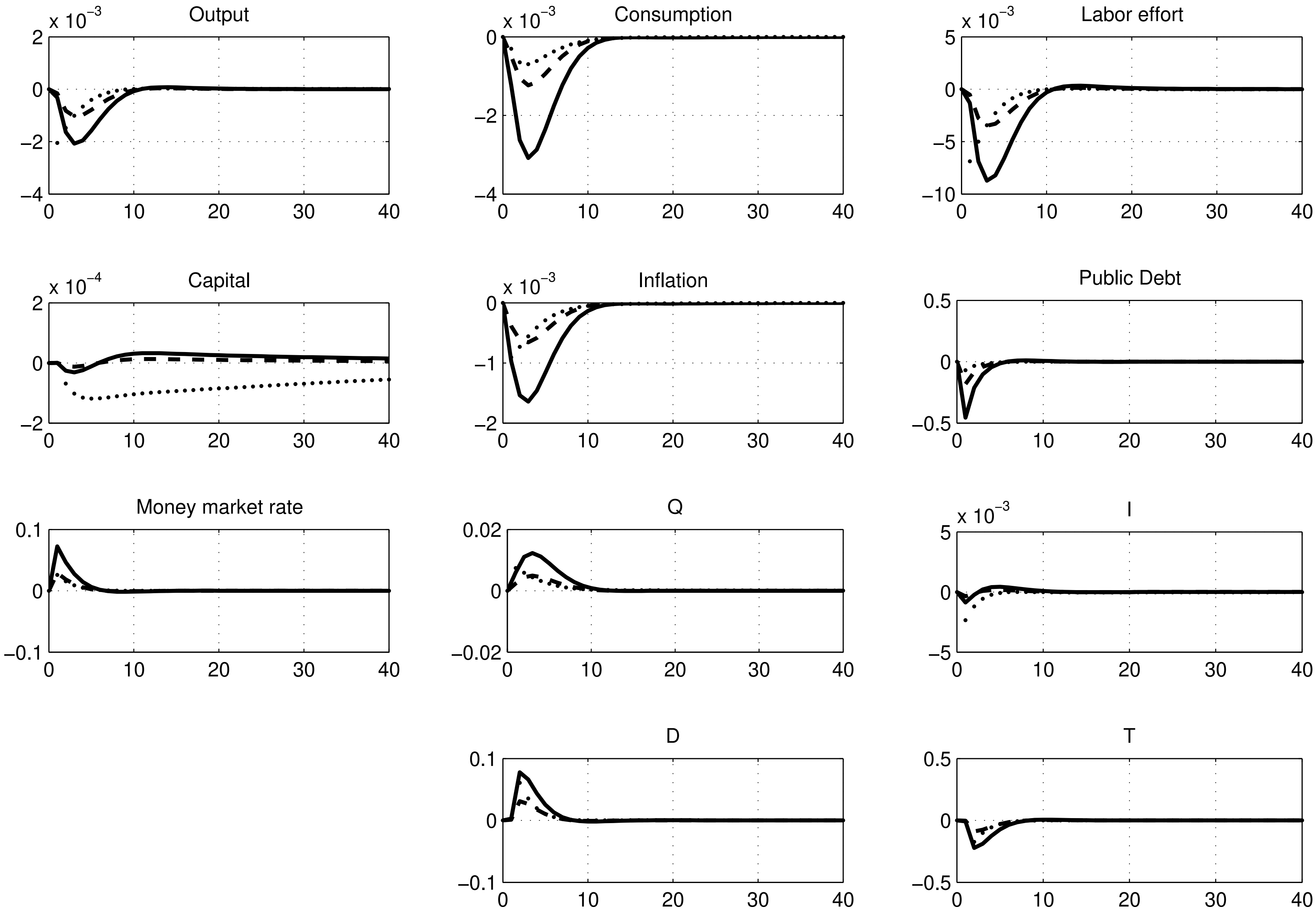
The following three tables report the impulse response function under the following stochastic shocks:

- productivity
- monetary policy
- fiscal policy

Technology Shock



monetary policy Shock



Government expenditure Shock