

Fiscal Rules in the Euro Area: Moving from Demand Management to Supply Side Stabilization Policy

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Abstract

In this paper we present a calibrated New Keynesian monetary union model to explore the stabilization role of national fiscal authorities in an environment with distortionary taxes and debt financed expenditures. The model of the monetary union is structured as in Benigno (2004), but augmented by liquidity-constrained consumers and productive government expenditures. Beyond analyzing the role played by automatic stabilizers we report evidence that active fiscal taxation rules that engineer a negative correlation to the evolution of the inflation rate can largely wipe out any built up in price dispersion.

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1 Introduction

With the launch of the European Monetary Union (EMU) a rich array of new challenges for issues of macroeconomic policy design was opened. In recent years a rich strand of literature has stressed the role of monetary policy to enhance welfare in an environment of nominal rigidities (Woodford, 2003). Canzoneri, Diba and Cumby (2005) estimate the cost of nominal rigidities to be as much as three percent of consumption each period and claim that these can be virtually eliminated by sophisticated monetary authorities. However this strand of literature has so far paid little attention to the role of fiscal policy as a stabilization agent in a multicountry setting with decentralized fiscal authorities. In particular, the role of distortionary taxes and debt financed expenditures has been completely neglected in a monetary union setting.

Most of the existing literature implements fiscal policy under a regime of lump-sum taxation and balanced budgets as originally modeled in the popular monetary union framework of Benigno (2004). Beetsma and Jensen (2005) report evidence for gains from fiscal stabilization policy in a monetary union due to a reduction of inefficient fluctuations in inflation rates and terms of trade. Gali and Monacelli (2006) find a role for fiscal stabilization policy beyond the efficient provision of public goods. They claim that fiscal policy is not only advantageous from the viewpoint of each country but also beneficial for the union as a whole. A similar conclusion was reached by Bofinger and Mayer (2006) who explore the advantages of an active decentralized fiscal demand management in a monetary union and conclude that national fiscal authorities can build firewalls that prevent country specific shocks from spreading to the rest of the union.

Our paper, though similar in spirit, differs from the above cited papers in several ways. First, we abandon the ad-hoc assumption of government expenditures in utility. This modeling strategy seems dubious as most government expenditures are salaries, interest rate payments, public transfers or public investment items all

of which enter either the intertemporal flow budget constraint of consumers or alternatively enhance the private sector production technologies. Therefore they should not enter directly the representative household's utility function.

Second, key to our analysis is the assumption that we depart from the balanced budget and lump-sum taxation hypothesis. This is mainly motivated by the empirical evidence that lump-sum taxation and balanced budgets do not play an important role in OECD countries. On the theoretical side it is well known from the RBC literature that distortionary taxes are ineffective and procyclical under a continuous balanced budget regime (King, Plosser and Rebelo, 1988). Additionally Schmitt-Grohe and Uribe (1997) have shown that distortionary taxes may produce multiple equilibria if they are conditioned on the state of the cycle. Notwithstanding these results it has prevailed that multiple equilibria can be virtually ruled out if fiscal authorities react sufficiently strong with tax rates to the level of existing debt (Canzoneri, Cumbi and Diba, 2001). In particular the steady-state level of taxes is determined by long run solvency considerations. This is in fact close in spirit to the 60% Maastricht criterion as it automatically puts a cap on the growth of outstanding debt.

To build a realistic model which creates a potentially powerful environment for fiscal authorities we draw on Linnemann and Schabert (2005) and enhance the production technology by productive government spending. Additionally we built on Gali, Lopez-Salido and Valles (2004) and assume that a fraction of the overall population is liquidity-constrained consumers which are by construction Non-Ricardian in nature as they do not smooth consumption optimally but consume each period their labor income. The basic framework for the monetary union reflects the model of Benigno (2004). Additionally we include a rich menu of fiscal variables. We explicitly formulate fiscal tax rules, fiscal spending rules and take care of intertemporal solvency considerations. Based on this framework we investigate whether countercyclical supply side taxation and demand management can contribute to improve macroeconomic stability.

Since Clarida, Gali and Gertler (1999) it is common knowledge that monetary authorities can completely offset shocks originating from households preferences in a simple New Keynesian framework. To that extend we investigate the ability of supply side oriented tax-policy to unwind the impact of cost-push shocks on marginal costs and thus on prices.

A supply side oriented fiscal stabilization policy operates over multiple channels. On the downside of course a more active use of taxes levied on labor reduces welfare as the expected labor disutility increases under the standard assumption of a convex cost function. Accordingly the inverse of the Frisch elasticity of labor supply plays a key role for the extend of (symmetric) shifts in the steady state. Coenen, McAdam and Straub (2006) estimate that a steady state reduction of 16 percent in the tax wedge increases hours worked by more than 10 percent. On the upside fiscal policy directly stabilizes the evolution of marginal costs and thereby the pricing behavior of firms. This effect has the potential to dramatically reduce the detrimental impact of cost-push shocks on consumer welfare.

Our analysis is closest related to the study of Andres and Domenech (2006), who explore the role of fiscal policy for macroeconomic stability for the Euro area for the case of neutral technology shocks. Their results suggest that distortionary taxes tend to reduce output volatility relative to lump-sum taxes when significant rigidities are present. Nevertheless they do not analyze the role of variations in supply side taxes levied on labor.

Our findings suggest that countercyclical supply-side taxation rules can virtually wipe out the impact of cost-push shocks on the inflation rate and thereby contribute to macroeconomic stability.

The paper is structured as follows. In Section 2, the New Keynesian model that integrates Benigno (2004), Linnemann and Schabert (2005) and Gali, Lopez and Valles (2004) is presented. Section 3 presents the calibration. In Section 4 we discuss the role of demand management and supply side taxation. Section 5 summarized the main findings and concludes.

2 The Model

We employ a New Keynesian multicountry framework that consists of firms, households and fiscal and monetary authorities. Firms are partitioned as usually in each region into final good producers and a continuum of intermediate good producers indexed $i \in (0, n)$ and $i \in [0, n)$, which each produce a differentiated type of good using labor services. Additionally we assume that the production technology is enhanced by productive government spending as in Linnemann and Schabert (2005). Following Benigno (2004) we assume that each intermediate good producer views the currency area as an integrated market and just posts a single price for its product no matter whether it is sold domestically or abroad. Thus we employ the assumption of producer pricing. Intermediate good producers are assumed to have some monopoly power over prices that are set in a staggered fashion as in Calvo (1983). Households are partitioned in each region into Ricardian and Non-Ricardian households as in Gali, Lopez Salido and Valles (2004).

2.1 Prices, Demand and Final Goods Market Equilibrium

The basic notational framework draws on Benigno (2004) and Obstfeld, Rogoff (2001). Let us introduce an index j that is specific to an agent and an index i that is specific to a region. Note it holds that $i = H$ if $j \in [0, n)$ and $i = F$ if $j \in [n, 1)$, where n should be interpreted as the population size of region H and $(1-n)$ should be interpreted as the population size of region F. Assume that the price index in region i is defined as:

$$P^i = (P_H^i)^n (P_F^i)^{1-n}. \quad (1)$$

Thus the price index in region i is a geometric average of price bundles of goods produced in region H and F . Benigno (2004) assumes that producers view the currency area as an integrated market and just post a single price independently whether the product is sold domestically or abroad. This pricing strategy is usually referred to as producer pricing (Devereux, 200x). In particular it means that there exist just two price indices, namely P_H and P_F in the union. Each regional prize index P_H^i itself is composed out of a continuum of differentiated goods. In particular it holds that:

$$P_H^i = \left[\left(\frac{1}{n} \right) \int_0^1 P^H(h)^{1-e} dh \right]^{\frac{1}{1-e}} \quad P_F^i = \left[\left(\frac{1}{1-n} \right) \int_0^1 P^F(f)^{1-e} df \right]^{\frac{1}{1-e}}, \quad (2)$$

where e is the elasticity of substitution between differentiated goods consumed in country i or j .

Given the Dixit-Stiglitz aggregates the generic household i and j solves its intra- and intertemporal optimization problem in the usual manner. Following Obstfeld and Rogoff (1998, 2000) the consumption index in region C^j is defined as:

$$C^j = \frac{(C_H^j)^n (C_F^j)^{1-n}}{n^n (1-n)^{1-n}}. \quad (3)$$

The Dixit-Stiglitz aggregates of consumption across the continuum of differentiated goods produced respectively in region H and region F are given by:

$$C_H^j = \left[\left(\frac{1}{n} \right)^{\frac{1}{e}} \int_0^n c^j(h)^{\frac{e-1}{e}} dh \right]^{\frac{e}{e-1}}, \quad C_F^j = \left[\left(\frac{1}{1-n} \right)^{\frac{1}{e}} \int_n^1 c^j(f)^{\frac{e-1}{e}} df \right]^{\frac{e}{e-1}}. \quad (4)$$

The intratemporal expenditure minimization problem of a generic household located in region H is solved as follows. In a first step he decides optimally given the Cobb-Douglas type consumption index (3) how much to allocate on goods produced domestically $C_{H,t}$ and in the rest of the union C_F , given his planed expenditures $P_t^i C_t^i$ as enshrined in the Euler-equation for the share of Ricardian

consumers whereas for the share of Non-Ricardian consumers (as we will see below) just consumes total labor income earned in each period. Solving the optimization problem leads to the following system of Walrasian demand equations:

$$C_H = n \left(\frac{P_H}{P} \right)^{-1} C \quad C_H = (1-n) \left(\frac{P_F}{P} \right)^{-1} C. \quad (5)$$

Given the expenditures on C_H and C_F the consumer then solves the expenditure minimization problem how to allocate the consumption shares optimally among the differentiated goods produced domestically and in the rest of the currency area:

$$C_{H,t}(h) = \left[\frac{P_{H,t}(h)}{P_H} \right]^{-e} T_t^{1-n} C_H \quad C_{H,t}(h) = \left[\frac{P_{H,t}(h)}{P_H} \right]^{-e} T_t^{1-n} C_F. \quad (6)$$

Fiscal authorities are assumed to have a complete home bias. The Dixit Stiglitz aggregates are equal to:

$$G^H = \left[\frac{1}{n} \int_0^n g(h)^{\frac{e-1}{e}} dh \right]^{\frac{e}{e-1}}, \quad G^F = \left[\frac{1}{1-n} \int_0^n g(f)^{\frac{e-1}{e}} df \right]^{\frac{e}{e-1}}. \quad (7)$$

In each region the government solves its intratemporal cost minimization problem which leads to the following demand system:

$$g(h) = \left(\frac{p(h)}{P_H} \right)^{-e} G^H \quad g(f) = \left(\frac{p(f)}{P_H} \right)^{-e} G^F. \quad (8)$$

Collecting the set of isoelastic demand equations the aggregate resource constraint in region H and F can be stated as follows:

$$Y_t^H = T_t^{1-n} C_t + G_t^H \quad Y_t^F = T_t^{-n} C_t + G_t^F, \quad (9)$$

where T denotes the terms of trade defined as $T_t = (P_{H,t}/P_{F,t})$.

2.2 Households

The monetary union is populated by a continuum of agents on the interval $[0,1]$ which is divided into two regions H and F , where the home region H is populated by a share of agents located on the segment $[0,n)$, while the rest is located on the segment $[n,1]$. On each segment there is a mass of λ of rule of liquidity-constraint consumers while the rest are Ricardian consumers. Thus a region specific aggregate variable X_t^j , where the generic index j may refer to region H or F is then defined as follows:

$$X_t^j = \mathbf{I} X_t^{j,r} + (1-\mathbf{I}) X_t^{j,0}, \quad (10)$$

where the superscript (0) denotes optimizing or Ricardian consumers whereas the superscript (r) denotes Non-Ricardian consumers.

2.2.1 Optimizing Households

Let us assume that household j , belonging to region H or F is characterized by the following period utility function:

$$U_t^{o,j} = E_t \left\{ \sum_{i=1}^{\infty} \mathbf{b}^{t+i} U_{t+i} \right\}. \quad (11)$$

Where E_t is the expectations operator conditioned on the information set available at time t , and $\mathbf{b} \in (0,1)$ is a discount factor. Period utility function takes the following functional form:

$$U_t^{o,j} = \mathbf{z}_t^{j,o,C} \frac{(C_t^{o,j} - H_t^{j,o})^{1-s}}{1-s} - \mathbf{z}_t^{o,j,N} \frac{N_t^{j,o,1+h}}{1+h}, \quad (12)$$

where $C_t^{j,o}$ is households j 's consumption in period t , and $\mathbf{z}_t^{o,C}$ is a common preference shock. $H_t^{j,o}$ denotes external habit formation which evolves

according to: $H_t^{j,o} = hC_{t-1}^{j,o}$; \mathbf{s} is a coefficient of relative risk aversion, $N_t^{j,o}$ is households j 's labor supply, \mathbf{h} is the inverse of the Frisch labor supply elasticity. All optimizing households are homogeneous in consumption as they are equipped with equal initial endowments and have access to complete contingent claims markets.

Household j maximizes lifetime utility with respect to the following flow budget constraint:

$$C_t^{j,o} + \frac{B_{j,t}^j}{P_t^j (R_t)} + \frac{M_t^{j,o}}{P_t^j} \leq (1 - \mathbf{t}_t^d) \frac{W_t^j N_t^{j,o}}{P_t^j} + \frac{\Pi_t^{j,o}}{P_t^j} + \frac{B_{j,t-1}^j}{P_t^j} + \frac{M_{t-1}^j}{P_t^j}, \quad (13)$$

where $B_{j,t}^j$ is a bond issued by both national governments. We assume that both governments just have access to the same debt instrument and that financial markets view the bonds issued as indistinguishable. We think this seems to be a realistic description of the Euro-area where government bonds issued by the individual member states are perceived as (almost) identical. Alternatively it would have been equally possible to assume that both governments issue idiosyncratic bonds which are linked by tight arbitrage conditions (see Benigno, 2004). The bonds pay a gross interest equal to the risk free rate R_t . Additionally W_t^j is the nominal wage rate. As we assume that labor productivity of Ricardian and Non-Ricardian consumers is identical we can drop the superscript (o). $\Pi_t^{j,o}$ are nominal profits redeemed to shareholders and $\mathbf{t}_t^{j,d}$ are region specific distortionary labor income taxes reducing the real effective wage income of households.

The relevant first order conditions are:

$$\mathbf{I}_t^{j,o} = E_t \mathbf{b} \left(\mathbf{I}_{t+1}^{j,o} \frac{P_t^j (1 + R_t)}{P_{t+1}^j} \right), \quad (14)$$

$$\mathbf{I}_t^{j,o} = E_t \left[\mathbf{z}_t^{j,o} (C_t^{j,o} - H_t)^{-\mathbf{s}} \right], \quad (15)$$

$$\frac{W_t^j}{P_t^i} (1 - \mathbf{t}_t^{j,d}) = \frac{(N_t^{j,o})^h}{I_t^{j,o}}, \quad (16)$$

where λ_t is the Lagrangian linked to the intertemporal budget constraint that equates the marginal utility of consumption.

2.2.2 Non-Ricardian Consumers

Let us assume that in each region H and F there is respectively a mass of $(1-\lambda)$ on the segment $[0;n]$ and $[n,1]$ that are liquidity constraint (see Gali, Salido, Valles (2004)). Let their period utility be given by:

$$U_t^{j,r} = \frac{1}{1-s^r} (C_t^{j,r} L_t^c)^{1-s^r}, \quad (17)$$

where L_t denotes leisure and C_t consumption. Non-Ricardian consumers maximize their utility subject to the constraint that each period the labor income is equal to their nominal consumption:

$$P_t^i C_t^{j,r} = W_t^j N_t^{j,r} (1 - \mathbf{t}_t^{r,d}). \quad (18)$$

Consolidating the first order conditions of Non-Ricardian households we arrive at the following set of conditions:

$$N_t^{j,r} = \frac{1}{1 + \mathbf{c}}, \quad (19)$$

$$C_t^{j,r} = \frac{1}{1 + \mathbf{c}} \frac{W_t^j}{P_t^i} (1 - \mathbf{t}_t^d), \quad (20)$$

which displays that the work effort supplied is just a constant amount of labor and consumption commoves with period t real wages.

2.2.3 Aggregation of Consumption and Labor

The aggregate consumption and employment levels in each region H or F evolve according to:

$$C_t^j = I C_t^{j,r} + (1-I) C_t^{j,0}, \quad (21)$$

$$N_t^j = I N_t^{j,r} + (1-I) N_t^{j,0}. \quad (22)$$

Making use of equation (19) and (20) equations (21) and (22) can be stated as follows:

$$C_t^j = \frac{I}{1+c} \frac{W_t^j}{P_t^i} + (1-I) C_t^{j,0} \quad (23)$$

$$N_t^j = \frac{I}{1+c} + (1-I) C_t^{j,0}. \quad (24)$$

Note that some optimality conditions will be independent of λ . This holds in particular true for the (log-linearized) labor supply schedule as Non-Ricardian households just supply a constant amount of hours worked each period (Gali, Lopez-Salido, Valles, 2004).

2.3 Optimizing Firms and Price Setting

The intermediate good sector behaves in the usual manner in an environment of monopolistic competition and sticky prices (Sbordone, 2001). Profit by firm j at time t is given by:

$$\Pi_{j,t} = P_{H,j,t}^H Y_{H,j,t}^{H,F} - W_t^H N_{j,t}^H, \quad (25)$$

where the cost function is equal to:

$$Q_{H,j,t} = W_{H,t} N_{H,j,t} \quad (26)$$

Note that due to the assumption of producer pricing, the domestically produced output by firm j is either sold domestically H or in the foreign region F at the same price. Therefore for notational convenience we will drop the superscript $P^{H,F}$ in the following. Thus whereas the firm draws revenues from the whole currency area $P_{H,j,t} Y_{H,j,t}^{H,F}$, its costs $Q_{H,j,t}$ are purely domestic.

Each firm has access to the following technology:

$$Y_{H,j,t} = (N_{H,j,t})^a (G_{H,t})^{1-a}. \quad (27)$$

Following Linnemann and Schabert (2005) we assume that government spending $G_{H,t}$ is productive in the sense that government expenditures raise the current production and the marginal productivity of labor. Accordingly government expenditure is comparable to an aggregate technology shock. Let us define real marginal costs as follows:

$$\mathbf{j}_{H,j,t} = \frac{\partial Q_{H,j,t}}{P_{H,t} \partial Y_{H,j,t}} = \frac{1}{\mathbf{a}} \frac{(1 + \mathbf{t}_{w,t}^f) w_{H,t}}{Y_{H,j,t}} N_{j,t}^H = \frac{1}{\mathbf{a}} S_{H,j,t}, \quad (28)$$

where w_t defines the real wage: $w_{H,t} = (W_{H,t} / P_{H,t})$. Following Gali and Monacelli (2006) we deflate the nominal wage by the index of domestically produced goods by $P_{H,t}$. The variable $S_{H,j,t}$ denotes the real labor share of firm j . Substituting out labor by the production technology yields:

$$\mathbf{j}_{H,t} = \frac{1}{\mathbf{a}} (1 + \mathbf{t}_t^{w_f}) w_t^H \left(\frac{Y_t^H}{G^{1-a}} \right)^{\frac{1}{\mathbf{a}}}, \quad (29)$$

which nicely depicts that marginal costs are negatively correlated with government expenditure. In general equilibrium with flexible labor markets the equilibrium condition for wages is given by:

$$(1 - \mathbf{t}_t^d) w_t^H = \frac{(N_t^H)^h}{(C_t^H - h C_{t-1}^H)^{-s}}. \quad (30)$$

Firms face frictions as in Calvo (1983), which implies a staggered price setting. The price index is defined as a weighted average of a fraction $(1 - \mathbf{q}_p)$ that resets prices and a fraction of \mathbf{q}_p that sticks with last period's price level (Gali, Gertler, Salido-Lopez, 2001):

$$P_{H,t} = \left[(1 - \mathbf{q}_p) \tilde{P}_{H,t}^{1-e} + \mathbf{q}_p P_{t-1}^{1-e} \right]^{\frac{1}{1-e}} \quad (31)$$

The fraction $(1 - \mathbf{q}_p)$ that resets prices is partitioned into two groups. A share of \mathbf{w}_p resets their prices by indexing to last periods inflation rate:

$$P_t^* = P_{t-1}^* \left(\frac{P_{t-1}}{P_{t-2}} \right), \quad (32)$$

while the remaining share of $(1 - \mathbf{w}_p)$ optimizes. The fraction of $(1 - \mathbf{q}_p)(1 - \mathbf{w}_p)$ that optimizes maximizes its intertemporal profit function by solving the following Lagrangian:

$$L^j = E_t \sum_{i=0}^{\infty} (\mathbf{q}\mathbf{b})^i \Delta_{j,t+i} \left(\left[\tilde{P}_{H,j,t} Y_{H,j,t+i} - \mathbf{a} P_{H,t+i} \mathbf{j}_{H,j,t+i} Y_{H,j,t+i} \right] - \mathbf{J}_{j,t+i}^H \left[Y_{H,j,t+i} - \left(\frac{\tilde{P}_{H,j,t}}{P_{H,t+i}} \right)^{-e} Y_{H,t+i} \right] \right) \quad (33)$$

, where $\tilde{P}_{H,j,t}$ denotes the optimal reset price by those that optimize. The assumption of producer pricing simplifies the exposition as only the following pair of prices $\{\tilde{P}_{H,j,t}; \tilde{P}_{F,j,t}\}$ needs to be optimized by foreign and domestic firms respectively. The relevant first order condition is given by:

$$\left(\tilde{P}_{H,j,t} \right) = \frac{\mathbf{e}}{\mathbf{e} - 1} E_t \left\{ \frac{\sum_{i=0}^{\infty} (\mathbf{q}\mathbf{b})^i \Delta_{j,t+i} \left[\mathbf{a} Y_{H,t+i} \mathbf{j}_{j,t+i} (P_{H,j,t+i})^{1+e} \right]}{\sum_{i=0}^{\infty} (\mathbf{q}\mathbf{b})^i \Delta_{j,t+i} \left[P_{H,t+i}^e Y_{H,t+i} \right]} \right\} \quad (34)$$

Note that $(\tilde{P}_{F,j,t})$, the optimal price of foreign producers, can be derived in complete analogy. Thus it is given by:

$$\left(\tilde{P}_{F,j,t} \right) = \frac{\mathbf{e}}{\mathbf{e} - 1} E_t \left\{ \frac{\sum_{i=0}^{\infty} (\mathbf{q}\mathbf{b})^i \Delta_{j,t+i} \left[\mathbf{a} Y_{F,t+i} \mathbf{j}_{j,t+i} (P_{F,j,t+i})^{1+e} \right]}{\sum_{i=0}^{\infty} (\mathbf{q}\mathbf{b})^i \Delta_{j,t+i} \left[P_{F,t+i}^e Y_{F,t+i} \right]} \right\}. \quad (35)$$

2.4 Fiscal Authorities

The government flow budget equation can be stated as follows:

$$B_{H,t+1} + \mathbf{t}_t^d P_{H,t} w_{H,t} N_{H,t} + \mathbf{t}_t^{w_f} P_{H,t} w_{H,t} N_{H,t} = R_t B_{H,t} + P_{H,t} G_{H,t}, \quad (36)$$

where the government located in region H spends resources to finance nominal government expenditure $P_{H,t} G_{H,t}$ and interest payments on the outstanding debt $R_t B_{H,t}$. These spending categories are financed by taxes on labor income which is classified into tax rolls collected from households $\mathbf{t}_t^d W_{H,t} N_{H,t}$ living in region H and employee's labor tax payments $\mathbf{t}_t^{w_f} W_{H,t} N_{H,t}$.

Equation (36) in real terms can be stated as:

$$b_{H,t+1} + \mathbf{t}_t^d w_t^H N_t^H + \mathbf{t}_t^{w_f} w_t^H N_t^H = (R_t) b_{H,t} \mathbf{p}_{H,t}^{-1} + g_{H,t}. \quad (37)$$

Solving (37) for the tax rate and evaluating the equation in steady state it holds that:

$$\bar{\mathbf{t}}^{H,tax} = \left(\bar{\mathbf{t}}^{H,d} + \bar{\mathbf{t}}^{H,w_f} \right) = \frac{(\bar{R} \bar{\mathbf{p}}_H^{-1} - 1) \bar{b}_H + \bar{G}}{\bar{w}_H \bar{N}_H}, \quad (38)$$

which assures fiscal solvency in the long run. Let us postulate that fiscal policy implements the following tax rule:

$$\mathbf{t}_t^{H,d} = \mathbf{k}_1 \left[\frac{\mathbf{x}}{b} (b_t^H - b) + \bar{\mathbf{t}} \right] \quad (39)$$

$$\mathbf{t}_t^{H,w_f} = (1 - \mathbf{k}_1) \left[\frac{\mathbf{x}}{b} (b_t^H - b) + \bar{\mathbf{t}} \right], \quad (40)$$

Thus we conjecture as proposed by Linnemann and Schabert (2005) that tax rates are linked to the deviation of debt from its steady state value. For low values of \mathbf{x} government expenditure policies are initially largely reflected in movements in government debt while eventually returning to steady state over the cycle. The parameters κ_1 is the share of tax rolls collected from households and $(1 - \kappa_1)$ is the share of tax rolls collected from.

Government expenditures $G_{H,t}$ evolve in response to the state of the cycle, fluctuations in the terms of trade and are assumed to be highly correlated:

$$G_{H,t} = G_0 \left(\frac{Y_{H,t}}{Y_{H,t}^{flex}} \right)^{f_y} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{f_T} \left(\frac{G_{H,t-1}}{G_{H,t-2}} \right)^{f_g}, \quad f_y < 0, f_T, f_g > 0 \quad (41)$$

, where f_y, f_g and f_T denote the fiscal reaction coefficients.

3 Calibration

The parameters of the model are calibrated according to values typically found in related work (see for example Smets and Wouters, 2003, Del Negro et al. 2005, and Leith and Malley, 2005, for estimations of DSGE models of the Euro area). The discount factor \mathbf{b} is fixed to 0.99, implying a 4% steady state real interest rate in a quarterly model. The elasticity's of the households' utility function \mathbf{s} were set to one in line with Del Negro et al. (2005) and \mathbf{h} was set to 2 as proposed by Coenen, McAdam and Straub (2006). The steady-state mark-up of intermediate good producers over nominal marginal costs is set at 10 per cent, implying $\mathbf{e} = 11$. the supply side of the model is calibrated to replicate a considerable degree of stickiness in prices and wages. For price setters we calibrate $\mathbf{q}_p = 0.75$ which implies that prices are fixed on average for 4. Quarters. This reflects the range of estimates that can be found for the Euro-area. Del Negro et. al. (2005) estimate $\mathbf{q}_p = 0.67$ whereas Gali, Gertler and Lopez-Salido (2001) report evidence of average price durations of round about four quarters using single equation GMM approach, while Welz (2006) following a Bayesian approach estimates a duration of 6.5 quarters. On the upper end Smets and Wouters (2003) find evidence that price contracts last on average for ten quarters. Comparable studies for the US like Altig et al. (2005) report much lower price

durations of just 1.6 quarters, which they claim to be more consistent with recent evidence drawn from US micro-data. The share of backward looking price setters was set to $w_p = 0.75$ in line with Coenen, McAdam and Straub (2005) which adjust reset prices in each period by complete indexation to inflation. The empirical evidence on the degree of partial indexation of prices to past inflation rates in the Euro-area vary from 0.29 to 0.75. Leith and Maley (2005) estimate a value of 0.29, while Coenen, McAdam and Straub (2006) propose to calibrate the degree of indexation to a value of 0.75.

In the consumption Euler equation the degree of habit formation is substantial and indicates that the response of competition to an interest rate shock is largely driven by habits. We set $h=0.88$ as estimated in Henzel et al (2007) which implies that an expected one percentage point increase in the short term interest rate for four quarters has an impact on consumption of round about 0.12%.

The Taylor rule coefficients display the familiar values. We calibrate the inflation coefficients to 1.25 and the output gap coefficient to 0.5. In addition we allow for a response to changes in the inflation rate and output gaps terms as in Smets and Wouters (2003). The autoregressive interest rate coefficients were calibrated to display a substantial degree of interest rate smoothing which is reported in most of the literature.

The share of Non-Ricardian households was set equal to 0.33 which is in line with the calibration implemented by Coenen, McAdam and Straub (2005). In a simulation analysis Gali, Lopez-Salido and Valles (2004) applied $I = 0.85$.

The fiscal parameters are calibrated to be consistent with the intertemporal solvency conditions. The ratio of labor income tax to outstanding debt was set equal to 0.42, which is consistent with a labor share of $a = 0.8$ and the Maastricht Treaty that superimposes a debt to GDP ratio of 0.6 in the long run. The government expenditure to debt ratio was set equal to 0.33 which reflects a government consumption share of 0.2, consistent with the specification of the production technology and the value used in Schabert and Linnemann (2005). The

gross steady state tax rate was set to $\bar{\tau} = 0.25$, which is consistent with a balanced budget in the long run.

Table 1 : Calibrated Parameters

Parameter		Calibration
A. Households		
Discount factor	b	0.99
Inverse of the intertemporal elasticity of substitution	s	1.00
Habit Formation	h	0.88
Inverse of the Frisch elasticity of labor supply	h	2.00
Share of Non-Ricardian Households	l	0.25
B. Intermediate-Good Firms		
Share of labor income in value added	a	0.80
Price elasticity of demand for an intermediate good variety	e	11.00
Price Stickyness	q_p	0.75
Share of backward-looking price setters	w_p	0.75
C. Monetary Policy		
Taylor rule: smoothing	d_1	0.70
Taylor rule: smoothing	d_2	0.12
Taylor rule: inflation	m_p	1.50
Taylor rule: Output gap	m_y	0.25
Taylor rule: Change in Inflation Rate	$m_{\Delta p}$	0.22
Taylor rule: Change in Output gap	$m_{\Delta y}$	0.17
D. Fiscal Authorities		
Spending rule: GDP	f_y	-0.25
Spending Rule: TOT	f_T	0.10
Tax rule: Debt	c	0.10
Employers Labor Income Tax/GDP	$\bar{\tau}^{wf} \bar{w} \bar{N} / \bar{b}$	0.21
Employees labor Income Tax/GDP	$\bar{\tau}^d \bar{w} \bar{N} / \bar{b}$	0.21
Government Expenditure/Debt	\bar{g} / \bar{b}	0.33
Gross steady state tax rate	$\bar{\tau} = \bar{\tau}^w + \bar{\tau}^h$	0.25

The automatic stabilizers in the fiscal spending rule were set equal to 0.25, which is in line with Taylor (2001), whereas the reaction to changes in the TOT were calibrated to be equal to 0.1 as fiscal policy can improve welfare by reacting to inefficient fluctuations in TOT (see Table 1 for a summary).

4 Simulation Analysis: Fiscal Rules and Macroeconomic Stability

Given the above calibration, we proceed to present the role of fiscal stabilization policy in a monetary union. The section is structured as follows: In a first step we will illustrate the role of national fiscal authorities in the case of symmetric shocks originating from the supply and the demand side of the model. We analyze in particular the role of fiscal authorities for the case of shocks to household preferences, shocks to the inflation adjustment equation. For convenience we also report on the reaction of the common central bank. In a second step we repeat the exercise under asymmetric shocks as there is ample evidence that fiscal authorities can prevent spill over effects to the rest of the union (Bofinger and Mayer, 2007).

4.1 A Note on Distortionary Taxation

Fiscal authorities are described by the equations (87) to (91). Throughout the simulation exercise we assume that taxes are collected by distortionary taxation on labor. To illustrate the welfare implications of distortionary taxation it is useful to make a simple example before going into the more complicated DSGE multicountry framework. Assuming, as in Prescott (2004) logarithmic utility $\ln C + j \ln(1 - N)$, where j measures the value of leisure relative to

consumption and a constant return Cobb-Douglas technology: $Y = K^a N^{1-a}$, hours worked can be states as :

$$N = \frac{1-a}{1-a + (C/Y)j / (1-\bar{\tau})}. \quad (42)$$

This displays the familiar result that labor utilization is diminishing in the steady state level of the tax $\bar{\tau}$. Prescott (2004) claims the steady state tax wedge between the Euro-area and the US as the driving force to explain the lower labor utilization rate in Europe. Equation (38) indicates that our model would recommend lowering the ratio of the government expenditures to wage income or the debt to wage income ratio in order to melt down the tax-wedge.

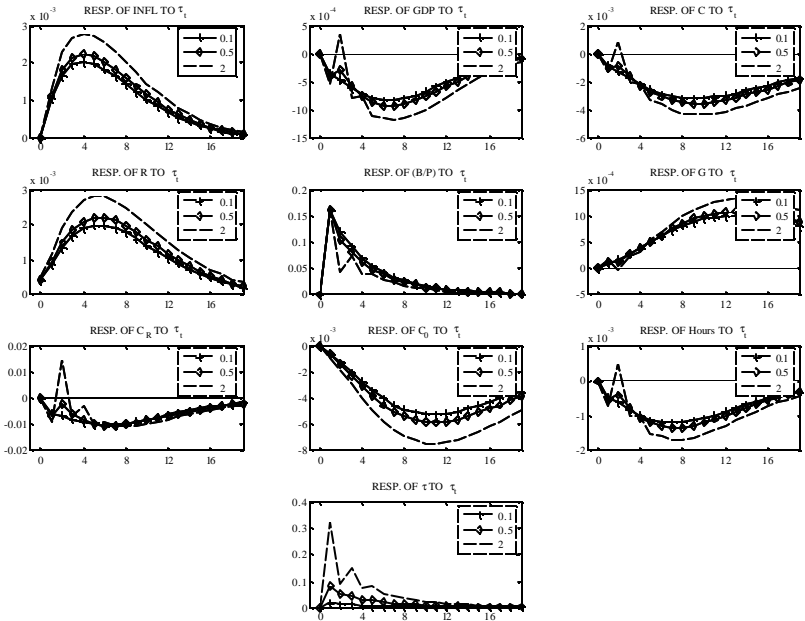
Notwithstanding the argument by Prescott (2004) our analysis does not focus on the steady state level of the tax wedge but on the cyclical movements of labor taxes around a steady-state ratio. Quite arguably given the convex nature of the labor disutility the steady state argument cannot be separated from cyclical considerations. Clearly an increase in the expected variability of labor taxation will increase the expected labor disutility due to the convex nature of the cost function.

Figure 1 depicts the dynamic response of selected variables to a one-percentage point increase in employees tax contributions levied on labor under alternative assumptions on tax rules. The case of $c = 0.1$ depicts the baseline where taxes only mildly respond to movements in real debt. Under the alternative tax rules for $c = 0.5$ and $c = 2$ tax rates are more tightly connected to contemporaneous movements in real debt. The simulation horizon is 20 quarters.

The impulse responses bear a rich menu of informative details on the role of distortionary taxes from a cyclical viewpoint. First of all, a shock to tax rates levied on labor increases marginal costs and thus builds up inflationary pressure to which the central bank reacts with increases in the inflation rate. Higher real interest rates induce the fraction of households that have access to government

bond markets to reallocate consumption into the future which generates a stabilization recession. Accordingly the governments react mechanically to the subdued economic activity with an expansionary fiscal stance.

Figure 1 : Symmetric Labor Tax Shock



Remark 1: Suppose that the New Keynesian Phillips curve is flat in real marginal cost. Then a shock to the employee’s tax rate levied only induces quantitatively weak responses in all other variables.

The quantitative role of a shock to distortionary taxes on the cycle is largely governed by the slope of the Phillips curve. Obviously there is a consensus that New Keynesian Phillips curves are extremely flat with respect to marginal cost (Christiano, Eichenbaum and Evans, 2005; Smets and Wouters, 2003, Woodford,

2003,). Typically Woodford calibrates the slope coefficient somewhere in the neighborhood of $k = 0.025$ (Woodford, 2003). This value implies that movements of the inflation rate are quantitatively somewhat disconnected from movements in marginal costs. Therefore the overall cyclical impact of a temporary increase in tax rates on the inflation rate and the other variables is quite limited. Nevertheless the impulse response experiment strongly discourages from connected tax rates stronger to the level of outstanding debt.

Remark 2: *Suppose that tax rates are a function of the contemporaneous level of outstanding debt. Then the impulse response experiment recommends to assign a low feedback coefficient α as otherwise tax rate volatility induces macroeconomic instability.*

For the case of $\beta = 0.5$ and $\beta = 2$ the faster return of real debt to steady state has to be traded-off against the more cyclical behavior of tax rates itself. These induce a more cyclical pattern in inflation rates due to mark-up pricing in the intermediate good sector, a stronger response of the central bank, and thus a somewhat stronger deterioration in the tax base itself. Thus our analysis clearly recommends to largely disconnect tax rates from the level of outstanding debt over the cycle by implementing a low feedback coefficient in tax rules.

4.2 Fiscal Spending Rules, Macroeconomic Stability: Symmetric Shocks

Figure 2 displays the dynamic response of selected variables to a one percentage point increase in a symmetric shock to consumer preferences under different assumptions on fiscal spending rules. All variables are depicted as percentage point deviations from steady state. The simulation horizon is 20 quarters. The line

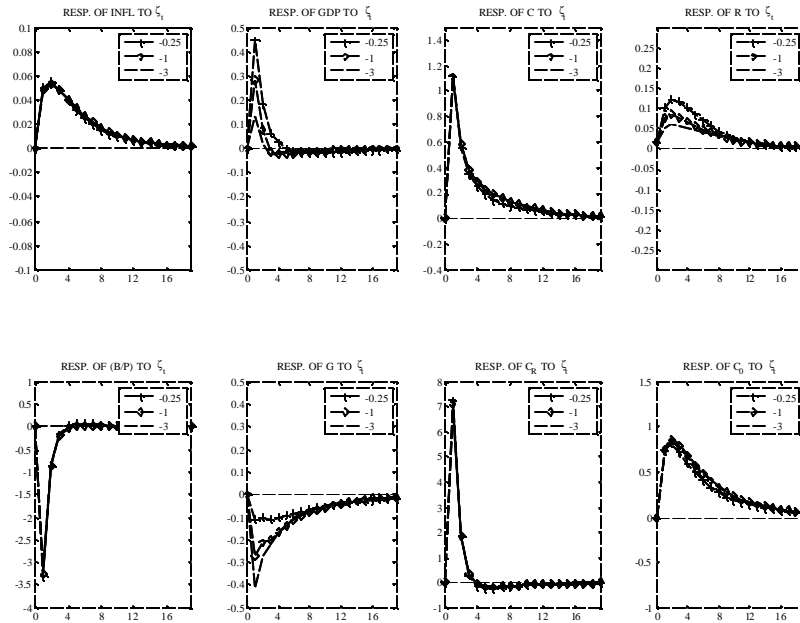
associated with $f_y = -0.1$ show the impulse responses of the baseline calibration of the model. The impulse responses linked to $f_y = -1$ and $f_y = -3$ correspond to increasing degrees of countercyclical fiscal activity. The increase in consumption triggered by the positive shock to consumer preferences triggers an increase in real income and real wages. As labor markets are assumed to be flexible this implies a sharp increase in real wages on which liquidity-constraint consumers react strongly on impact as they have a propensity to consume which is equal to one each period. Due to the increase in production and inflation monetary policy is tightened and fiscal spending becomes restrictive.

Remark 3: *For the class of fiscal spending rules as described by equation (41) a more active stance of fiscal authorities on the cycle for increasing value of f_y succeeds to stabilize GDP.*

As fiscal policy becomes more active ($f_y = -1$, $f_y = -3$) it becomes successful to limit the increase in production. Thereby the period income of Non-Ricardian consumers increases by lower degrees, compared to a scenario where fiscal policy is less hawkish on output movements. The consumption of Ricardian households somewhat crowds-in for a more active fiscal policy as they foresee future tax cuts over the next quarters. As liquidity constraint consumers are only one third of the overall population optimizing households dominate the picture and aggregate consumption hardly responds.

Figure 3 portrays the dynamics of selected variables to a one-percentage point shock to the mark-up. Obviously the built up in inflationary pressure triggers a sharp reaction of monetary authorities which contracts contemporaneous consumer spending and engineers a stabilization recession to which Non-Ricardian consumers instantaneously react as their period income shrinks.

Figure2: Symmetric Household Preference Shocks

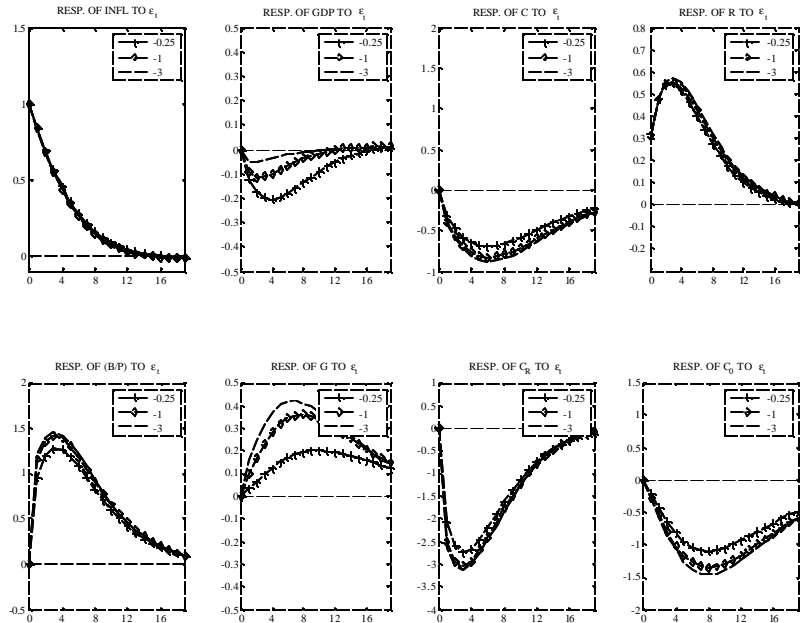


Remark 4: For the case of a shock to the inflation-adjustment equation an increase in productive government expenditures succeeds to stabilize output without creating additional inflationary pressure.

Figure 3 illustrates that classical fiscal demand management succeeds to stabilize output without building up inflationary pressure. This result is due to the productivity enhancing nature of fiscal expenditures as labor becomes more productive. Although fiscal authorities succeed to stabilize output this comes at the cost of a prolonged cycle in consumption aggregates. A more countercyclical fiscal stance seems welfare reducing as the expected future tax increases on labor income crowd-out private consumption and lead to a somewhat more active

monetary stance. Only for the ad-hoc assumption that government expenditures are in utility functions the welfare picture might change.

Figure 3: Symmetric Shock to the Inflation Adjustment Equation



4.3 Fiscal Policy Rules: Moving from Demand Management to Supply Side Stabilization

The simulation results reported in the last section reveal that there is a macroeconomic relevance for classical demand management in a DSGE framework. In particular it prevailed that fiscal authorities succeeded to stabilize GDP without creating inflationary pressure as long as government expenditures are productive.

In this section we will show that fiscal policy can achieve even better stabilization results by taking a supply side perspective. The basic intuition is quite simple. Fiscal policy has a rich menu of instruments by which fiscal authorities can directly influence the demand as well as the supply side of the economy. This is a great advantage compared to monetary policy since, as laid down in the classical Clarida, Gali Gertler (1999) contribution monetary authorities face a trade -off in the case of cost shocks. The non-trivial problem for monetary policy prevails as it has leverage on the consumption path of Ricardian consumers but no direct leverage on the price setting behavior of firms. This forces monetary authorities to induce a stabilization recession and to trade-off the emerging inflation gap against the output gap for the case of cost push shocks. From a welfare oriented perspective it is common knowledge that the inflation gap and the implied price dispersion are the main source of welfare losses. Therefore the univocal recommendation that price stability should be the dominant goal of a welfare oriented policy is generally accepted (Woodford, 2003).

In this section we will show that a supply side management of fiscal authorities can largely overcome this trade -off faced by monetary authorities and smooth out price dispersion to a large extend.

Assume that fiscal authorities in both regions are guided by the following modified tax rule for the employee's tax contribution:

$$\mathbf{t}_t^{H,d} = \mathbf{k}_1 \left[\frac{\mathbf{x}_1}{b} (\hat{b}_t^H - b) + \bar{\mathbf{t}} \right] + \mathbf{x}_2 \hat{\mathbf{p}}_t \quad \mathbf{x}_2 < 0 \quad (42)$$

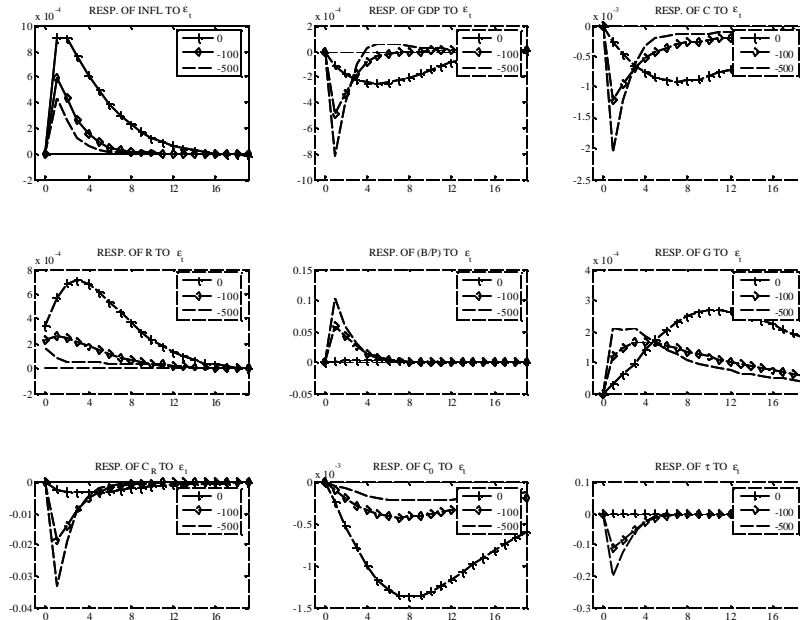
Thus we postulate that $\mathbf{t}_t^{H,d}$ is conditioned on the inflation rate. In particular we conjecture that $\mathbf{x}_2 < 0$ which means that fiscal authority's temporary cut taxes if inflationary pressure builds up. As we will see below such an active supply side taxation rule succeeds to smooth out economic cycles.

Figure 4 portrays the dynamic responses of selected variables to a shock in the mark-up. For the case of $\mathbf{x}_2 = 0$ the baseline scenario depicts the case were tax rules purely obey fiscal solvency considerations. For the case of $\mathbf{x}_2 = -100$ and

$x_2 = -500$ tax rules engineer a path for tax rates which is strongly negatively correlated with the inflation rate.

Remark 5: *A supply side oriented stabilization tax policy can limit price dispersion by unwinding the impact of cost-push shocks on the cost calculus of the intermediate good sector by changing tax rates countercyclical to the evolution of the path of the inflation rate.*

Figure 4: Fiscal Rules and Supply Side Stabilization



In particular a sharp cut in taxes levied on labor prevents any built-up in pressure on marginal costs. As firms foresee that marginal costs are largely flat as the positive shock to the mark-up is undone by a tax cuts the inflation process is stabilized tremendously. Due to the moderate increase in inflation rates monetary authorities only moderately increase the interest rate. This in term largely prevents

that Ricardian households reallocate consumption into the future. The evolution of the consumption aggregate of Ricardian households is by large degrees smoother than in the baseline. The cut in tax rates generates a spike in the outstanding debt which eventually returns to the baseline. Non-Ricardian consumers on the contrary react on impact on the drop in real wages and cause a spike in output in the first quarters which returns quickly to baseline. In an economy with virtually no liquidity constraint consumers $I \approx 0$ also GDP would be stabilized right from the outset as can be seen from **Figure 5**.

Figure 5: Fiscal Rules and Supply Side Stabilization: A Counterfactual Simulation

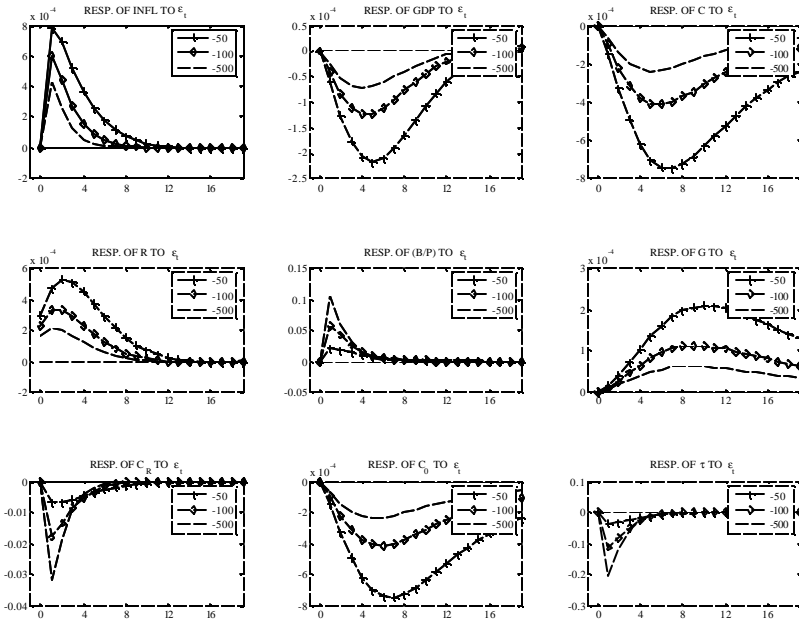
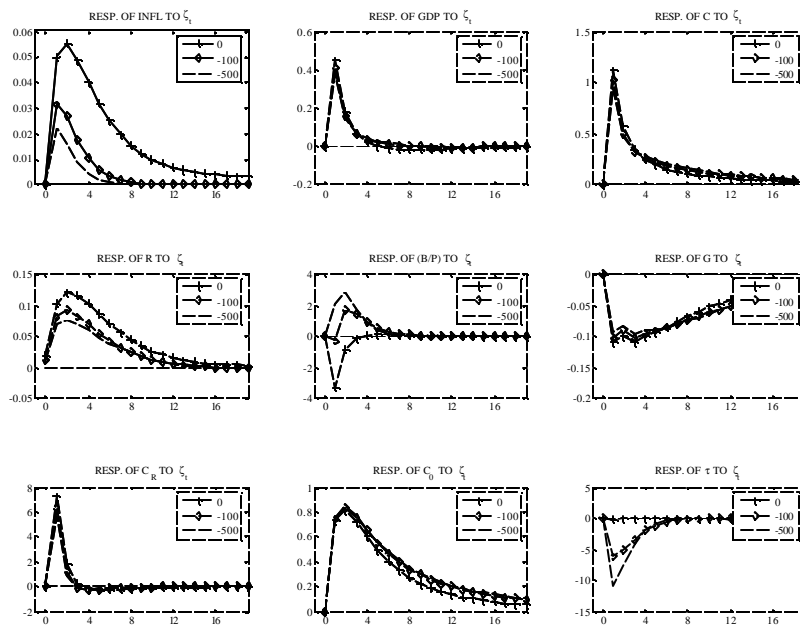


Figure 5 depicts the dynamic responses of selected variables to an auto-correlated shock to consumer preferences under the baseline scenario and a supply side oriented tax rule with either $\mathbf{x}_2 = -100$ or $\mathbf{x}_2 = -500$.

Remark 6: A supply side oriented tax policy can attenuate inflationary pressure for the case of a shock to consumer preferences at virtually no costs in terms of output.

Figure 6: Fiscal Rules and Supply Side Stabilization: A Shock to Consumer Preferences



As fiscal policy engineers tax cuts on labor that are negatively correlated with movements in real marginal costs it succeeds to stabilize the cost pressure put on firms in the intermediate good sector. Accordingly firms that are called upon to reset prices in the intermediate good sector will set their newly set reset prices closer to the current price level. This prevents to a large extent the built up of any price dispersion across the intermediate good sector. As price dispersion is considered to be the main source of welfare losses such a policy seems promising. Consumption aggregates are largely unaffected by fiscal policy as the shock to

consumer preferences is assumed to be correlated Only debt spikes temporarily due to the sustained tax cuts.

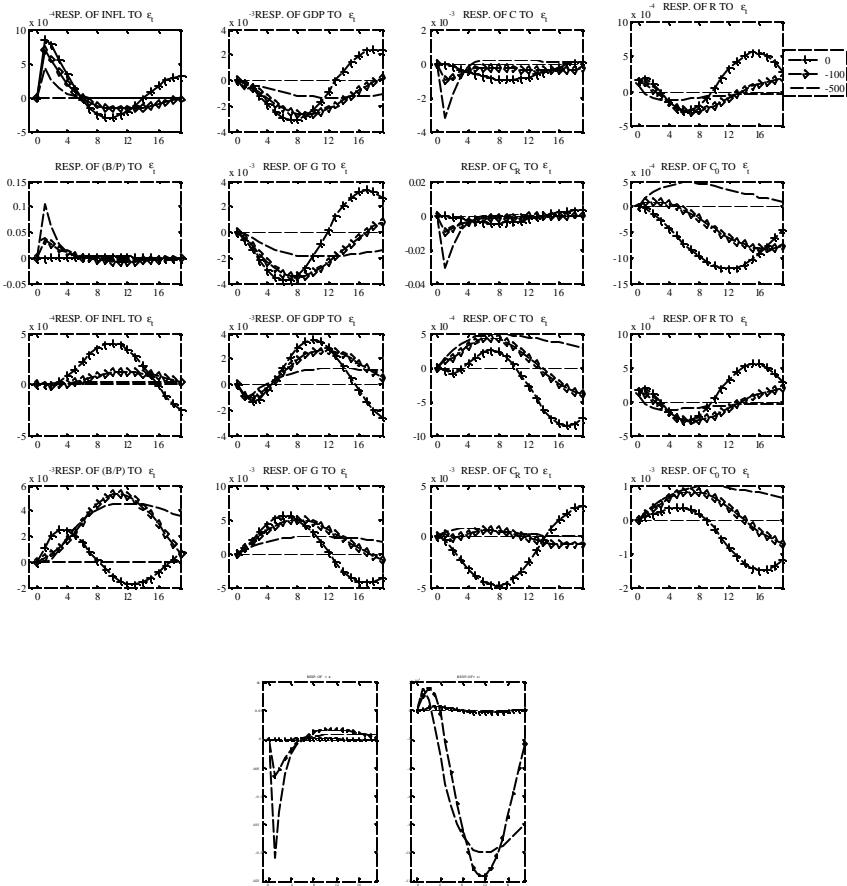
4.4 Supply Side Taxation and Asymmetric Shocks

It is well known from the literature on the optimal currency area that asymmetric shocks give a natural environment for national authorities to dampen the effects of desynchronized business cycles (Mundell, 1961). In particular, asymmetric shocks induce persistent fluctuations in terms of trade which spread national shocks across borders. Bofinger and Mayer (2007) report evidence that in such an environment fiscal policy can be of particular use by stabilizing national output gaps. A similar conclusion is drawn by Beetsma and Jensen (2005). In the following we will show that a supply side oriented stabilization policy that implements equation (42) is very successful in stabilizing asymmetric shocks, compared to the benchmark case where tax rules just obey fiscal solvency considerations (equation (39) and (40)).

Figure 7 reports the dynamic response of selected variables to a one percentage point cost-push shock under different assumptions on the fiscal tax rule. For the baseline scenario with $\mathbf{x}_2 = 0$ a cost-push shock in one part of the union induces very persistent swings in all variables. The built-up in inflationary pressure in the part of the union that was hit by the shock leads to a modest reaction of the common central bank. Accordingly the rest of the union suffers on the one hand from a tighter monetary stance but profits on the other hand from expenditure switching of consumers due to favorable fluctuations in terms of trade. For the case of the baseline scenario where fiscal policy sustains from supply side stabilization the terms of trade effects dominate the picture and the expenditure switching of consumers leads to an aggregate demand driven built-up in inflation rates in the rest of the union.

Remark 7: For the case of an asymmetric cost-push shock a tax policy that engineers a negative correlation between the evolution of national inflation rates and the evolution of taxes on labor can stabilize inflation and succeeds to smooth terms of trades effectively.

Figure 7: Fiscal Rules and Supply Side Stabilization: Asymmetric Mark-up Shocks



As in the case of a symmetric shock an active supply side stabilization policy can virtually smooth out any fluctuations in the inflation rate. For the case of an

asymmetric shock the model dynamics are somewhat more complicated. The country that was originally hit by the shock cuts instantaneously tax rates to stabilize the evolution of marginal costs and thus effectively stabilizes the inflation rate. For the rest of the union the tighter monetary stance dominates the cycle over the first quarters after the shock. In particular, the inflation rate mildly drops, output somewhat declines and fiscal spending becomes expansionary. Eventually after four quarters the terms of trade effects triggered by the asymmetric shock start to unfold. In particular the deterioration of foreign terms of trade lead to expenditure switching of foreign and domestic consumers which triggers an increase in aggregate demand and inflationary pressure. Now fiscal authorities start to cut back taxes on labor which almost completely stabilizes the evolution of marginal costs and thus the inflation process. GDP also moves smoother although as fiscal expenditures are assumed to be correlated they become procyclical which somewhat lengthens the cycle.

In sum, compared to a scenario where fiscal policy remains passive the cycle can be substantially smoothed.

5 Conclusion

The launch of the European Monetary Union has opened a whole array of challenges for issues of macroeconomic design in the Euro Area. In particular, the role of fiscal policy as a potentially powerful national stabilization agent is on the agenda. We presented a New Keynesian multicountry model for the Euro area with the intention to explore whether fiscal policy is able to increase macroeconomic stability. To build a realistic setting for fiscal authorities we draw on Linnemann and Schabert (2005) and enhanced the production technology by productive government spending. Additionally we built on Gali, Lopez-Salido and Valles (2004) and Coenen, McAdam and Straub (2006) and assumed that a

fraction of the overall population consists of liquidity-constrained consumers. The basic multicountry setting draws on Benigno (2004). Key to our analysis is the assumption that we depart from the balanced budget and lump-sum taxation hypothesis. This is mainly motivated by the empirical evidence that lump-sum taxation and balanced budgets do not play an important role in OECD countries. Based on this framework we evaluated by means of impulse-response analysis the ability of fiscal authorities to stabilize economic cycles.

Our results are quite promising. We recommended a tax rule that builds in automatic supply-side stabilization elements. In particular, the policy rule virtually eliminates to a large extent price dispersion which is generally considered to be the main source of welfare losses attached to price rigidities. The proposed tax rule engineers a negative correlation between the evolution of the tax rate and the evolution of the inflation rate over the cycle. This dramatically reduces price dispersion in the economy as those price setters that are called upon to reset prices will project that cycles in marginal costs will be largely undone by cuts in labor taxes.

Our analysis suggests that a sophisticated supply-side stabilization policy could potentially reduce any cycles grounded out of sticky prices. If these results prove robust in future research they may call to generally rethink the role of fiscal authorities. Our analysis indicates that tax instruments might be a powerful tool to smooth economic cycles. Supply-side stabilization policy opens a promising new array of research questions as it opens the possibility to smooth away effectively a broad range of unpleasant cost-push shocks in an environment of sticky prices.

Appendices

The Linearized Model

This appendix summarizes the log-linear approximation of the model around a symmetric equilibrium steady state with zero inflation. A variable \hat{X}_t denotes the log-linear approximation from the steady state value:

$$\hat{X}_t = \ln(X_t) - \ln(\bar{X}),$$

where \bar{X} denotes the steady state value of X_t .

Fiscal authorities

The budget constraint:

$$\hat{b}_{H,t+1} = \frac{\bar{g}_{H,t}}{\bar{b}_{H,t}} \hat{g}_{H,t} - \frac{\bar{w}_H \bar{N}_H \bar{\tau}_H^d}{\bar{b}_{H,t}} (\mathbf{t}_t^{H,d} + \hat{w}_t^H + \hat{N}_{H,t}) - \frac{\bar{w}_H \bar{N}_H \bar{\tau}_H^{w_f}}{\bar{b}_{H,t}} (\mathbf{t}_t^{H,w_f} + \hat{w}_t^H + \hat{N}_{H,t})$$

$$\hat{b}_{F,t+1} = \frac{\bar{g}_{F,t}}{\bar{b}_{F,t}} \hat{g}_{F,t} - \frac{\bar{w}_F \bar{N}_F \bar{\tau}_F^d}{\bar{b}_{F,t}} (\mathbf{t}_t^{F,d} + \hat{w}_t^F + \hat{N}_{F,t}) - \frac{\bar{w}_F \bar{N}_F \bar{\tau}_F^{w_f}}{\bar{b}_{F,t}} (\mathbf{t}_t^{F,w_f} + \hat{w}_t^F + \hat{N}_{F,t})$$

The tax rules:

$$\mathbf{t}_t^{H,d} = \frac{\mathbf{k}_1}{b} \mathbf{x} \hat{b}_t^H + \mathbf{h}_t^{H,d},$$

$$\mathbf{t}_t^{H,w_f} = \frac{(1-\mathbf{k}_1)}{b} \mathbf{x} \hat{b}_t^H + \mathbf{h}_t^{H,w_f},$$

$$\mathbf{t}_t^{F,d} = \frac{\mathbf{k}_1}{b} \mathbf{x} \hat{b}_t^F + \mathbf{h}_t^{F,d},$$

$$\mathbf{t}_t^{F,w_f} = \frac{(1-\mathbf{k}_1)}{b} \mathbf{x} \hat{b}_t^F + \mathbf{h}_t^{F,w_f},$$

Fiscal Spending Rules:

$$\hat{g}_{H,t} = \mathbf{f}_y (\hat{Y}_{H,t} - \hat{Y}_{H,t}^{flex}) - \mathbf{f}_g \hat{T}_t + \mathbf{f}_{1,g} \hat{g}_{H,t-1} + \mathbf{f}_{2,g} \hat{g}_{H,t-2} + \mathbf{h}_t^{H,g}$$

$$\hat{g}_{F,t} = \mathbf{f}_y (\hat{Y}_{F,t} - \hat{Y}_{F,t}^{flex}) + \mathbf{f}_T \hat{T}_t + \mathbf{f}_{1,g} \hat{g}_{F,t-1} + \mathbf{f}_{2,g} \hat{g}_{F,t-2} + \mathbf{h}_t^{F,g}$$

Flex Price Equilibrium:

$$\hat{Y}_t^{H,flex} = \mathbf{s}_1 \mathbf{e}_t^a + \mathbf{s}_2 \hat{\mathbf{x}}_t + \mathbf{s}_3 \hat{Y}_{t-1}^{H,flex}$$

$$\hat{Y}_t^{F,flex} = \mathbf{s}_1 \mathbf{e}_t^a + \mathbf{s}_2 \hat{\mathbf{x}}_t + \mathbf{s}_3 \hat{Y}_{t-1}^{F,flex}$$

Households

The consumption Euler equation: Ricardian Households

$$\hat{C}_t^{H,o} = \frac{1}{1+h} E_t \hat{C}_{t+1}^{H,o} + \frac{h}{1+h} \hat{C}_{t-1}^{H,o} - \frac{1-h}{(1+h)\mathbf{s}} E_t (\hat{R}_t - \hat{\mathbf{p}}_{t+1}^H) + (\mathbf{x}_t^H - \mathbf{x}_{t+1}^H)$$

$$\hat{C}_t^{F,o} = \frac{1}{1+h} E_t \hat{C}_{t+1}^{F,o} + \frac{h}{1+h} \hat{C}_{t-1}^{F,o} - \frac{1-h}{(1+h)\mathbf{s}} E_t (\hat{R}_t - \hat{\mathbf{p}}_{t+1}^F) + (\mathbf{x}_t^F - \mathbf{x}_{t+1}^F)$$

The consumption Lagrangian is equal to:

$$\mathbf{I}_t^{H,o} = -\mathbf{s} \frac{1}{1-h} \hat{C}_t^{H,o} + \mathbf{s} \frac{h}{1-h} \hat{C}_{t-1}^{H,o}$$

$$\mathbf{I}_t^{F,o} = -\mathbf{s} \frac{1}{1-h} \hat{C}_t^{F,o} + \mathbf{s} \frac{h}{1-h} \hat{C}_{t-1}^{F,o}$$

The consumption Euler equation: Non-Ricardian Households

$$\hat{C}_t^{H,r} = \hat{W}_t^H - \hat{P}_t^H .$$

$$\hat{C}_t^{F,r} = \hat{W}_t^F - \hat{P}_t^F .$$

Consumption and Labor Aggregates

$$\hat{C}_t^H = \mathbf{I} \frac{\bar{C}^r}{\bar{C}} \hat{C}_t^{H,r} + (1-\mathbf{I}) \frac{\bar{C}^o}{\bar{C}} \hat{C}_t^{H,o}$$

$$\hat{C}_t^F = \mathbf{I} \frac{\bar{C}^r}{\bar{C}} \hat{C}_t^{F,r} + (1-\mathbf{I}) \frac{\bar{C}^o}{\bar{C}} \hat{C}_t^{F,o}$$

$$\hat{N}_t^F = (1 - I) \hat{N}_t^{F,0}.$$

$$\hat{N}_t^F = (1 - I) \hat{N}_t^{F,0}.$$

Firms

Phillips curves

$$\hat{p}_{H,t} = \frac{w}{q + w[1 - q(1 - b)]} \hat{p}_{H,t-1} + \frac{bq}{q + w[1 - q(1 - b)]} E_t \hat{p}_{H,t+1} + \frac{(1-w)(1-q)(1-bq)}{q + w[1 - q(1 - b)]} \frac{a}{a - e(a-1)} \hat{f}_{H,t}$$

$$\hat{p}_{F,t} = \frac{w}{q + w[1 - q(1 - b)]} \hat{p}_{F,t-1} + \frac{bq}{q + w[1 - q(1 - b)]} E_t \hat{p}_{F,t+1} + \frac{(1-w)(1-q)(1-bq)}{q + w[1 - q(1 - b)]} \frac{a}{a - e(a-1)} \hat{f}_{F,t}$$

Marginal cost

$$\hat{f}_{H,t} = \hat{w}_t^H + \frac{t^{w_f}}{1 + t^{w_f}} \hat{t}_t^{w_f} + a^{-1} \hat{Y}_t^H + a^{-1} (a - 1) \hat{g}_t^H - e_t^{H,a} + e_t^{H,e}$$

$$\hat{f}_{F,t} = \hat{w}_t^F + \frac{t^{w_f}}{1 + t^{w_f}} \hat{t}_t^{w_f} + a^{-1} \hat{Y}_t^F + a^{-1} (a - 1) \hat{g}_t^F - e_t^{F,a} + e_t^{F,e}$$

Real wages

$$\hat{w}_t^H = \frac{t^d}{1 - t^d} \hat{t}_t^d + \frac{h}{a} \hat{Y}_t^H - \left(\frac{h}{a} \right) (1 - a) \hat{g}_t^H + \frac{s}{1 - h} \hat{C}_t^H - \frac{hs}{1 - h} \hat{C}_{t-1}^H + \mathbf{x}_t^{H,L}$$

$$\hat{w}_t^F = \frac{t^d}{1 - t^d} \hat{t}_t^d + \frac{h}{a} \hat{Y}_t^F - \left(\frac{h}{a} \right) (1 - a) \hat{g}_t^F + \frac{s}{1 - h} \hat{C}_t^F - \frac{hs}{1 - h} \hat{C}_{t-1}^F + \mathbf{x}_t^{F,L}$$

Hours Worked

$$\hat{N}_{H,t} = \frac{1}{a} \hat{Y}_{H,t} - \frac{(1-a)}{a} \hat{g}_{H,t}$$

$$\hat{N}_{F,t} = \frac{1}{\mathbf{a}} \hat{Y}_{F,t} - \frac{(1-\mathbf{a})}{\mathbf{a}} \hat{g}_{F,t}$$

Shocks

Interest rate shock

$$z_t^W = V_W z_{t-1}^W + \tilde{z}_t^W$$

Government spending shock

$$\mathbf{h}_t^{H,g} = V_{H,g} \mathbf{h}_{t-1}^{H,g} + \tilde{\mathbf{h}}_t^{H,g}$$

$$\mathbf{h}_t^{F,g} = V_{F,g} \mathbf{h}_{t-1}^{F,g} + \tilde{\mathbf{h}}_t^{F,g}$$

Government tax shocks

$$\mathbf{h}_t^{H,d} = V_{H,d} \mathbf{h}_{t-1}^{H,d} + \tilde{\mathbf{h}}_t^{H,d}$$

$$\mathbf{h}_t^{F,d} = V_{F,d} \mathbf{h}_{t-1}^{F,d} + \tilde{\mathbf{h}}_t^{F,d}$$

$$\mathbf{h}_t^{H,w_f} = V_{H,w_f} \mathbf{h}_{t-1}^{H,w_f} + \tilde{\mathbf{h}}_t^{H,w_f}$$

$$\mathbf{h}_t^{F,g} = V_{F,g} \mathbf{h}_{t-1}^{F,g} + \tilde{\mathbf{h}}_t^{F,g}$$

Preference shocks

$$\mathbf{x}_t^H = V_{H,w_f} \mathbf{x}_{t-1}^H + \mathbf{x}_t^H$$

$$\mathbf{x}_t^F = V_F \mathbf{x}_{t-1}^F + \tilde{\mathbf{h}}_t^F$$

Price Mark-up shock

$$\mathbf{e}_t^{H,e} = V_{H,e} \mathbf{e}_{t-1}^{H,e} + \tilde{\mathbf{e}}_t^{H,e}$$

$$\mathbf{e}_t^{F,e} = V_{F,e} \mathbf{e}_{t-1}^{F,e} + \tilde{\mathbf{e}}_t^{F,e}$$

Productivity shock

$$\mathbf{e}_t^{H,a} = V_{H,a} \mathbf{e}_{t-1}^{H,a} + \tilde{\mathbf{e}}_t^{H,a}$$

$$\mathbf{e}_t^{F,a} = V_{F,a} \mathbf{e}_{t-1}^{F,a} + \tilde{\mathbf{e}}_t^{F,a}$$

Some definitions

The price level in each region H and F evolves according to:

$$\hat{p}_t = n\hat{p}_{H,t} + (1-n)\hat{p}_{F,t}$$

where it holds that:

$$\hat{p}_{H,t} = \hat{\mathbf{p}}_{H,t} + \hat{p}_{H,t-1}$$

$$\hat{p}_{F,t} = \hat{\mathbf{p}}_{F,t} + \hat{p}_{F,t-1}$$

Inflation is given by:

$$\hat{\mathbf{p}}_t^W = n\hat{\mathbf{p}}_{H,t} + (1-n)\hat{\mathbf{p}}_{F,t}$$

Consumption is given by:

$$\hat{Y}_t^W = n\hat{Y}_{H,t} + (1-n)\hat{Y}_{F,t}$$

$$\hat{Y}_t^{flex} = n\hat{Y}_{H,t}^{flex} + (1-n)\hat{Y}_{F,t}^{flex}$$

Where national output is defined as:

$$\hat{Y}_t^H = (1-n)\hat{T}_t + \hat{C}_t^W + \hat{g}_t^H$$

$$\hat{Y}_t^F = -n\hat{T}_t + \hat{C}_t^W + \hat{g}_t^F$$

Terms of trade:

$$\hat{T}_t = \hat{P}_{H,t} - \hat{P}_{F,t}$$

Monetary Authorities

$$\hat{R}_t^{EU} = \mathbf{d}_1 \hat{R}_{t-1}^{EU} + (1-\mathbf{d}_1) \left[\mathbf{f}_p \hat{\mathbf{p}}_t^W + \mathbf{f}_y \hat{Y}_t^W \right] + \mathbf{f}_{\Delta p} \Delta \hat{\mathbf{p}}_t^W + \mathbf{f}_{\Delta y} \Delta \hat{Y}_t^{EU} + z_t^{EU}$$

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