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Documento de Trabajo n.º 0314

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SERVICIO DE ESTUDIOS

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Abstract

This paper analyzes the effect of the fiscal structure upon the trade-off between inflation and output stabilization in the presence of technological shocks in a DGE model with nominal and real rigidities. The model reproduces the main features of European economies and it integrates a rich menu of fiscal variables as well as a target on the debt to output ratio. The main result of this paper is that distortionary taxes tend to increase output volatility relative to lump-sum taxes unless substantial rigidities are present. We explore in detail the mechanisms that generate such a result, and the conditions under which the supply-side effects of distortionary taxes and the procyclical behaviour of public spending induced by fiscal rules prevail over the conventional effect of automatic stabilizers operating through disposable income.

Keywords: Fiscal rules, macroeconomic stability, distortionary taxes.
JEL Classification: E32, E52, E63.

1 Introduction

Recent macroeconomic research has stressed the relevance of the trade-off that the monetary authority faces between inflation and output stability when the economy is hit by supply shocks (Clarida, Galí and Gertler, 1999). In this paper we focus on a potential determinant of that policy trade-off that has received scant attention so far: distortionary taxes. Textbook macroeconomics tells us that, under a continuous balanced budget, automatic stabilizers built in distortionary taxes fail to operate since the public sector surplus becomes procyclical, thus aggravating economic fluctuations. King, Plosser and Rebelo (1988) suggested that this may also happen in a RBC model and Stockman (2001) showed that the welfare implications of balanced-budget rules may be substantial. Furthermore, Schmitt-Grohé and Uribe (1997) found that there might be sunspot equilibria if tax rates adjust to achieve a balanced budget. However, fiscal arrangements currently in place in Europe and elsewhere are not so tight. Although most modern fiscal systems incorporate explicit consolidation rules with debt to output ratio targets, they are still compatible with moderate and long-lasting deviations from target. Moderate budget deficits are allowed to give fiscal stabilizers a chance, in a long-run balanced budget environment, in which many advocate for a cautious use of discretionary and transitory fiscal changes. Whether or not automatic stabilizers contribute to reduce the volatility of output in such a framework is yet unsettled.

In this paper we address this issue by comparing the volatility of output in two otherwise identical economies with different tax structures: distortionary versus lump-sum. Since lump-sum taxes do not affect individual choices, output volatility under lump-sum taxation is a very appropriate benchmark to evaluate the stabilization merits of income and consumption taxes. As we described in section 2, technology shocks are the only source of fluctuations in our model, which includes a rich menu of fiscal variables such as income and spending taxes, public consumption and investment, transfers, government spending rules and debt targets. The model also allows for real and nominal rigidities, such as investment adjustment costs and sticky prices. In both respects, the model departs from the standard RBC framework, as the one considered by Gali (1994), in which income taxes generate greater output volatility than lump-sum ones. These features turn out to be of critical importance to determine the volatility of output in presence of technology shocks, in particular, nominal inertia unfolds several channels through which automatic stabilizers are expected to exert a moderating influence on output variability. The benchmark model matches the most salient long-run and business cycle features of a representative European economy, under the assumption of technology shocks as the only source of fluctuations. The size of the public sector is set to realistic values and it includes a balanced tax structure in which public spending is financed resorting to income and consumption taxes.

Section 3 shows that, for the benchmark parameterization and regardless of the intensity of monetary policy, lump-sum taxation always generates less output variability than any other tax structure in which revenues are linked to economic activity. Interestingly, the poorer stabilization performance of distortionary tax structures is compatible with a strong positive correlation between public surpluses and output. In section 4 we look in more detail at the mechanisms that explain the main result of the preceding section. Both demand and supply channels contribute to affecting the volatility of output under distortionary taxation with respect to an economy with lump-sum taxes. An important result of this section is that the gap between the volatility of output under these tax structures narrows as price stickiness and investment adjustment costs increase. Thus, output volatility under distortionary taxes can be lower than under lump-sum taxation for large nominal and real rigidities. Finally, section 5 concludes.

2 The model

2.1 Firms and households

2.1.1 Price setting: nominal inertia

The economy is populated by i intermediate goods producing firms. Each firm faces a downward sloping demand curve for its product (y_i) with finite elasticity ε

$$y_{it} = y_t \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} \tag{1}$$

where $\left[\int_0^1 (y_{it})^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} = y_t$ and $P_t = \left[\int_0^1 (P_{it})^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}$. Following Calvo (1983), each period a measure $1-\phi$ of firms set their prices, $\widetilde{P}_{it}$, to maximize the present value of future profits,

$$\max_{\widetilde{P}_{it}} E_t \sum_{j=0}^{\infty} \rho_{it,t+j} (\beta\phi)^j \left[\widetilde{P}_{it} \overline{\pi}^j y_{it+j} - P_{t+j} mc_{it,t+j} (y_{it+j} + \kappa) \right] \tag{2}$$

subject to

$$y_{it+j} = \left(\widetilde{P}_{it} \overline{\pi} \right)^{-\varepsilon} P_{t+j}^{\varepsilon} y_{t+j} \tag{3}$$

where $\rho_{t,t+j}$ is a price kernel representing the marginal utility value to the representative household of an additional unit of profits accrued in period $t+j$, β the discount factor, $mc_{t,t+j}$ the marginal cost at $t+j$ of the firm changing prices at t and κ a fixed cost of production. The remaining (ϕ per cent) firms set $P_{it} = \overline{\pi} P_{it-1}$ where $\overline{\pi}$ is the steady-state rate of inflation. The first order condition of this problem is

$$\widetilde{P}_{it} = \frac{\varepsilon}{\varepsilon - 1} \frac{\sum_{j=0}^{\infty} (\beta\phi)^j E_t \left[\rho_{it,t+j} P_{t+j}^{\varepsilon+1} mc_{it+j} y_{t+j} \overline{\pi}^{-j\varepsilon} \right]}{\sum_{j=0}^{\infty} (\beta\phi)^j E_t \left[\rho_{it,t+j} P_{t+j}^{\varepsilon} y_{t+j} \overline{\pi}^{j(1-\varepsilon)} \right]} \tag{4}$$

and the aggregate price index at t

$$P_t = \left[\phi \left(\overline{\pi} P_{t-1} \right)^{1-\varepsilon} + (1-\phi) \widetilde{P}_t^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{5}$$

2.1.2 Capital and labor demand: cost minimization

The optimal combination of capital (k) and labor (l) is obtained from the cost minimization process of the firm:

$$\min_{k_{it}, l_{it}} \left(r_t k_{it} + w_t l_{it} \right) \tag{6}$$

subject to

$$y_{it} = A_t k_{it}^{\alpha} l_{it}^{1-\alpha} (g_t^p)^{\theta} - \kappa \tag{7}$$

where w_t is the real wage and r_t is the rental cost of capital. It is assumed that the variable A_t, which stands for the total factor productivity, follows the process.

$$\ln A_t = \rho_z \ln A_{t-1} + z_t^a \tag{8}$$

where z_t^a is white noise and $0 < \rho_z < 1$. Notice also that in order to simplify the model, following Barro (1990) output depends only on public investment (g_t^p) and not on the public capital stock. The presence of g_t^p in the production function is a potentially powerful channel through which fiscal policy may affect output, and it is included to capture the productivity enhancing effect of public spending, but we shall check the robustness of our results to the presence of this channel.

Aggregating the first order conditions of this problem we obtain the demand for labor (l_t) and capital (k_t),

$$w_t = mc_t (1-\alpha) A_t k_t^{\alpha} l_t^{-\alpha} (g_t^p)^{\theta} \tag{9}$$

$$r_t = mc_t \alpha A_t k_t^{\alpha-1} l_t^{1-\alpha} (g_t^p)^{\theta} \tag{10}$$

2.1.3 Households

The utility function of the representative j_{th} household is non separable in leisure $(1 - l_t)$ and consumption (c_t) and separable in public consumption (g_t^c) and investment:

$$U(c_t, 1 - l_t, g_t^c, g_t^p) = \frac{\left(c_t^{\gamma}(1 - l_t)^{1-\gamma}\right)^{1-\sigma} - 1}{1 - \sigma} + \Gamma(g_t^c, g_t^p) \tag{11}$$

As in Baxter and King (1993), while public spending increase utility they do not affect directly to household's decisions. There is a cash-in-advance constraint that links the money demand (M_t) and current cash transfers (τ_t^m) to consumption,

$$P_t(1 + \tau_t^c)c_t \leq M_t + \tau_t^m \tag{12}$$

Households allocate their income (labor income, capital income, interest payments on bond holdings (B_t), their share of profits of the firms (Ω_{it}), and public transfers $(P_t g_t^s)$) and current cash holdings to buy consumption and investment goods (e_t), and to accumulate savings either in bonds or money holdings for $t + 1$:

$$\begin{aligned} & M_{t+1} + \frac{B_{t+1}}{(1 + i_{t+1})} + P_t(1 + \tau_t^c)c_t + P_t e_t && (13) \\ = \quad & P_t(1 - \tau_t^w)w_t l_t + P_t(1 - \tau_t^k)r_t k_t + B_t + M_t + \tau_t^m + P_t g_t^s + \int_0^1 \Omega_{it} di \end{aligned}$$

The tax structure includes taxes on labor income (τ_t^w), capital income (τ_t^k) and consumption (τ_t^c). The accumulation of capital results from the households' investment decisions. They face a constant depreciation rate (δ) and due to installation costs $\Phi(e_t/k_t)$ only a proportion of investment spending goes to increase the capital stock

$$k_{t+1} = \Phi\left(\frac{e_t}{k_t}\right) k_t + (1 - \delta)k_t \tag{14}$$

2.2 Equilibrium and monetary and fiscal policies

The symmetric monopolistic competition equilibrium is defined as the set of quantities that maximizes the constrained present value of the stream of utility of the representative household and the constrained present value of the profits earned by the representative firm, and the set of prices that clears the goods markets, the labor market and the money, bonds and capital markets. The extensive representation of the aggregate symmetric equilibrium is given by[2]

$$k_{t+1} = \Phi\left(\frac{e_t}{k_t}\right)k_t + (1-\delta)k_t \tag{15}$$

$$\lambda_t = \frac{\gamma\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma}}{(1+\tau_t^c)(1+i_{t+1})c_t} \tag{16}$$

$$\lambda_t(1-\tau_t^w)w_t = \frac{(1-\gamma)\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma}}{(1-l_t)} \tag{17}$$

$$\lambda_t\beta^{-1} = E_t\left(\lambda_{t+1}\frac{1+i_{t+1}}{\pi_{t+1}}\right) \tag{18}$$

$$q_t = \left[\Phi'\left(\frac{e_t}{k_t}\right)\right]^{-1} \tag{19}$$

$$\frac{q_t}{\beta} = E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left((1-\tau_{t+1}^k)r_{t+1} + q_{t+1}\left[\Phi\left(\frac{e_{t+1}}{k_{t+1}}\right) + (1-\delta) - \Phi'\left(\frac{e_{t+1}}{k_{t+1}}\right)\frac{e_{t+1}}{k_{t+1}}\right]\right)\right\} \tag{20}$$

$$\frac{M_t}{P_t} + \frac{\tau^m}{P_t} = (1+\tau_t^c)c_t \tag{21}$$

$$w_t = mc_t(1-\alpha)A_t k_t^{\alpha} l_t^{-\alpha}(g_t^p)^{\theta} \tag{22}$$

$$r_t = mc_t\alpha A_t k_t^{\alpha-1} l_t^{1-\alpha}(g_t^p)^{\theta} \tag{23}$$

$$\widetilde{P}_t = \frac{\varepsilon}{\varepsilon-1}\frac{\sum_{j=0}^{\infty}(\beta\phi)^j E_t\left[\rho_{t,t+j}P_{t+j}^{\varepsilon+1}mc_{t+j}y_{t+j}\overline{\pi}^{-j\varepsilon}\right]}{\sum_{j=0}^{\infty}(\beta\phi)^j E_t\left[\rho_{t,t+j}P_{t+j}^{\varepsilon}y_{t+j}\overline{\pi}^{j(1-\varepsilon)}\right]} \tag{24}$$

$$P_t = \left[\phi\left(\overline{\pi}P_{t-1}\right)^{1-\varepsilon} + (1-\phi)\widetilde{P}_t^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{25}$$

$$\pi_t \equiv \frac{P_t}{P_{t-1}} \tag{26}$$

$$P_t\tau_t^w w_t l_t + P_t\tau_t^k r_t k_t + P_t\tau_t^c c_t - P_t(g_t^c + g_t^p + g_t^s) = -\frac{B_{t+1}}{(1+i_{t+1})} + B_t - M_{t+1} + M_t \tag{27}$$

$$y_t = c_t + e_t + g_t^c + g_t^p \tag{28}$$

$$y_t = A_t k_t^{\alpha} l_t^{1-\alpha}(g_t^p)^{\theta} - \kappa \tag{29}$$

$$\frac{E_t\rho_{t,t+j}}{E_t\rho_{t,t+j-1}} = \frac{E_t(\lambda_{t+j}/P_{t+j})}{E_t(\lambda_{t+j-1}/P_{t+j-1})} \tag{30}$$

[2] The model solution as well as the log-linearized system describing the dynamics are contained in a technical appendix available at http://iei.uv.es/~rdomenec/AD/tech_appendix.pdf.

where λ_t is the lagrange multiplier of the intertemporal decision problem of the household and q_t is Tobin's q. The model is completed with the rules of the monetary and fiscal policy instruments: i_t, g_t^c, g_t^p, g_t^s.

Monetary policy is represented by a standard Taylor rule:

$$i_t = \rho_r i_{t-1} + (1-\rho_r)\bar{i} + (1-\rho_r)\rho_\pi(\pi_t - \overline{\pi}) + (1-\rho_r)\rho_y \widehat{y}_t + z_t^i \tag{31}$$

in which the monetary authority sets the interest rate (i_t) to prevent inflation deviating from its steady-state level ($\pi_t - \overline{\pi}$) and to counteract movements in the output gap ($\widehat{y}_t$); $\bar{i}$ is the steady-state interest rate and the current rate moves smoothly ($0 < \rho_r < 1$) and has an unexpected component, z_t^i.

Provided that ρ_π is above a certain threshold value, fiscal policy must be designed to satisfy the present value budget constraint of the public sector for any price level in order to obtain a unique monetary equilibrium (Leeper, 1991, Woodford, 1996, Leith and Wren-Lewis, 2000). A simple way of making this requirement operational is to assume that either taxes or public spending respond sufficiently to the level of debt (Canzoneri, Cumby and Diba, 2001). These feedback rules also represent the quantitative deficit and/or debt targets made explicit in most developed countries' fiscal systems nowadays (Corsetti and Roubini, 1996, Bohn, 1998 and Ballabriga and Martinez-Mongay, 2002). In fact, the Stability and Growth Pact can be interpreted as implying such a feedback since a deficit objective in terms of GDP is equivalent in the long run to a target of the debt to output ratio.

The theoretical requirements of a Ricardian policy can be satisfied with a feedback behaviour of either revenues or expenditures, but the empirical evidence indicates that successful consolidations in industrialized countries have been based on spending cuts (see von Hagen, Hallet and Strauch, 2001, Alesina and Perotti, 1997). Cyclical changes in tax rates are not very realistic and may, under some circumstances, lead to multiple (sunspot) equilibria, thus inducing additional instability (Schmitt-Grohé and Uribe, 1988). Therefore, for realistic purposes, all τ_t^w, $\tau_t^k$and τ_t^c will be assumed constant for all t and we will use fiscal rules in which the deviation of each component of public spending (consumption, g_t^c, investment, g_t^p and/or transfers, g_t^s) from its steady-state value is a function of the deviation of the debt to output ratio from its target:

$$\frac{g_t}{\overline{g}} = \left(\frac{b_{t-j}}{y_{t-j}}\frac{\overline{y}}{\overline{b}}\right)^{-\alpha_b}\left(\frac{y_t}{\overline{y}}\right)^{-\alpha_y}, \qquad \alpha_b, \alpha_y \geq 0 \tag{32}$$

where the bar over the variables indicates steady-state values.

2.3 Calibration

In order to analyze the main implications of our model in terms of the interactions between monetary and fiscal policy, we have obtained a numerical solution of the steady state as well as of the log-linearized system. Table 1 summarizes the values of the calibrated baseline parameters. Although most of these parameters refer to EMU, in some cases, when no evidence exists for European countries, it is assumed that they are similar to the values habitually used for the United States. Thus, the relative risk aversion coefficient (σ) is 2, the discount factor (β) is 0.9926, following Christiano and Eichenbaum (1992), and, since we assume that in the steady state households allocate 0.31 of their time to market activities (as in Cooley and Prescott, 1995), the share of consumption in utility (γ) has been chosen to be 0.4453.

Table 1
Calibration of baseline model

σ	β	γ	α	θ	δ	σ_z	ρ_z	ε	κ	Θ	ϕ
2.0	0.9926	0.4453	0.40	0.10	0.021	0.0045	0.80	6.0	0.20	-0.12	0.75
τ^w	τ^k	τ^c	g^c/y	g^s/y	g^p/y	α_b^c	α_b^p	α_b^s	ρ_r	ρ_π	π
0.43	0.21	0.14	0.18	0.16	0.06	0.4	0.4	0.0	0.5	2.0	$1.02^{0.25}$

The elasticity of output with respect to private capital (α) is 0.4, as in Cooley and Prescott (1995). The value of the output elasticity to productive public expenditure (θ) is more controversial, as Gramlich (1994) has pointed out, since its estimated value ranges from 0 to 0.39. Nevertheless, Cassou and Lansing (1998) have shown that the observed decline in the US ratio of capital to private capital can be reconciled with optimal fiscal policy when the elasticity of output with respect to g^p is 0.1. The depreciation rate (δ) is equal to 0.021 as estimated by Christiano and Eichenbaum (1992). The standard deviation (σ_z) and the first order autocorrelation coefficient (ρ_z) of the technology shock are set to 0.0043 and 0.8 respectively, whereas the investment ratio elasticity of the price of capital ($\Theta \equiv \Phi'' \left(\overline{e}/\overline{k}\right) / \Phi'$) is set to -0.12. These values have been chosen in order to produce GDP cycles that mimic the volatility of output and investment observed in EMU in our baseline model (see Agresti and Mojon, 2001). Following Christiano, Eichembaum and Evans (1997), the elasticity of demand with respect to price (ε) is set to 6, consistent with a steady-state mark-up, $\varepsilon/(\varepsilon - 1)$, equal to 1.2. The fixed cost in production (κ) is set to 0.2, to produce zero profits in the steady state, where the output has been normalized to 1 in the baseline model. The probability of price adjustment in a given period

$(1-\phi)$ is 0.25, in line with some of the estimated values of this parameter for the Euro area by Galí, Gertler and López-Salido (2001).

Fiscal policy parameters have been calibrated after computing the tax rates for EMU members using the method proposed by Mendoza, Razin and Tesar (1994): 0.43 for labor taxes (τ^w), 0.21 for taxes on capital income (τ^k) and 0.14 for consumption taxes (τ^c). For the same sample of countries and years, government consumption over GDP ($\overline{g}^c/\overline{y}$) is 0.18 , transfers ($\overline{s}/\overline{y}$) are 0.16 and productive public expenditure ($\overline{g}^p/\overline{y}$) is 0.06. This calibration yields a public debt of 60 per cent of annual GDP in the steady state, which was the reference level in the Maastricht Treaty. The feedback parameter to public debt in the fiscal rule for government consumption and productive public expenditure (α_b^c and α_b^p) in the baseline model are set to 0.4, whereas α_b^s is equal to zero to avoid transfers becoming procyclical, something at odds with the empirical evidence in EMU since unemployment benefits are countercyclical.

The last set of parameters refers to the interest rate rule. In the baseline model, we set the autocorrelation coefficient of the interest rate (ρ_r) equal to 0.5 and the response to inflation deviations from target (ρ_π) equal to 2. These values imply a response of the interest rate to inflation slightly quicker and more aggressive than the one usually estimated for EMU countries (see, Doménech, Ledo and Taguas, 2002). The steady-state level of gross inflation ($\overline{\pi}$) is set to $1.02^{0.25}$, that is, the target level of the ECB.

The model with transitory supply shocks (i.e., shocks in z_t^a) has been simulated 100 times, producing 200 observations. We take the last 100 observations and compute the steady-sate value ($\overline{x}$), the relative standard deviation to output of the relative deviations from the steady state (σ_x/σ_y, except for GDP which is just σ_y), the first-order autocorrelation (ρ_x) and the contemporaneous correlation with output (ρ_{xy}) of each variable.[3] We have also simulated an economy with zero tax rates on consumption, labor and capital incomes, in which public spending is financed using a lump-sum tax such that $\overline{g}^s/\overline{y} = -0.26$, but with otherwise identical fiscal structure as that in the benchmark model ($\overline{g}^c/\overline{y} = 0.18$, $\overline{g}^p/\overline{y} = 0.06$, $\frac{\overline{b}}{\overline{y}} = 0.6$).

The main statistics of these simulations are reported in Table 2. The baseline model reproduces most business-cycle facts of the European economies. The effects of distortionary taxation on the steady-state values of the main variables are substantial in comparison to the economy with lump-sum taxes (see, for example, Chari and Kehoe, 1999). Interestingly, the standard deviation of

[3] To avoid spurious correlation, we do not filter the simulated data (see Cogley and Nason, 1995).

Table 2
Business cycles statistics

	Baseline model				Lump-sum taxation model			
x	$\overline{x}$	σ_x/σ_y	ρ_x	ρ_{xy}	$\overline{x}$	σ_x/σ_y	ρ_x	ρ_{xy}
y	1.00	1.00	0.84	1.00	2.16	0.91	0.82	1.00
c	0.53	0.52	0.88	0.98	1.00	0.54	0.89	0.93
e	0.23	2.61	0.80	0.96	0.64	2.27	0.79	0.99
g^c	0.18	0.74	0.94	0.80	0.39	0.43	0.84	0.99
g^p	0.06	0.74	0.94	0.80	0.13	0.43	0.84	0.99
b	2.40	1.22	0.99	-0.47	5.19	0.09	0.86	-0.90
m	0.60	0.56	0.87	0.99	1.00	0.58	0.88	0.94
mc	0.83	0.22	0.49	-0.81	0.83	0.23	0.37	-0.80
q	1.00	0.31	0.79	0.89	1.00	0.27	0.78	0.94
l	0.31	0.18	0.91	0.93	0.50	0.14	0.91	0.78
i^1	1.24	0.10	0.88	-0.97	1.24	0.08	0.86	-0.99
r^1	3.60	0.59	0.88	0.74	2.84	0.64	0.89	0.80
w	1.94	0.51	0.90	0.98	2.58	0.55	0.90	0.96
π	1.005	0.06	0.66	-0.93	1.005	0.05	0.60	-0.95
pbs	0.018	0.15	0.91	0.81	0.018	0.10	0.84	-0.99

1 In percentage. q is the Tobin's q, and pbs is the primary budget surplus

output is lower in the economy with lump-sum taxes (0.91 vs. 1). The relative volatilities of public consumption, productive public expenditures and public debt are also larger in the economy with distortionary taxes than in the model with lump-sum taxes. In the next section we take a closer look at this feature.

The impulse/response functions for these two models in Figure 1 illustrate the results of Table 2 in more detail. The supply shock produces an increase in GDP that leads to a fall in the public debt. Besides this direct effect, in the model with distortionary taxation, the increase in private consumption and in capital and labor incomes also produces a rise in public revenues, with positive effects on the public budget. This indirect effect through taxes, which induces an additional sharp reduction of public debt, is absent in the economy with constant lump-sum taxes. As a result, the deviations of public debt and spending from their steady states last longer with substantial effects upon hours and output.

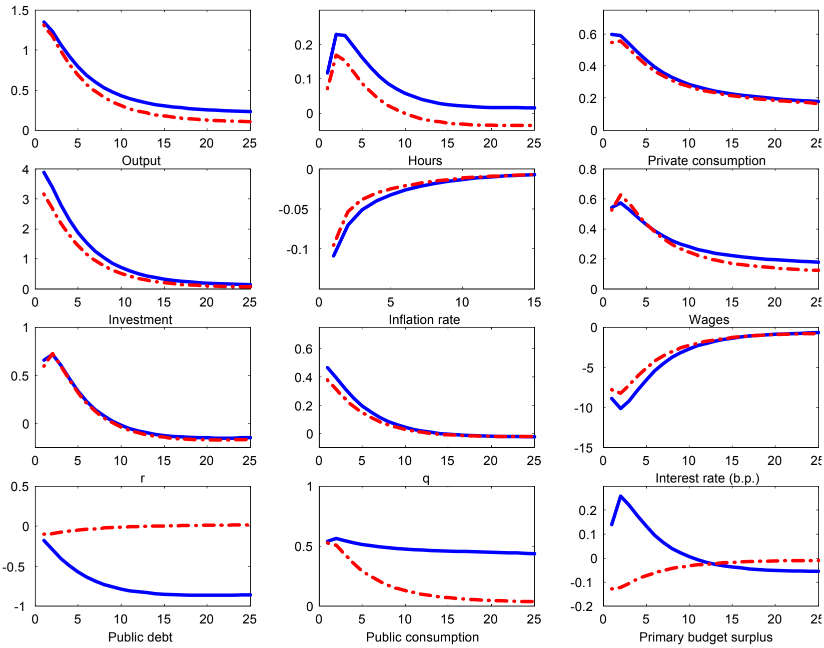

Figure 1: Impulse-response to a positive supply shock in the baseline model (solid line) and in the economy with lump-sum taxes (dashed line).

3 Alternative distortionary taxes versus lump-sum taxation

In this section, we assess the extent to which automatic stabilizers affect the ability of economic policy to deliver its objectives of low inflation and output volatility in the presence of technological shocks. For this purpose, we compare the position of the inflation-output variance frontier under alternative tax structures. These frontiers are drawn for different values of the interest rate response to the inflation rate (ρ_π), while holding constant the remaining parameters that characterize the economy.

Figure 2 shows the main result of the paper: when public spending is financed through lump-sum taxes, a given monetary policy is able to deliver less output volatility than any other tax structure; this holds for any value of the standard

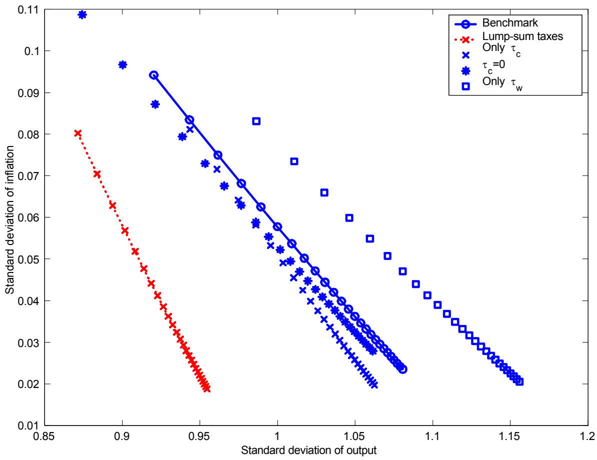

Figure 2: Variance frontier for alternative tax structures.

deviation of the inflation rate.

The fact that automatic stabilizers built into the distortionary tax system contribute to destabilizing the economy, as compared with an economy with lump-sum taxes, is striking. The mechanisms that generate this result operate both through the demand and the supply side of the model. Income taxes reduce the labor supply and the capital/output ratio in the steady state (Galí, 1994).[4] In that case a positive shock to total factor productivity leads to a larger percentage change in the use of the two private productive factors, and hence to larger output fluctuations than those that would prevail in a lump-sum tax system. Our model includes these channels along with those related to the response of public spending.

Fiscal revenues and spending are related to economic activity in a variety of ways. Distortionary taxes are linked either to income or to consumption and Ricardian fiscal policies incorporate another channel through which the tax/spending system must be linked to economic activity. In order to prevent public debt from exploding, the budget surplus must react when the level of

[4] Using the FOCs, it can be easily shown that the labour supply is more elastic and responsive to shifts in labour demand in the economy with distortionary taxation since the elasticity is a decreasing function of the steady-state labour supply

$$\left.\frac{\partial \widehat{l}_t}{\partial \widehat{w}_t}\right|_{\overline{c}} = \left(\frac{\overline{l}}{1+\overline{l}} + \frac{\overline{i}}{1+\overline{i}}\right)^{-1}$$

debt departs from its target. When public revenues are sensitive to the level of economic activity, a positive technological shock causes opposite movements in output and the level of debt, inducing a sharp fall in the debt to output ratio. Thus, public spending must react accordingly, generating an additional shock. The combination of (positive) technology and, current or anticipated, public spending shocks, induces a strong output increase. Thus the standard deviation of output increases relative to that of an economy in which taxes do not respond to the rise in economic activity. In the latter case there is a much more moderate fall in the debt to output ratio that mitigates the response of g_t^c and g_t^p.

The stronger response of public consumption in the economy with distortionary taxes is compatible with the procyclical behaviour of the primary budget balance. In Table 2, the contemporaneous correlation between output and the primary budget surplus (*pbs*) is positive and very high (0.81) in the economy with distortionary taxation, as a consequence of very procyclical fiscal revenues. This correlation is in accordance with the empirical evidence in EMU (0.71).[5] On the contrary, in the economy with lump-sum taxes the correlation between output and the primary budget surplus is -0.99, since fiscal revenues are constant whereas public expenditures are procyclical due to fiscal consolidation.

This pattern indicates that correlations between output and public deficits at the business cycle frequencies are not informative about the effectiveness of fiscal stabilizers when different tax structures are compared. This correlation is at the heart of model-based estimates of the strength of fiscal stabilizers (see, among others, Auerbach, 2002) that proceed in two steps, first computing the cyclical response of taxes and then multiplying it by the estimated fiscal multipliers. Since budget surpluses are meant to reduce output, and the empirical evidence is that distortionary taxes are associated with high surpluses in booms, then the implication follows nicely: distortionary taxes help to moderate cyclical fluctuations. Our results do not contradict the evidence, that is, automatic stabilizers exert the expected effect on the budget surplus. However, they are not able to reduce the standard deviation of output below the level that would have been achieved with lump-sum taxes. Procyclical surpluses do not necessarily bring about more output stabilization.

Figure 2 also reveals two additional results. Firstly, alternative structures of the tax system hardly affect the position of the IOF. Compared with the benchmark economy, extreme cases of consumption taxation or income taxation

[5] This correlation is obtained using annual data from 1970 to 2001 and the Hodrick-Prescott filter with a smoothing parameter equal to 10.

only lead to minor increases in the standard deviation of output for a given standard deviation of inflation. Only in the case in which public spending is fully financed with taxes on labor income ($\tau_w > 0, \tau_k = \tau_c = 0$) does the standard deviation of output rise by a significant amount. This higher volatility is due to the increase in the elasticity of the labor supply which enhances the impact of a technology shock on hours. We also observe that the IOF is hardly affected by changes in τ_k.[6] The second feature is that the shifts of the IOF's are almost horizontal in most cases. This means that for a given parameter ρ_π, the choice of the tax system does affect the standard deviation of output but leaves that of inflation virtually unaltered. This confirms that in a monetary regime the level and standard deviation of inflation are mainly determined by monetary policy.[7]

4 Supply and demand effects of fiscal policies

In this section we assess the importance of the different channels through which income and consumption taxes amplify technology-driven output fluctuations: price inertia, fiscal rules, public investment in the production function, labor supply and private capital accumulation. Supply and demand channels are not easily disentangled since the combination of technological shocks and the induced fiscal responses, shift the aggregate demand around an upward sloping supply curve that also moves as a result of labor and capital fluctuations. To gain some insight into the importance of each channel, we carry out some counterfactual exercises which are summarized in Table 3, where we display the standard deviation of output for the economy with lump-sum (σ_y^l) and with distortionary taxes (σ_y^d) and their ratio when ρ_π is equal to 2.

Let us first focus on the supply channels. Distortionary taxes enhance the procyclical movement of labor supply, capital accumulation and total factor productivity in our model. Taxes on labor income increase the demand for leisure in the steady state, whereas taxes on capital income reduce the steady-state level of the capital/output ratio. Both effects enhance cyclical deviations

[6] When $\tau_k = 0$, the capital to output ratio is the same in the economy with distortionary taxation as in the economy in which government spending is financed through lump-sum taxes. As pointed out by Galí (1994), since the output response to technology shocks depends on the response of investment, which is a function of y/k, the small shifts of the IOF when τ_k varies indicate that the importance of this supply channel is smaller than the effects through the labour supply.

[7] The only exception to this pattern is the structure in which revenues are raised on capital and labour income but not on consumption ($\tau_w, \tau_k > 0, \tau_c = 0$) and ρ_π is relatively small. In this case, there is a sizeable increase in the standard deviation of inflation along with a fall in the standard deviation of output.

Table 3
Sensitivity of σ_y to alternative model parameterizations when $\rho_\pi = 2.0$

Alternative model	lump-sum taxes σ_y^l	distortionary taxes σ_y^d	relative volatility σ_y^d/σ_y^l
Model 1 (*benchmark*) ($\gamma = 0.45, \theta = 0.1, \alpha_b^c = \alpha_b^p = 0.4, \alpha_b^s = 0$)	0.9119	1.0000	1.0966
Model 2: Inelastic labor supply ($\gamma \simeq 1$)	0.8375	0.8769	1.0470
Model 3: TFP independent of g^p ($\theta = 0$)	0.8583	0.9289	1.0823
Model 4: Consolidation effort ($\alpha_b^c = \alpha_b^p = 0.2, \alpha_b^s = 0$)	0.8800	0.9158	1.0407
Model 5: Delayed consolidation ($\alpha_b^c = \alpha_b^p = 0.4, \alpha_b^s = 0, j = 8$)	0.8707	0.9205	1.0572
Model 6: Fiscal rule in transfers ($\alpha_b^c = \alpha_b^p = 0, \alpha_b^s = 0.4$)	0.8416	0.8564	1.0176
Model 7: Model 2+Model 3+Model 6. ($\gamma \simeq 1.0, \theta = \alpha_b^c = \alpha_b^p = 0, \alpha_b^s = 0.4$)	0.7948	0.8069	1.0152

from the steady state as compared with an economy with lump-sum taxation. We have made total factor productivity dependent on the amount of public investment, which moves along with public revenues according to the fiscal rules in the model.

The standard deviation of output in Model 2 is obtained under the assumption of an (almost) inelastic labor supply ($\gamma \approx 1$), which makes the economy more stable, regardless of the tax structure. The gap between economies with lump-sum taxation and those with distortionary taxes also narrows significantly; roughly half of the additional destabilizing effect associated with distortionary taxation is explained by fluctuations in the labor supply. Setting $\theta = 0$ in our production function (or alternatively when $\alpha_b^p = 0$), as in Model 3, also reduces the volatility of output, although the ratio σ_y^d/σ_y^l is barely affected, which indicates that this channel not very important.

Next we assess the importance of alternative definitions of the fiscal consolidation rule. Neither a strong feedback (high α_b) nor an immediate response to the movements in the debt to output ratio ($j = 0$) are necessary to obtain a unique equilibrium. A Ricardian fiscal rule could be characterized by low and slow responses to deviations of the debt to output ratio from its target and still be sufficient to guarantee existence and uniqueness. Model 4 in Table 3 differs from the benchmark in the intensity of fiscal consolidation. We set α_b to 0.2, which is in some sense too low, since it implies that it takes a very long time before the real debt returns to its steady-state value after a technological shock. The relative volatility falls in this case to 1.04.

Alternatively, it can be argued that instantaneous stabilization is far too strict, and that even the more demanding fiscal programs allow for a delayed response of the public surplus, and thus to a slower adjustment of the debt/output ratio. This can be represented in our model setting $j > 0$ in equation (32). Large values of j introduce an important change in the time pattern of the response of public spending to changes in public revenues. A delayed reaction of public spending makes the budget surplus more procyclical mitigating the cyclical effect of fiscal consolidation. In particular, Model 5 allows for 8 lags in the time elapsed before the fiscal variables respond to the deviation of debt from its steady state after a technological shock. As in the previous exercise, slower consolidation reduces the relative volatility associated with both tax structures, but it still remains significantly above 1 ($\sigma_y^d/\sigma_y^l = 1.06$).

Not surprisingly, the most important reduction in the relative volatility of output between both economies occurs when only transfers are used to stabilize the debt to output ratio. In Model 6 we have set $\alpha_b^c = \alpha_b^p = 0$ and $\alpha_b^s = 0.4$. When this alternative policy is implemented the volatility of output in the economy with distortionary taxes is just 1.8 per cent above the one in the economy with lump-sum taxes. This is an interesting case for comparative purposes. In the economy with distortionary taxes, transfers can also be interpreted as a negative lump-sum tax. These transfers only enter the economy through the household budget constraint and exactly compensate the wealth effect of current bond holdings. In this case, the fiscal rule avoids the transitory distortionary effects that the changes in public spending may have on the decisions of private agents. Consolidation through transfers eliminates the wealth effect and the additional demand impulse associated with the rule, also affecting the response of the labor supply.[8] The fact that the relative volatility of output falls now indicates that consolidation through government spending explains a sizeable part of the relative volatility observed in the benchmark model. Taking the exercises in Models 4, 5 and 6 together indicates that the presence of price inertia allows for a demand effect that may be more or less powerful depending on the

[8] In this case, all variables with the exception of transfers and public debt are independent of the value of α_b^s and j in the fiscal rule. Since public transfers do not appear in the overall resource constraint and public consumption and investment are independent of public debt ($\alpha_b^c = \alpha_b^p = 0$), the log-linearized dynamic model is block-recursive.

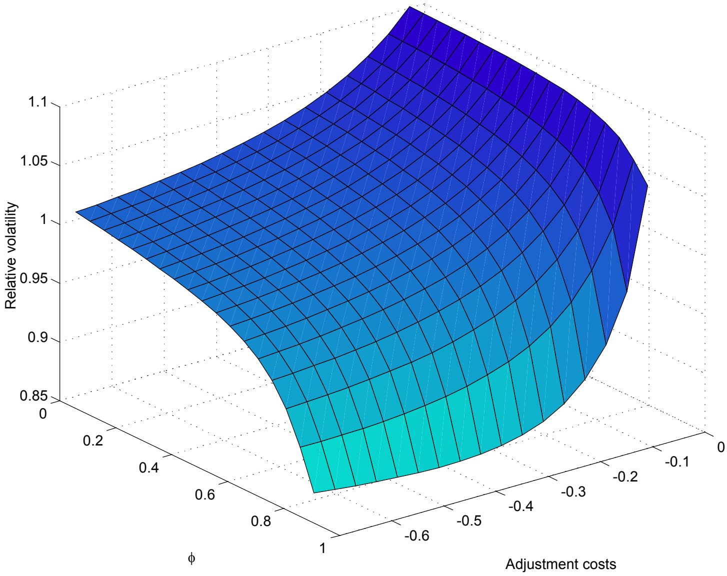

Figure 3: Relative volatility of output (σ_y^d/σ_y^l) for different combinations of price stickiness and investment adjustment costs.

component of public spending that is used to achieve fiscal consolidation as well as on the intensity of the consolidation effort.

Model 7 in Table 3 incorporates the features of models 2, 3 and 6. As expected, this calibration reduces the destabilizing effects of distortionary taxation to a minimum. In this extreme case, the differences in standard deviation are virtually negligible (relative volatility 1.015), although the standard deviation is still smaller with lump-sum taxes.

Finally, we assess the role played by both nominal and real inertia as regards the relative volatility of output. Price inertia is a key feature of the model. A positive supply shock associated with falling prices leads to a smaller real wage increase the slower the adjustment of prices. This weakens the response of labor and hence reduces the strength of the supply channel. A general assessment of the role played by nominal and real rigidities is carried out in Figure 3, which depicts how the relative output volatility evolves as we move from the standard RBC model towards a model with Keynesian features. Two important points must be stressed here. Firstly, In order to avoid a procyclical public consumption or investment, fiscal consolidation is made through transfers. Nevertheless, we have checked that this assumption does not alter the main results of this exercise. Secondly, price inertia or capital adjustment costs have no effects upon steady state values and, therefore, changes in ϕ or in Θ do not affect the capital/output ratio or the size of the economy in the long run. In others words, in this exercise we are sure that changes in the relative volatility of output are driven by variations in absolute volatility since the steady state level of output remains constant in both economies, with distortionary or lump-sum taxes.

Output volatility under distortionary taxes relative to the economy with lump-sum taxes is very high when both price inertia and investment adjustment costs are absent. Therefore, Gali's (1994) results are a particular case in this surface when $\phi = \Theta = 0$. However, high price inertia and capital adjustment costs reduce this ratio. In fact, these two features reinforce each other, and for high values of these two parameters relative volatility is significantly below one. The explanation of this result is the following. High values of ϕ reduce the impact on prices and, therefore,on real wages, making the response of hours after a supply shock also lower. A similar motive happens in the case of higher capital adjustments costs. In this case, the higher the value of Θ the smaller the response of investment and capital to a supply shock and, as before, this effect is more pronounced in the economy with distortionary taxes where the capital to output ratio in steady state is smaller.

Summarizing, there are three main channels trough which taxes affect the volatility of output in an economy with a long-run debt target. Firstly, the conventional demand side argument is that distortionary taxes mitigates the fluctuations of disposable income. Secondly, fiscal consolidation may induce procyclical movements in public consumption and investment. An thirdly, distortionary taxes enhance the volatility of labour and capital. The exercise represented in Figure 3 helps to assess the relative importance of these mechanisms. Since only transfers are used to achieve fiscal consolidation, the second channel does not operate because g^c and g^p are acyclical. In the RBC economy the destabilizing supply effects of distortionary taxation prevails. When nominal and real rigidities are present, the relevance of the demand channel increases, to become the dominant effect when these frictions are sufficiently large.

5 Concluding remarks

The main result of this paper is that distortionary taxes tend to increase output volatility relative to lump-sum taxes unless substantial nominal and real rigidities are present. Although distortionary taxes induce a positive contemporaneous correlation between output and the budget surplus, they may contribute to worsen the output-inflation variance trade-off, as compared with an economy in which public spending is financed through lump-sum taxes. This is a robust result in an economy which reproduces some empirical facts of European countries and departs from a standard RBC model in many respects, therefore generalizing previous findings in the literature.

Other findings are summarized as follows. Firstly, supply channels account for a significant proportion of the destabilizing effects of distortionary taxes. Secondly, automatic stabilizers operating through the demand side of the economy do not compensate the procyclical movements in aggregate supply; on the contrary, they may increase the size of economic fluctuations associated with distortionary taxes.

Finally and more importantly, the strength of nominal and real rigidities is a critical determinant of these results, since relative output volatility is very sensitive to price stickiness and capital adjustment costs. As these rigidities become large, the volatility of output under distortionary taxes falls below that under lump-sum, thus indicating that automatic stabilizers do their best in economies with frictions.

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