Automatic Stabilizers, Fiscal Rules and Macroeconomic Stability *

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European Economy Review (forthcoming)

February, 2005.

Abstract

This paper analyzes the effect of the fiscal structure upon the trade-off between inflation and output stabilization induced by technological shocks in a DGE model with nominal and real rigidities that also integrates a rich menu of fiscal variables as well as a target on the debt to output ratio. The channels trough which fiscal policy affects macroeconomic stability include supply-side effects of distortionary taxes, the procyclical behavior of public spending induced by fiscal rules and the conventional effect of automatic stabilizers operating through disposable (permanent) income. The paper investigates these channels and concludes that, contrary to what has been found in RBC models, distortionary taxes tend to reduce output volatility relative to lump-sum taxes when significant rigidities are present. We also study that the stabilization effect of alternative (distortionary) tax structures and find that these are only relevant if substantial rigidities are present.

Keywords: Fiscal rules, macroeconomic stability, distortionary taxes.

JEL Classification: E32, E52, E63.

1. Introduction

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. In this paper we focus on a potential determinant of that policy trade-off that

* We would like to thank two anonymous referees, Antonio Fatás, Jordi Galí, Giovanni Ganelli, Tommaso Monacelli, Juergen von Hagen and the participants in the CEPR meeting "Political, Institutional and Economic Determinants of Fiscal Policy", the 18th annual congress of the EEA, the 2003 annual meeting of the Royal Economic Society, the XXVIII Simposio of Analsis Económico, the III Workshop on EMU Macroeconomics Institutions and Policies at Milan, the III Complutense International Seminar on European Economy, and the Bank of Spain, University of Valencia and Universty of Glasgow seminars. Financial support by CICYT grant SEC2002-0026 and EFRD is gratefully acknowledged. *Address for comments*: J. Andrés and R. Doménech, Análisis Económico, Universidad de Valencia, 46022 Valencia, Spain. *e-mail*: javier.andres@uv.es and rafael.domenech@uv.es.

has received scant attention so far: distortionary taxes. Textbook macroeconomics tells us that, under a continuous balanced budget, automatic stabilizers built in distortionary taxes are ineffective since public sector expenditure 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. Fiscal arrangements currently in place in Europe and elsewhere are not so tight. Many economists advocate for a cautious use of discretionary fiscal changes and some advanced economies incorporate explicit consolidation rules designed to achieve medium run balanced budget. Still, these rules are compatible with moderate and long-lasting deviations from target to give fiscal stabilizers a chance. Whether or not automatic stabilizers contribute to reduce the volatility of output in such a framework is yet unsettled, although there have been some recent attempts to answer this question (see, for example, Buti, Martinez-Mongay, Sekkat and van den Noord, 2003).

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 the appropriate benchmark to evaluate the stabilization merits of income and consumption taxes. As we describe 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. More importantly, the model allows for real and nominal rigidities, such as investment adjustment costs and sticky prices. These features turn out to be of critical importance to determine the volatility of output in the 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 some 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 realistic tax structure in which public spending is financed resorting to income and consumption taxes.

Section 3 contains the main result of the paper: for reasonable parameterizations of the model, distortionary taxes deliver less output variability than lump-sum ones. This is what text-book Keynesian models of the economy would predict but it is in stark contrast with the results obtained by Galí (1994) in a standard RBC framework. Additionally we show that looking at the correlation between public surpluses and output tells nothing about the stabilization performance of a particular tax structure. In section 4 we look in more detail into the different channels trough which fiscal stabilizers operate in a full-fledged dynamic general equilibrium model. We find that as price stickiness and investment adjustment costs rise, distortionary taxes strengthen employment volatility but tend to reduce the variability of output; also in this case the conventional effect of automatic stabilizers operating through disposable (permanent) income becomes stronger, thus reverting the destabilizing effects of distortionary taxation that is obtained in RBC models. We also find a clear pattern as far as output volatility is concerned among different distortionary tax structures. In models with substantial rigidities, output volatility rises with the tax rate on capital income, whereas this less clear in frictionless RBC models. Finally, section 5 concludes.

2. The model

2.1 Firms and households.

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 is

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

We shall further assume that capital cannot be instantaneously reallocated across firms, so that the marginal costs of firms adjusting prices differ from those not adjusting at time t (see Sbordone, 2002).

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

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

where w_t is the real wage, r_t is the rental cost of capital and κ is a fixed cost which avoids extraordinary profits in steady state. 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 output depends on public capital (k_t^g). The presence of k_t^g 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. We assume that the law of motion of public capital is given by

$$k_{t+1}^g = (1-\delta) k_g^g + g_t^p \tag{9}$$

where g^p is public investment.

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

$$w_t = mc_t(1-\alpha)A_t k_t^{\alpha} l_t^{-\alpha}(k_t^g)^{\theta} \tag{10}$$

$$r_t = mc_t \alpha A_t k_t^{\alpha-1} l_t^{1-\alpha}(k_t^g)^{\theta} \tag{11}$$

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:

$$U(c_t, 1-l_t, g_t^c, g_t^p) = \frac{\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma} - 1}{1-\sigma} + \Gamma(g_t^c, g_t^p) \tag{12}$$

As in Baxter and King (1993), while public spending increases utility it does 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,

$$P_t(1+\tau_t^c)c_t \leq M_t + \tau_t^m \tag{13}$$

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 $t+1$:

$$\begin{aligned} & M_{t+1} + \frac{B_{t+1}}{(1+i_{t+1})} + P_t(1+\tau_t^c)c_t + P_t e_t \\ = \quad & P_t(1-\tau_t^w)w_t l_t + P_t(1-\tau_t^k)r_t k_t + B_t + M_t + \tau_t^m + P_t g_t^s + \int_0^1 \Omega_{it} di \end{aligned} \tag{14}$$

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 $\Phi\left(e_t/k_t\right)$ only a proportion of investment spending goes to increase the capital stock

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

For the installation costs we use the same function as Bernanke, Gertler and Gilchrist (1999).

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 of our model is given by the equations in the Appendix.[2] To close the model monetary policy is represented by a standard Taylor rule:

$$i_t = \rho_r i_{t-1} + (1-\rho_r)\bar{i} + (1-\rho_r)\rho_\pi(\pi_t - \overline{\pi}) + (1-\rho_r)\rho_y \widehat{y}_t + z_t^i \qquad (16)$$

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 empirical evidence indicates that successful consolidations in industrialized countries have been based on spending cuts (see von Hagen, Hughes Hallet and Strauch, 2001, Alesina and Perotti, 1997). Furthermore, 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, 1997, and Guo and Harrison, 2004). Therefore, 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

[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.

Table 1
Calibration of baseline model

σ	β	γ	α	θ	δ	σ_z	ρ_z	ε	κ	Θ	ϕ
1.0	0.9926	0.4316	0.40	0.10	0.021	0.0062	0.80	6.0	0.20	-0.145	0.65
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	0.0	0.0	0.4	0.7	2.0	$1.02^{0.25}$

deviation of the debt to output ratio from its target:

$$\frac{g_t}{\overline{g}} = \left(\frac{b_{t-j}}{y_{t-j}}\frac{\overline{y}}{\overline{b}}\right)^{-\alpha_b}, \qquad \alpha_b \geq 0 \tag{17}$$

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, which has been simulated at a quarterly frequency. 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 1, 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.

The elasticity of output with respect to private capital (α) is 0.4, as in Cooley and Prescott (1995). The output elasticity to public capital (θ) is set to 0.1, within the range of the estimated values obtained by Gramlich (1994) ($0.0 - 0.39$). 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 -0.145. 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

Table 2
Business cycles statistics

	Baseline model				Lump-sum taxes			
x	$\overline{x}$	σ_x/σ_y	ρ_x	ρ_{xy}	$\overline{x}$	σ_x/σ_y	ρ_x	ρ_{xy}
y	1.000	1.00	0.86	1.00	2.187	1.07	0.85	1.00
c	0.527	0.80	0.89	0.97	1.016	0.73	0.89	0.96
e	0.234	2.59	0.85	0.98	0.646	2.32	0.84	0.99
b	2.400	1.26	0.99	-0.09	5.2484	0.04	0.82	0.59
m	0.597	0.80	0.89	0.97	1.011	0.73	0.89	0.95
mc	0.833	0.69	0.55	-0.82	0.833	0.71	0.49	-0.79
q	1.000	0.37	0.84	0.93	1.000	0.33	0.83	0.94
l	0.300	0.38	0.46	-0.74	0.492	0.27	0.37	-0.64
i^1	1.240	0.10	0.92	-0.98	1.240	0.09	0.91	-0.98
r^1	3.600	0.47	0.77	0.24	2.840	0.47	0.70	0.28
w	2.000	0.59	0.94	0.93	2.666	0.52	0.95	0.84
π	1.005	0.08	0.62	-0.90	1.005	0.07	0.57	-0.88
pbs	0.018	0.14	0.88	0.62	0.018	0.10	0.84	-0.85

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

given period $(1-\phi)$ is 0.35, 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 transfers (α_b^s) in the baseline model is set to 0.4. Since transfers are lump-sum, the choice of α_b^s does not have any effect on the dynamics of the variables in the model with the exception of public debt.

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 0.7 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, each producing 200 observations. We take the last 100 observations and compute the averages over the 100 simulations of the steady-state value ($\overline{x}$), the standard deviation of each variable relative to that of output (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.[4] The baseline model reproduces some important business-cycle facts of the European economies. Thus, according to Agresti and Mojon (2001), the standard deviation of output using the HP filter for EMU countries from 1970 to 1999 was 1.0, the autocorrelation of output was 0.86, and the relative standard deviations of consumption and investment were 0.79 and 2.59 respectively. The standard deviation of output is slightly lower in the economy with distortionary taxes (1.00 vs. 1.07). Nevertheless, the relative volatilities of consumption and investment are larger in this than in the model with lump-sum taxes, suggesting that composition effects of the aggregate demand components are important in order to explain output volatility. Since the consolidation is made through public transfers (i.e., $\widehat{g}_t^c = \widehat{g}_t^p = 0$) the deviations of output from its steady state are given by:

$$\widehat{y}_t = \frac{\overline{c}}{\overline{y}}\widehat{c}_t + \frac{\overline{e}}{\overline{y}}\widehat{e}_t \tag{18}$$

In the economy with distortionary taxes the investment to output ratio ($\overline{e}/\overline{y}$) is smaller contributing to reduce output volatility. Also notice that, due to both nominal and real rigidities, the correlation between employment and output is negative in line with the empirical findings of Gali (2004 and 1999) and Rotemberg (2003), who find a negative response of employment after a technology shocks for the U.S. economy. The negative response of employment is larger in the economy with distortionary taxes, helping then to stabilize output to a greater extent that in the economy with lump-sum taxes where employment is less volatile. The mechanism that explains the larger elasticity of employment under distortionary taxation is very simple: income taxes reduce the labor supply and the capital/output ratio in the steady state (Galí, 1994).[5] Therefore, a positive shock

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

[4] As we can see in Table 2, the effects of distortionary taxation on the steady-state values ($\overline{x}$) of the main variables are substantial in comparison to the economy with lump-sum taxes in accordance, for example, with the results of Chari and Kehoe (1999).

[5] 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

to total factor productivity leads to a larger percentage change in the use of the two private productive factors.

The impulse/response functions for these two models in Figure 1 illustrate these results in more detail. The supply shock produces an increase in GDP that leads to a fall in the public debt ratio. 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 budget surplus. This indirect effect through taxes, which induces an additional sharp reduction of the public debt to output ratio, is absent in the economy with constant lump-sum taxes. As a result, the budget surplus is procyclical in the economy with distortionary taxes with a contemporaneous correlation with output equal to 0.62, slightly below the observed correlation for EMU countries from 1970 to 2002 equal to 0.71.[6]

3. 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 first result of the paper: when public spending is financed through distortionary taxes, a given monetary policy delivers less output volatility than with lump-sum taxes.[7] This result is consistent with the conventional wisdom that credits distortionary taxation with a substantial stabilizing role, but it is in stark contrast with the findings in RBC models in which automatic stabilizers built into the distortionary tax system contribute to generate higher output volatility than in an economy with lump-sum taxes. The RBC result crucially depends on the supply side effects of distortionary taxes;

decreasing function of the steady-state labour supply

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

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

[7] As it is standard in the literature, these frontiers are computed varying the coefficient of inflation in the interest rate rule, from 1.2 to 4.0. In all fiscal structures the size of the government relative to GDP is the same.

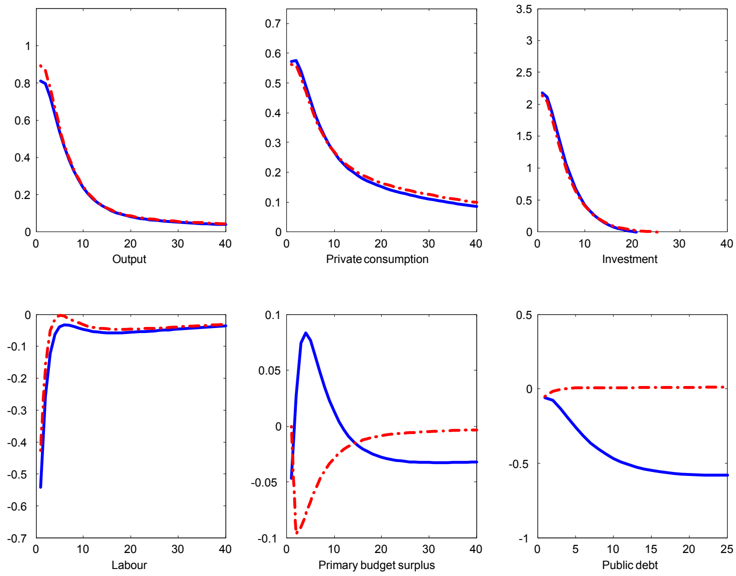

Figure 1: *Impulse-response to a positive supply shock in the baseline model (solid line) and in the economy with lump-sum taxes (dashed line).*

these reduce the level of steady-state employment, capital and output thus increasing the volatility of these variables. As we discuss later, this channel is, along with the enhanced role of more traditional ones operating through the demand side, of great importance to explain the different pattern of volatilities obtained in an economy with nominal and real frictions.

In our baseline economy with distortionary taxes, and in which public transfers respond to the deviations of public debt, the contemporaneous correlation between output and the primary budget surplus (pbs) is positive and very high (0.62) (Table 2). On the contrary, in the economy with lump-sum taxes that correlation is -0.85, since fiscal revenues are constant whereas public expenditures are procyclical due to fiscal consolidation. These correlations should be interpreted with some caution, since they do not imply that procyclical surpluses are unambiguously associated with more output stabilization. As we shall discuss later, the same pattern of correlations arises in the model without rigidities, while in that case distortionary taxation induces more output volatility than lump-sum ones. In other words, the budget surplus is always procyclical with distortionary taxes (and countercyclical in the lump-sum case), but the ability of these automatic stabilizers to dampen output fluctuations depends on the degree of real and nominal rigidities. Thus, unlike what is often asserted, correlations between output

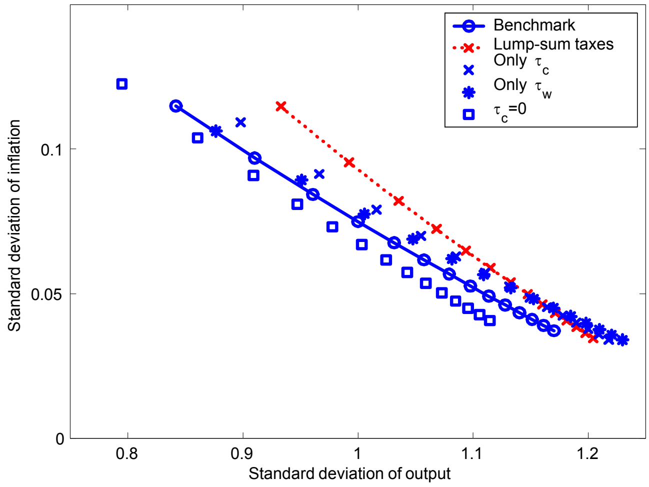

Figure 2: *Standard deviation frontier for alternative tax structures.*

and public deficits at the business cycle frequencies are not informative in assessing the stabilizing effect of automatic stabilizers.[8]

Figure 2 also shows that alternative tax structures affect the position of the IOF (the frontier of the standard deviations of inflation and output). Compared with the benchmark economy, extreme cases of consumption taxation or income taxation lead to some variations in the standard deviation of output for a given standard deviation of inflation. In the case in which public spending is fully financed with taxes on labor income ($\tau_w > 0, \tau_k = \tau_c = 0$) the standard deviation of output rises by a significant amount for high values of the coefficient of inflation in the interest rate rule. We also observe that the IOF is also affected by changes in τ_k.[9]

[8] Most empirical work in this field (see, among others, Auerbach, 2002) proceeds in two steps, first computing the cyclical response of taxes and then multiplying it by the estimated fiscal multipliers. The empirical evidence is that distortionary taxes are associated with high surpluses in booms then, since budget surpluses are meant to reduce output, the implication follows nicely: distortionary taxes help to moderate cyclical fluctuations. Our results do not contradict the evidence since automatic stabilizers exert the expected effect on the budget surplus. However, the ability to reduce the standard deviation of output below the level that would have been achieved with lump-sum taxes depends significantly on the characteristics of the model.

[9] 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.

Table 3 shows the results of some exercises that shed some additional light into the incidence of different tax structures. Holding constant monetary policy parameters ($\rho_\pi = 2.0, \rho_r = 0.7$) and the size of the government as a share of GDP, we compute the standard deviation of output (σ_y), consumption (σ_c) and employment (σ_l) under alternative tax structures. Rows (1) and (2) reproduce the same results of Table 2: the economy with distortionary taxation yields lower volatility of output than the economy with lump-sum taxes as we have explained above, although the volatilities of consumption and employment are higher. In Rows (3) and (4) we maintain the level of indirect taxes as in the baseline ($\tau^c = 0.14$) and change the level of direct taxes between capital and labor taxes. The lower standard deviation of output is obtained in the economy with higher capital income taxes. In this case, both the volatility of employment and capital are higher, but since employment is countercyclical this helps to reduce the volatility of output, at the cost of a higher volatility of consumption. Finally, in rows (5) and (6) we analyze two alternative extreme economies: one in which public expenditure is financed exclusively with an income tax ($\tau^k = \tau^w = 0.41$) and an alternative case where public revenues consist only of indirect taxes ($\tau^c = 0.89$). As in the preceding case, the income tax increases the elasticity of labor supply, reducing the volatility of output and increasing the volatility of consumption, compared with the economy in which the consumption tax is equal to 0.89.[10] Table 3 also shows that the presence of rigidities affects the comparison across tax structures as regards the volatility of consumption and employment. Whereas the volatility of consumption is substantially lower under distortionary taxation than under any other scheme in the RBC economy, this results does not carries over the model with nominal and real inertia, in which all models but model (3) display similar consumption volatilities.

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 employment and capital fluctuations. To gain some insight into the importance of each channel, we carry out some counterfactual exercises which are summarized in Table 4, where we display the standard deviation of output for the economy with lump-sum (σ_y^l) and with

[10] Again, in this case the size of the economy is affected by the tax structure in the expected way: the steady-state level of output is larger when indirect taxes are used instead of income taxes.

Table 3
Output volatility under alternative tax structures

Economy with real and nominal rigidities	σ_y	σ_c	σ_l
(1) Baseline ($\tau^k = 0.21, \tau^w = 0.43, \tau^c = 0.14$)	1.00	0.80	0.37
(2) Lump-sum taxes	1.07	0.78	0.28
(3) $\tau^k = 0.79, \tau^w = 0, \tau^c = 0.14$	0.85	0.96	0.58
(4) $\tau^k = 0, \tau^w = 0.58, \tau^c = 0.14$	1.05	0.75	0.32
(5) $\tau^k = \tau^w = 0.41, \tau^c = 0$	0.95	0.84	0.44
(6) $\tau^k = \tau^w = 0, \tau^c = 0.89$	1.05	0.76	0.31
RBC economy			
(7) Baseline ($\tau^k = 0.21, \tau^w = 0.43, \tau^c = 0.14$)	1.74	0.89	0.72
(8) Lump-sum taxes	1.57	0.75	0.50
(9) $\tau^k = 0.79, \tau^w = 0, \tau^c = 0.14$	1.65	1.54	0.34
(10) $\tau^k = 0, \tau^w = 0.58, \tau^c = 0.14$	1.81	0.80	0.86
(11) $\tau^k = \tau^w = 0.41, \tau^c = 0$	1.71	1.02	0.62
(12) $\tau^k = \tau^w = 0, \tau^c = 0.89$	1.72	0.78	0.72

distortionary taxes (σ_y^d) and their ratio when ρ_π is equal to 2 and ρ_r is equal to 0.7.

Let us first focus on the demand channels. 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. Thus consolidation through transfers eliminates the wealth effect on consumption and on the labor supply. In Model 2 we change the fiscal rule, imposing that the fiscal consolidation is now achieved through the public components of aggregate demand ($\alpha_b^c = \alpha_b^p = 0.4$) instead of transfers ($\alpha_b^s = 0$).[11] The ratio of volatilities changes as compared with the baseline economy (Model 1). The procyclical response of public spending, necessary to prevent public debt from exploding, increases aggregate demand and has very significant effects on the volatility of output.

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 3 in Table 4 differs from Model 2 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

[11] Since public transfers do not appear in the overall resource constraint and public consumption and investment are independent of public debt , the model is block-recursive under $\alpha_b^c = \alpha_b^p = 0$. 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.

quite long time before the real debt returns to its steady-state value after a technological shock. The relative volatility falls in this case from 0.96 to 0.94.

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 (17). 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 4 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 ($\sigma_y^d/\sigma_y^l = 0.95$). The results of Model 1 to 4 confirm the relevance of demand channels through which the tax system affects volatility in the presence of price inertia; the strength of this is channel depends on the component of public spending that is used to achieve fiscal consolidation as well as on the intensity of the consolidation effort.

Now we focus on the supply channels. As we discussed earlier, these channels are of great importance and arise because we are taking into account both the steady-state and the business cycle effects of taxes. Distortionary taxes enhance the volatility of labor supply and capital accumulation. 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 magnify the cyclical deviations 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 capital, which moves along with public revenues according to the fiscal rules in the model.

In Model 5 all parameters are as in Model 2 except for an (almost) inelastic labor supply ($\gamma \approx 1$), which makes the economy more unstable, regardless of the tax structure. Under this assumption, the gap between economies with lump-sum taxation and those with distortionary taxes narrows significantly; thus, roughly half of the additional stabilizing 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 6, reduces only very slightly the volatility of output observed in Model 2 particularly in the economy with distortionary taxes, affecting the ratio σ_y^d/σ_y^l.

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 employment and hence reduces the

Table 4
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 (*baseline economy*) $(\gamma = 0.45, \theta = 0.1, \alpha_b^c = \alpha_b^p = 0, \alpha_b^s = 0.4)$	1.07	1.00	0.94
Model 2: Fiscal rule in g^c and g^p $(\alpha_b^c = \alpha_b^p = 0.4, \alpha_b^s = 0)$	1.097	1.05	0.96
Model 3: Consolidation effort $(\alpha_b^c = \alpha_b^p = 0.2, \alpha_b^s = 0)$	1.087	1.02	0.94
Model 4: Delayed consolidation $(\alpha_b^c = \alpha_b^p = 0.4, \alpha_b^s = 0, j = 8)$	1.08	1.03	0.95
Model 5: Inelastic labor supply $(\gamma \simeq 1)$	1.18	1.15	0.98
Model 6: TFP independent of k^g $(\theta = 0)$	1.09	1.00	0.92

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, considering a large range of parameter combinations of both rigidities. Two important points must be stressed here. Firstly, in order to avoid a procyclical public consumption or investment, fiscal consolidation is made through transfers, as in our baseline economy. 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. Thus, in this exercise, changes in the relative volatility of output are only driven by variations in absolute volatilities.

Output volatility under distortionary taxes relative to the economy with lump-sum taxes (σ_y^d/σ_y^l) is above one when both price inertia and investment adjustment costs are absent. This is consistent with Galí's (1994) results since his model is represented by a particular case in the surface depicted in Figure 3 ($\phi = \Theta = 0$) and in row (11) of Table 3, with an income tax. Rows (7) to (12) of Table 3 generalize this result: output volatility in the RBC economy under lump-sum taxes is lower ($\sigma_y^l = 1.57$) than under any other fiscal structure with distortionary taxes, a finding which can be extended also

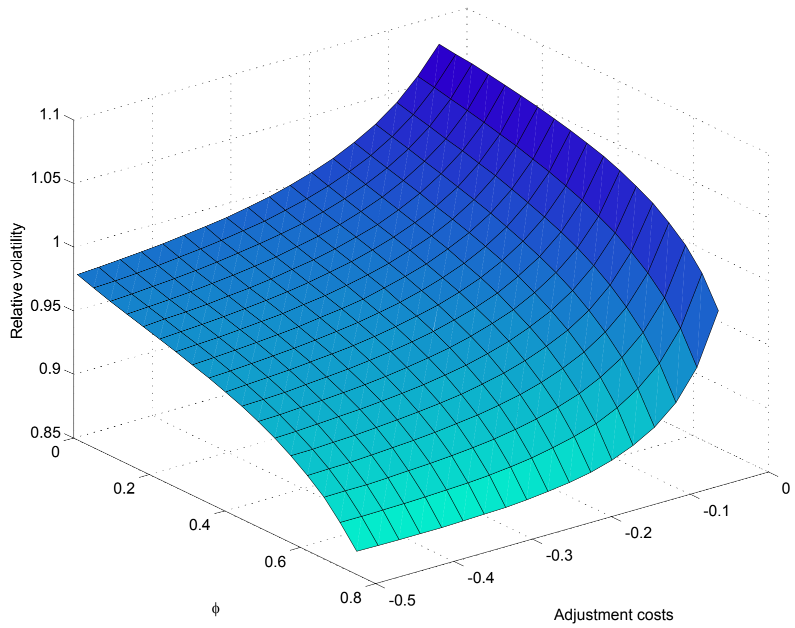

Figure 3: *Relative volatility of output (σ_y^d/σ_y^l) for different combinations of price stickiness and investment adjustment costs.*

to consumption volatility.

However, high price inertia and capital adjustment costs reduce this ratio. In particular, these two features reinforce each other, and for high values of these two parameters relative volatility is significantly below one, so that automatic stabilizers become effective. The explanation of this result is the following. Distortionary taxes always make employment more elastic than under lump-sum taxes because taxes on labor income increase the demand for leisure in the steady state. In the RBC economy, where rigidities are absent, the response of employment after a technology shock is positive. Therefore, the higher procyclical response of employment implies a higher output volatility under distortionary taxes than under lump-sum taxes. However, high values of ϕ reduce the impact on prices and, therefore, on real wages, lowering the response of hours after a supply shock. In fact, the response of employment is negative for high values of ϕ. The intuition of this countercyclical movement of employment is simple and consistent with the empirical evidence of Rotemberg (2003). The larger the nominal rigidities, the lower the increase in the demand of goods, and this means that, for a higher level of productivity, employment has to go down, since the demand of labor is lower. Despite this short-run fall on employment, forward looking households will increase their consumption since permanent income rises as a result of the technology shock. This wealth effect also reduces the labor supply since it increases the demand of leisure. Therefore, the result is lower employment and higher real wage. Again, as this effect is bigger in the economy with distortionary taxes because labor supply is more elastic, the countercyclical response of employment helps to stabilize output fluctuations and to reduce relative output volatility.

Higher capital adjustments costs reinforces this mechanism. 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. And thirdly, distortionary taxes amplify the volatility of employment 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 supply side channel is still powerful, but since employment falls on impact it works in the opposite direction reducing output volatility under distortionary taxation. Also, larger rigidities give a more prominent role to the fluctuations in aggregate demand, which are mitigated under distortionary taxation. The first, more conventional, channel is strengthened and the third, supply side one, is reversed in economies with large rigidities, making automatic stabilizers truly operative.

Table 3 also shows the incidence of rigidities on the comparison across alternative distortionary tax structures. Output volatility is always higher in the frictionless economy, but the differences across alternative tax structures are smaller.

5. Concluding remarks

Taxes on income are known to have negative steady state effects reducing the amount of capital and labor used in an economy and also output. In RBC models, these taxes also lead to greater volatility of output than lump-sum taxes. These results extend to the comparison with fiscal structures with taxes on consumption, and labor and capital incomes at different rates. The main result of this paper is that these results are reversed when substantial nominal and real rigidities are present. Distortionary taxes induce a positive contemporaneous correlation between output and the budget surplus and, under some particular circumstances, as the ones we have analyzed, they may contribute to improve 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.

We also find a clear pattern as far as output volatility is concerned among different distortionary tax structures. Output volatility rises with the tax rate on capital income. High labor income and/or consumption taxes increase the volatility of employment, thus reducing that of output since labor supply is countercyclical in economies with substantial rigidities. This pattern is much less pronounced in frictionless RBC models in which alternative fiscal systems with distortionary taxes have little effect on output volatility.

Other findings are summarized as follows. First, supply channels account for a significant proportion of the destabilizing effects of distortionary taxes. Second, the way fiscal consolidation affects 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.

6. Appendix

The aggregate symmetric equilibrium of our model is given by the following equations:

$$k_{t+1} = \Phi\left(\frac{e_t}{k_t}\right)k_t + (1-\delta)k_t \tag{19}$$

$$\lambda_t = \frac{\gamma\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma}}{(1+\tau_t^c)(1+i_{t+1})c_t} \tag{20}$$

$$\lambda_t(1-\tau_t^w)w_t = \frac{(1-\gamma)\left(c_t^{\gamma}(1-l_t)^{1-\gamma}\right)^{1-\sigma}}{(1-l_t)} \tag{21}$$

$$\lambda_t\beta^{-1} = E_t\left(\lambda_{t+1}\frac{1+i_{t+1}}{\pi_{t+1}}\right) \tag{22}$$

$$q_t = \left[\Phi'\left(\frac{e_t}{k_t}\right)\right]^{-1} \tag{23}$$

$$\frac{q_t}{\beta} = E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left((1-\tau_{t+1}^k)r_{t+1} + q_{t+1}\left[\Phi\left(\frac{e_{t+1}}{k_{t+1}}\right) + (1-\delta) - \Phi'\left(\frac{e_{t+1}}{k_{t+1}}\right)\frac{e_{t+1}}{k_{t+1}}\right]\right)\right\} \tag{24}$$

$$\frac{M_t}{P_t} + \frac{\tau^m}{P_t} = (1+\tau_t^c)c_t \tag{25}$$

$$w_t = mc_t(1-\alpha)A_t k_t^{\alpha} l_t^{-\alpha}(k_t^g)^{\theta} \tag{26}$$

$$r_t = mc_t\alpha A_t k_t^{\alpha-1} l_t^{1-\alpha}(k_t^g)^{\theta} \tag{27}$$

$$\widetilde{P}_t = \frac{\varepsilon}{\varepsilon-1}\frac{\sum_{j=0}^{\infty}(\beta\phi)^j E_t\left[\rho_{t,t+j}P_{t+j}^{\varepsilon+1}mc_{t+j}y_{t+j}\overline{\pi}^{-j\varepsilon}\right]}{\sum_{j=0}^{\infty}(\beta\phi)^j E_t\left[\rho_{t,t+j}P_{t+j}^{\varepsilon}y_{t+j}\overline{\pi}^{j(1-\varepsilon)}\right]} \tag{28}$$

$$P_t = \left[\phi\left(\overline{\pi}P_{t-1}\right)^{1-\varepsilon} + (1-\phi)\widetilde{P}_t^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{29}$$

$$\pi_t \equiv \frac{P_t}{P_{t-1}} \tag{30}$$

$$P_t\tau_t^w w_t l_t + P_t\tau_t^k r_t k_t + P_t\tau_t^c c_t - P_t(g_t^c + g_t^p + g_t^s) = -\frac{B_{t+1}}{(1+i_{t+1})} + B_t - M_{t+1} + M_t \tag{31}$$

$$y_t = c_t + e_t + g_t^c + g_t^p \tag{32}$$

$$y_t = A_t k_t^{\alpha} l_t^{1-\alpha}(k_t^g)^{\theta} - \kappa \tag{33}$$

$$k_{t+1}^g = g_t^p + (1-\delta)k_t^g \tag{34}$$

$$\frac{E_t\rho_{t,t+j}}{E_t\rho_{t,t+j-1}} = \frac{E_t(\lambda_{t+j}/P_{t+j})}{E_t(\lambda_{t+j-1}/P_{t+j-1})} \tag{35}$$

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.

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