Nominal rigidities and the effects of government spending shocks

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Abstract

This paper extends a standard dynamic general equilibrium model with price and wage rigidities in order to account for recent evidence on the response of macroeconomic variables to fiscal shocks. The model is augmented with two features: consumer preferences depend on government expenditures and public spending is productivity enhancing. Calibration of the model shows that, for alternative monetary policy rules and for plausible assumptions on the degree of complementarity between private and public expenditures and on the output elasticity of public spending, the effects of fiscal shocks predicted by the model are in line with the evidence.

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1 Introduction

New Neoclassical Synthesis models, also labelled New Keynesian models, have recently imposed themselves as the benchmark model used by monetary policy decision makers. They add to the Real Business Cycle framework, characterized by optimizing agents and rational expectations, Keynesian features such as monopolistic competition and nominal rigidities. The latter imply that inflation is forward looking, as firms and households are subject to limits on the frequency with which they are allowed to reset prices and wages and therefore need to plan ahead. If NNS models have proved very useful in the analysis of monetary policy, more controversial is their ability to describe realistically the transmission mechanism of fiscal policy, in particular the consequences of changes in public spending.

The issue of the effects of increases in public purchases on the economy has been widely debated in macroeconomics both from a theoretical and an empirical point of view. RBC and Keynesian models reach different conclusions on the matter. In both classes of models increases in public purchases cause a rise in output. However, in RBC models a fiscal shock produces a decline in consumption and real wages [1], while in Keynesian models the same shock typically leads to a rise in the same variables. The difference is due to the fact that in the RBC framework an increase in government spending causes a negative wealth effect while in the Keynesian setting consumption is crowded in due to the positive marginal propensity to consume.

Recent empirical studies seem to support the Keynesian view. Fatas and Mihov (2001), who analyze US data in a vector autoregression framework, find that increases in government expenditure are followed by a rise in consumption, investment and employment and a decline in real wages. The study by Blanchard and Perotti (2002) for the post-war US economy reaches similar conclusions: a shock in government spending causes output and private consumption to rise (however, private investment is crowded out). Marattin and Salotti (2011) apply a panel vector autoregression approach to EU countries and find evidence of a positive effect of increases in government spending on both private consumption and investment. In Burnside, Eichenbaum and Fisher (2004), who build on Ramey and Shapiro (1998), focusing on changes in defence spending, public spending increases raise output and private investment, without having a significant effect on private consumption. Finally, Mountford and Uhlig (2002) find that both residential and non-residential investment are lowered by a positive fiscal shock and that

[1] See, for example, Baxter and King (1993), Ludvigson (1996) and Edelberg, Eichenbaum and Fisher (1999).

private consumption does not change significantly. In conclusion, while results differ concerning the effects of government spending shocks on private investment, it is generally found that an increase in public purchases either increases or leaves private consumption almost unchanged.
A number of New Neoclassical Synthesis models have been developed in order to account for this evidence. Gali', Lopez-Salido and Valles (2007) build a model with sticky prices and rule of thumb consumers (i.e. consumers who each period spend their entire labor income without borrowing or saving) and show that under certain conditions the framework is consistent with the data. Linnemann (2004) demonstrates that in a model allowing for an unemployment insurance system accompanied by distortionary taxation consumption rises after a fiscal shock.
This paper aims to assess the effects of changes in government spending on the economy using a New Keynesian framework and assuming that government purchases directly affect agents' behaviour. The first hypothesis analyzed is that of productive government purchases: public spending enters the production function. The empirical relevance of this assumption has been tested in a number of studies estimating the elasticity of output with respect to public capital, whose main motivation is to provide an assessment of the hypothesis that the productivity slowdown in the United States dating from the 1970's has been caused by an under-investment in public capital. Aschauer (1989) and Lynde and Richmond (1993) find evidence of a significant contribution of public capital to productivity. Ai and Cassou (1995) estimate smaller values of public capital elasticity but, making use of a cost-benefit approach, conclude that the benefit of a marginal public capital expenditures is greater than its cost. From a theoretical point of view, Baxter and King (1993) analyze the impact of permanent and temporary changes in government spending within a RBC framework, finding that public investment increases dramatically both output and private investment.
Secondly, the implications of a relationship of substitutability or complementarity between private and public consumption are discussed. Bailey (1971) and Barro (1981) first introduced the idea that government and private spending are imperfect substitutes. This view is supported by an empirical study by Aschauer (1985), who provides evidence in favor of the hypothesis of substitutability. However, recent studies are more supportive of the hypothesis of complementarity. For instance, Karras (1994) argues that together with publicly provided goods and services which act as substitutes for private consumption, there are forms of government spending, e.g. public spending on transportation, which are complementary to private consumption and others which are both. His results suggest that public and private consumption must be regarded as complementary or unrelated. Evans and

Karras (1996) and Obuko (2003) also support complementarity while Amano and Wirjanto (1998) conclude that, given the weak degree of complementarity, the two variables are unrelated.
The paper is organized as follows. Section 2 presents a New Neoclassical Synthesis model with sticky prices and wages, in which government spending enters the production function and which allows for a degree of substitutability or complementarity between private consumption and public spending. Section 3 describes the equilibrium, section 4 gives details on the solution method and discusses the values given to the parameters and section 5 presents the results. Section 6 concludes.

2 The model

The model described in this section is a standard dynamic general equilibrium model with staggered prices and wages in which productive government spending is introduced. Firms produce differentiated goods and set prices according to the Calvo (1983)-Yun (1996) model and households offer differentiated labor services setting wages through the same mechanism adopted by firms. The government sector consists of a central bank and a fiscal authority. Lower-case letters denote real variables, while upper-case letters refer to nominal variables, with the exception of the nominal interest rate r_t. A hat on lower-case letters denotes logarithms of variables or their deviations from steady state.

2.1 Firms

Firms are monopolistically competitive and produce differentiated goods denoted by $y_t(i)$, where i $\in [0,1]$. The goods are combined into an output index making use of a CES technology:

$$y_t = \left[\int_0^1 y_t(i)^{\frac{1}{1+\eta_p}} di \right]^{1+\eta_p} \tag{1}$$

where y_t is the output index and $\eta_p > 0$ the price markup rate. The output index is then sold at the price

$$P_t = \left[\int_0^1 P_t(i)^{-\frac{1}{\eta_p}} di \right]^{-\eta_p} \tag{2}$$

The minimization of the production cost of y_t yields the demand function for the good produced by firm i, $y_t(i)$:

$$y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\frac{1+\eta p}{\eta p}} y_t \tag{3}$$

Firms share the same level of technology x_t and produce goods according to the Cobb-Douglas production function

$$y_t(i) = x_t k_t(i)^{\alpha} l_t(i)^{1-\alpha} g_t^{\xi} \tag{4}$$

where g_t represents government spending, $k_t(i)$ private capital and $l_t(i)$ the labor services supplied by households. α, $(1-\alpha)$ and ξ are the shares of the three inputs in the production function, which exhibits constant returns to scale with respect to the private inputs. The way government spending enters the production function follows Barro (1990). The government purchases a flow of services which are then made available to the private sector[2]. Firms minimize cost with respect to labor and private capital subject to (4) and take the nominal wage W_t and the rental cost of capital R_t^k as given. g_t is exogenously supplied by the government and includes both government consumption and government investment. Government spending contributes to the production process enhancing the productivity of both private capital and labor. As noted by Barro (1981), government expenditures with these features are, for example, the provision of a legal system, national defense and education. Finally, as pointed out by Canzoneri, Cumby and Diba (2005), the inclusion of public capital in the production function is particularly important as it provides the economy with one more way of reacting to shocks. The producers have the same aggregate factor demand functions given by

$$W_t = mc_t(1-\alpha) x_t g_t^{\xi} k_t^{\alpha} l_t^{-\alpha} \tag{5}$$

and

$$R_t^k = mc_t \alpha x_t g_t^{\xi} k_t^{-(1-\alpha)} l_t^{1-\alpha} \tag{6}$$

The individual firm resets the price of the good produced with probability $(1-\chi)$, as in Calvo (1983). It is assumed that χ is independent of the state of nature and of the timing of the last price adjustment and that $0 \leq \chi < 1$, implying complete price flexibility when $\chi = 0$. Following Yun (1996), prices which are not reset are increased at the rate of inflation Π, such that

$$P_{t+k}(i) = \Pi^k P_t(i) \tag{7}$$

[2] An alternative formulation of the production function would include the public capital stock instead of the government spending flow.

Consequently,

$$P_t = \left[(1-\chi)(P_t^*)^{-\frac{1}{\eta_p}} + \chi(\Pi P_{t-1})^{-\frac{1}{\eta_p}} \right]^{-\eta_p} \tag{8}$$

where P_t^* is the price chosen by the firm. Whenever the firm cannot reset its price, the price of the good is equal to the price set in the previous period increased at the rate Π[3]. Therefore, the following profit function is maximised by firms:

$$E_t \sum_{k=0}^{\infty} \chi^k \vartheta_{t,t+k} \left[(1+\zeta_p)\Pi^k P_t(i) y_{t+k}(i) - mc_{t+k} y_{t+k}(i)) \right] \tag{9}$$

where ζ_p is a subsidy to production paid by the government. The first order condition is given by:

$$E_t \sum_{k=0}^{\infty} \chi^k \vartheta_{t,t+k} \left[\left(\frac{1+\zeta_p}{1+\eta_p} \Pi^k P_t(i) - mc_{t+k} \right) \right] y_{t+k}(i) = 0 \tag{10}$$

2.2 Households

A continuum of households indexed by $j \in [0,1]$ offer differentiated labor services, denoted by $n_t(j)$, to firms. The sum of firms' demands for labor is equal to the labor index l_t:

$$l_t = \left[\int_0^1 n_t(j)^{\frac{1}{1+\eta_w}} dj \right]^{1+\eta_w} \tag{11}$$

with $\eta_w > 0$. The labor index is then bought by producers at the price

$$W_t = \left[\int_0^1 W_t(j)^{-\frac{1}{\eta_w}} dj \right]^{-\eta_w} \tag{12}$$

The total demand for the individual household labor is then

$$n_t(j) = \left[\frac{W_t(j)}{W_t} \right]^{-\frac{1+\eta_w}{\eta_w}} l_t \tag{13}$$

The utility function is separable in consumption, leisure and real money balances and can be written as:

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ U[c_{t+k}(j)] - V[n_{t+k}(j)] + Z\left[\frac{M_{t+k}(j)}{P_{t+k}} \right] \right\} \tag{14}$$

[3] See e.g. Yun (1996) and Erceg, Henderson and Levin (2000).

where E_t is the expectation operator at time t, β is the discount factor, c denotes consumption and M the nominal money balances. The components of the utility function take the following form:

$$U[c_t(j)] = \frac{1}{1-\sigma}[c_t(j)]^{1-\sigma} \tag{15}$$

$$V[n_t(j)] = \frac{1}{1+\psi}[n_t(j)]^{1+\psi} \tag{16}$$

$$F\left[\frac{M_t(j)}{P_t}\right] = \frac{\nu}{1-\mu}\left[\frac{M_t(j)}{P_t}\right]^{1-\mu} \tag{17}$$

The constant ν measures the weight of real money balances in the utility function. Households spend their labor income and their share of profits to consume, to purchase bonds and increase their money holdings. The consumers' budget constraint is given by:

$$P_t c_t(j) + P_t i_t(j) + M_t(j) + R_{t,t+1}B_t(j) = M_{t-1}(j) + B_{t-1}(j) + \tag{18}$$

$$+R_t^k k_t(j) + W_t(j)n_t(j) + \Lambda_t(j) - P_t t_t(j)$$

where $k_t(j)$ is capital, $i_t(j)$ is investment, $B_t(j)$ the quantity of bonds held by household j, t_t lump-sum taxation and $\Lambda_t(j)$ the dividends received by households. To rule out arbitrage opportunities, a stochastic discount factor $R_{t,t+1} = \frac{1}{1+r_t}$ is introduced, implying that $R_{t,t+1}B_t(j)$ is the current market price of a portfolio that will pay a nominal value of $B_t(j)$ at the end of time t. The household also earns labor income $W_t(j)n_t(j)$ and capital income $R_t^k k_t(j)$. Capital is accumulated according to the equation

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

where δ is the depreciation rate and $\Phi\left(\frac{i_t}{k_t}\right)$ is the adjustment cost function, with $\Phi'\left(\frac{i_t}{k_t}\right) > 0$ and $\Phi''\left(\frac{i_t}{k_t}\right) \leq 0$. Households maximize (14) with respect to consumption, private capital, investment, bonds and money holdings subject to (13), (18) and (19). The first order conditions with respect to k_{t+1} and i_t are given by:

$$E_t\left\{R_{t+1}^k + P_{t+1}q_{t+1}\left[\Phi\left(\frac{i_{t+1}}{k_{t+1}}\right) - \Phi'\left(\frac{i_{t+1}}{k_{t+1}}\right)\left(\frac{i_{t+1}}{k_{t+1}}\right) + (1-\delta)\right]\right. \tag{20}$$

$\frac{1}{P_t q_t}\Bigg\} = E_t[R_{t,t+1}]$

and

$$q_t = \frac{1}{\Phi'\left(\frac{I_t}{k_t}\right)} \tag{21}$$

The combination of the first order conditions for consumption and bonds yields the Euler equation

$$c_t^{-\sigma} = E_t\left[\beta(1+i_t)(c_{t+1})^{-\sigma}\frac{P_t}{P_{t+1}}\right] \tag{22}$$

The index j is omitted as identical preferences and complete contingent claims markets are assumed, which implies that all households will choose the same path of consumption. Households reset their wages with probability $(1-\phi)$, on the basis of a mechanism analogous to the one through which firms set their prices. Therefore, whenever a household is allowed to reset its wage, it maximizes the utility function (14) with respect to W_t. Assuming that whenever a household cannot reset its wage, which happens with probability ϕ, the latter is increased at the gross rate of inflation Π, the first order condition is given by:

$$E_t \sum_{k=0}^{\infty} \phi^k \beta^k \left[n_{t+k}(j)]^{\psi} + \frac{1+\zeta_w}{1+\eta_w}\frac{\Pi^k W_t(j)}{P_{t+k}} c_{t+k}^{-\sigma}\right] n_{t+k}(j) = 0 \tag{23}$$

where ζ_w is a subsidy to employment.

2.3 Public sector and market clearing

The central bank sets the interest rate following a variant of the Taylor (1993) rule (according to which the nominal interest rate r_t is a linear function of the gap between the inflation rate and the inflation target and of the gap between real output and trend output):

$$r_t = (1-\rho)\gamma_\pi \pi_t + (1-\rho)\gamma_y y_t + \rho r_{t-1} + \varepsilon_{t,m} \tag{24}$$

where γ_π and γ_y are the coefficients on the inflation and output gaps, $\varepsilon_{t,m}$ is an i.i.d. monetary policy shock and the parameter ρ is introduced to capture the tendency of central banks to adjust the interest rate only very slowly[4]. The government budget constraint is given by:

$$R_{t+1,t}B_t + P_t t_t = B_{t-1} + P_t g_t \tag{25}$$

[4]See Clarida, Gali' and Gertler (2000).

In addition, to ensure that the government budget constraint is satisfied at all times a no-Ponzi condition is imposed:

$$lim \frac{B_{t+T}}{\prod_{j=0}^{T}(1+r_{t+j})} = 0 \tag{26}$$

Following Chadha and Nolan (2003) and neglecting the role of seigniorage revenue, it is assumed that taxes evolve according to the following rule:

$$t_t = \theta_1 \frac{B_{t-1}}{P_t} + \theta_2 g_t \tag{27}$$

where θ_1 is the fraction of public debt reimbursed every period and θ_2 is the proportion of government spending backed by taxes. Therefore, when $\theta_2 = 1$ public spending is entirely funded by new taxes, while if $\theta_2 = 0$ any increase in government purchases is totally deficit-financed. The budget constraint and the fiscal rule are combined into the following equation:

$$R_{t+1,t} B_t = (1-\theta_1) B_{t-1} + (1-\theta_2) P_t g_t \tag{28}$$

describing the evolution of debt over time. Government spending follows a first order autoregressive process, which in log-linearized terms is:

$$g_t = \rho_g g_{t-1} + \varepsilon_{t,g} \tag{29}$$

where $\varepsilon_{t,g}$ is an i.i.d. shock with constant variance $\sigma^2_{\varepsilon_g}$. Finally, clearing of all markets requires:

$$y_t = c_t + i_t + g_t \tag{30}$$

2.4 Utility and government spending

The utility function is here modelled in order to incorporate government expenditures, taking the following form:

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ U[c_{t+k}(j)^*] - V[n_{t+k}(j)] + Z\left[\frac{M_{t+k}(j)}{P_{t+k}}\right] + \Gamma[g_t] \right\} \tag{31}$$

where $c_t(j)^*$ denotes effective consumption given by $c_t(j)^* = c_t(j) + \varrho g_t$, according to the formulation first suggested by Bailey (1971). However, the assumption $0 < \varrho < 1$, stating the existence of a degree of substitutability between private and government consumption, is dropped. Following Karras (1994), ϱ is allowed to take negative values, implying that a rise in public consumption increases the marginal utility of private consumption and

therefore that the two variables are complementary[5]. In order to avoid that the marginal utility of government consumption is forced to assume negative values, the term $\Gamma[g_t]$ has been added to the utility function. It is further assumed that $\frac{\partial \Gamma}{\partial g}$ is positive and that the consumers treat public expenditures as exogenous.
The maximization of utility gives the Euler equation:

$$(c_t + \varrho g_t)^{-\sigma} = E_t\left[\beta(1+i_t)(c_{t+1} + \varrho g_{t+1})^{-\sigma}\frac{P_t}{P_{t+1}}\right] \tag{32}$$

and the marginal rate of substitution is equal to

$$mrs_t = \frac{(c_t + \varrho g_t)^{-\sigma}}{n_t^{\psi}} \tag{33}$$

3 Equilibrium

The equilibrium conditions are then log-linearized around the steady state, obtaining a system in the 13 endogenous variables $\{\hat{y}_t, \hat{c}_t, \hat{i}_t, \hat{k}_t, \hat{l}_t, \hat{r}_t, \hat{r^k_t}, \hat{\pi}_p, \hat{\pi_w}, \hat{w}_t, \widehat{mrs}_t, \widehat{mc}_t, \hat{q}_t\}$, where a hat over lower case letters indicates the log-deviations of the variables from the steady state.

3.1 Firms

The log-linearization of the production function (4) and of the factor demand functions (5) and (6) yields:

$$\hat{y}_t = \hat{x}_t + (1-\alpha)\hat{l}_t + \alpha\hat{k}_t + \xi\hat{g}_t \tag{34}$$

$$\hat{w}_t - \hat{p}_t = \widehat{mc}_t + \hat{x}_t - \alpha\hat{l}_t + \alpha\hat{k}_t + \xi\hat{g}_t \tag{35}$$

$$\hat{r^k_t} - \hat{p}_t = \widehat{mc}_t + \hat{x}_t + (1-\alpha)\hat{l}_t - (1-\alpha)\hat{k}_t + \xi\hat{g}_t \tag{36}$$

Equation (8) is linearized around the steady state, giving:

$$\hat{p}_t = (1-\chi)\hat{p^*_t} + \chi\hat{p_{t-1}} \tag{37}$$

Considering that the relationship between nominal and real marginal cost, in log-linearized terms, is:

$$\widehat{MC}_t = \widehat{mc}_t + \hat{p}_t \tag{38}$$

[5] In the Auspitz-Lieben-Edgeworth-Pareto sense, see McCulloch (1977).

and with a number of further substitution, the following equation describing the dynamics of inflation is obtained:

$$\hat{\pi}_t = \beta E_t \widehat{\pi_{t+1}} + k_p \widehat{mc_t} \tag{39}$$

where $k_p = \frac{(1-\beta\eta_p)(1-\eta_p)}{\eta_p}$. This is the New Keynesian Phillips curve, linking current inflation to expected inflation and to the marginal cost.

3.2 Households

In steady state, the Euler equation (22) reduces to $\beta(1+\overline{R}) = 1$. Using this result, the first order condition is then linearized yielding:

$$\hat{c}_t = E_t[\widehat{c_{t+1}}] - \frac{1}{\sigma}(\hat{r}_t - \widehat{\pi_{t+1}}) \tag{40}$$

The log-linearization of the capital accumulation equation (19) yields:

$$\widehat{k_{t+1}} = \delta \hat{i}_t + (1-\delta)\hat{k}_t \tag{41}$$

Given that in steady state $\frac{\overline{I}}{\overline{K}} = \delta$ and assuming that $\Phi(\delta) = \delta$ and $\Phi'(\delta) = 1$, the log-linearized first order condition (20) is:

$$\hat{q}_t = [1-\beta(1-\delta)]E_t[\widehat{r^k_{t+1}} - \widehat{p_{t+1}}] - \hat{r}_t + E_t[\widehat{\pi_{t+1}}] + \beta E_t[\widehat{q_{t+1}}] \tag{42}$$

while (21) becomes:

$$\hat{i}_t = -\frac{\Phi'\left(\frac{\hat{i}_t}{\hat{k}_t}\right)}{\Phi''\left(\frac{\hat{i}_t}{\hat{k}_t}\right)}\frac{\overline{K}}{\overline{I}}\hat{q}_t + \hat{k}_t \tag{43}$$

The log-linearized wage setting rule is:

$$\Delta\hat{w}_t = \beta E_t[\Delta\widehat{w_{t+1}}] + k_w[\widehat{mrs}_t - (\hat{w}_t - \hat{p}_t)] \tag{44}$$

where

$$\widehat{mrs}_t = \sigma\hat{c}_t + \psi\hat{l}_t \tag{45}$$

Real wage changes over time according to:

$$\hat{w}_t - \hat{p}_t = \widehat{w_{t-1}} - \widehat{p_{t-1}} + \Delta\hat{w}_t - \hat{\pi}_t \tag{46}$$

Finally, the log-linearized Euler equation (32) and marginal rate of substitution (33) obtained assuming a direct effect of government spending on private consumption are:

$$\hat{c}_t = E_t[\widehat{c_{t+1}}] - \frac{1}{\sigma \bar{l}_c}(\hat{r}_t - \widehat{\pi_{t+1}}) + \varrho \frac{\bar{l}_g}{\bar{l}_c}(\widehat{g_{t+1}} - \hat{g}_t) \tag{47}$$

and

$$\widehat{mrs}_t = \sigma l_c \hat{c}_t + \sigma \varrho l_g \hat{g}_t + \psi \hat{l}_t \tag{48}$$

with $l_c = \frac{\overline{C}}{\overline{C}+\varrho\overline{G}}$ and $l_g = \frac{\overline{G}}{\overline{C}+\varrho\overline{G}}$.

3.3 Market clearing and technology shock

The linearized market clearing relation is:

$$\hat{y}_t = \frac{\bar{C}}{\bar{Y}}\hat{c}_t + \frac{\bar{I}}{\bar{Y}}\hat{i}_t + \frac{\bar{G}}{\bar{Y}}\hat{g}_t \tag{49}$$

The technology shock evolves according to the first order autoregressive process:

$$\hat{x_t} = \rho_x \hat{x_{t-1}} + \varepsilon_{t,x} \tag{50}$$

where $\varepsilon_{t,x}$ is an i.i.d. shock with variance σ_x^2.

4 Calibration

In this section, the values assigned to the parameters will be briefly discussed. Most values are taken from Erceg, Henderson and Levin (2000): the discount factor β is set equal to 0.99, σ equal to 1.5 and the capital share in the production function is $\alpha = 0.3$. The price and wage markup rates η_p and η_w are set equal to 1/3. The wage contract duration parameter is $\phi = 0.75$, implying that the average duration of a contract is 1 year. However, the parameter χ is set equal to 0.5 as in Benigno and Woodford (2004). The depreciation rate of capital is $\delta = 0.025$ and the persistence of the government spending shock is 0.9.

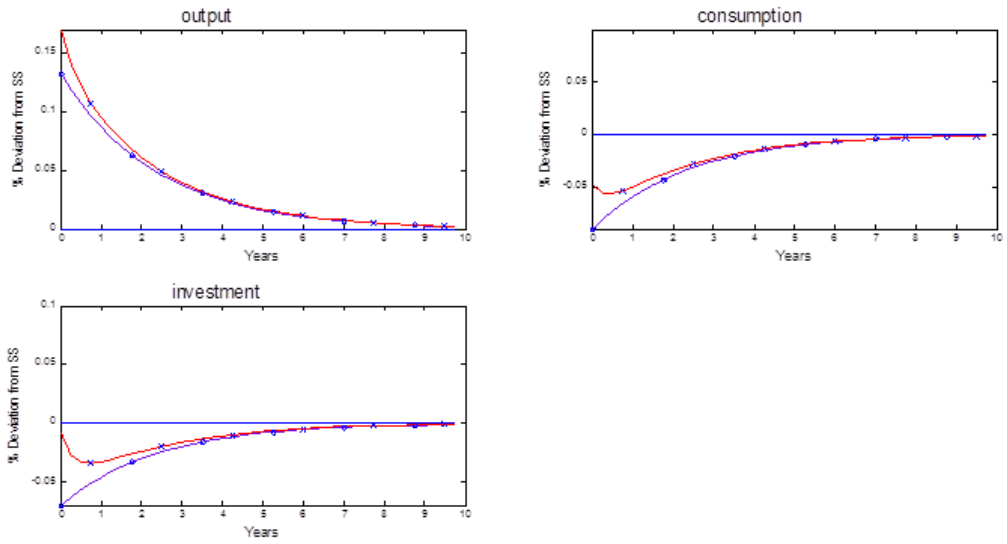
In order to assign a value to the parameter ξ, estimates of the output elasticity of public capital are used as a proxy. The empirical studies available provide a wide range of estimates: to cite a few, Eberts (1986) finds an estimated elasticity of 0.03, Ai and Cassou (1995) produce values ranging

between 0.15 and 0.26 while Aschauer (1989) estimates a value of 0.39. On the basis of these studies, in section 6 the effects of government spending shocks will be discussed for $\xi = 0.03$ (the estimate by Eberts), $\xi = 0.26$ (the highest value estimated by Ai and Cassou) and $\xi = 0.39$ (from the study by Aschauer).
The values taken by ϱ, which measures the degree of substitutability or complementarity between private and public spending, come from the estimates of Aschauer (1985) and Karras (1994). Aschauer (1985), using the full information maximum likelihood method applied to US data, gets estimates of the degree of substitutability of public expenditures for private consumption ranging between 0.23 to 0.42. Karras (1994), using a similar methodology for a sample of 30 countries, finds evidence of complementarity in almost all cases. In the next section, impulse responses will be plotted for $\varrho = 0.23$, $\varrho = 0.42$, $\varrho = -0.36$ and $\varrho = -1.34$. The latter are the estimates obtained by Karras (1994) for Germany and France and have been chosen in order to illustrate the implications of different degrees of complementarity.
Following the estimates of Clarida, Gali' and Gertler (2000), ρ is given a value of 0.9 while γ_π is equal to 1.5. The dynamics of the model are analyzed for two values of γ_y, $\gamma_y = 0.5$, which corresponds to an interest rule in which the central bank reacts to fluctuations in output and was originally suggested by Taylor (1993), and $\gamma_y = 0$. The second hypothesis is in line with recent evidence: for instance, Ireland (2000) runs a regression on the interest rate rule followed by the Fed since 1980 and finds that the coefficient on output is small (0.000372) and statistically insignificant.

5 Results

This section describes the impact of fiscal shocks on output, consumption and investment for different calibrations of the parameters. The linearized model is solved numerically using the method of undetermined coefficients described in McCallum (1999) and Uhlig (1999). The impulse responses are plotted against a benchmark model with price and wage rigidities in which public spending does not affect production ($\xi = 0$) and/or the utility function ($\varrho = 0$).
The implications of nominal rigidities for the consequences of government spending shocks are illustrated in Figure 1, which compares impulse responses to a one percent shock for the benchmark model and a version of the same model with flexible prices and wages (i.e. for $\chi = 0$ and $\phi = 0$). The figure shows that in both cases a fiscal shock is followed by an increase in output

Figure 1: **Government spending shock**
Nominal rigidities versus flexible prices
Purple line: flexible wages and prices. Red line: nominal rigidities (benchmark model).



and a decline in consumption and investment. In other words, a positive shock to government spending triggers a negative private wealth effect, as a higher proportion of the economy's output is absorbed by the public sector. However, the magnitude of this effect is lower than 0.1 percent for both consumption and investment.

In other words, a positive shock to government spending triggers a negative private wealth effect, as a higher proportion of the economy's output is absorbed by the public sector. However, the magnitude of this effect is lower than 0.1 percent for both consumption and investment. Moreover, when prices and wages are sticky the negative impact on consumption and investment is lower and the expansionary effect on output is accentuated.

5.1 Fiscal shocks and productive government spending

Figure 2 shows the dynamic reaction of the three macroeconomic variables to a government spending shock for alternative values of the share of government spending in the production function, $\xi = 0.03$, $\xi = 0.26$ and $\xi = 0.39$. Moreover, it is assumed that the monetary policy parameter γ_y is equal to 0: in other words, the central bank sets the interest rate independently of

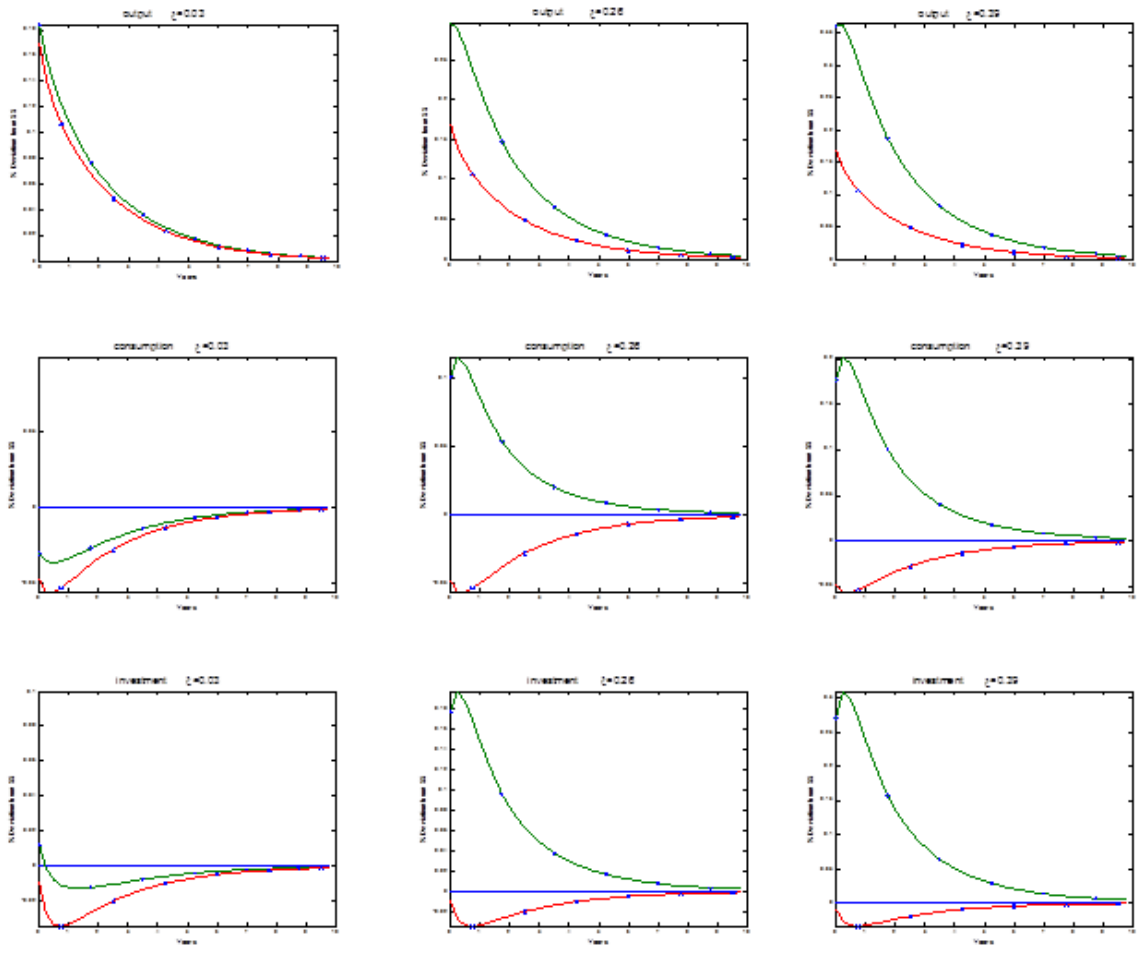
output fluctuations.

Setting the weight of public spending in the production function equal to 0.03, i.e. assuming that government spending has a modest impact on productivity, the positive effect of a government spending shock on output is amplified and the negative impact on consumption and investment is reduced with respect to the benchmark model and close to 0. Higher values of the government spending share ξ, implying a strong contribution of public spending to productivity, reverse the predicted effect of a positive fiscal shock on the components of output. For $\xi = 0.26$, the shock is followed by an increase in output considerably larger than in the benchmark model and by an increase in private consumption and investment. Finally, when the share of public spending is equal to 0.39, the increase in government spending has a strong positive effect on all three variables.
Overall, a positive government spending shock produces a positive private wealth effect, increasing consumption and investment, if the productivity of government spending is high enough to offset the increased absorption of the economy's resources by the government.

5.2 Government spending in the utility function

In this section, the implications of a relationship of substitutability or complementarity between private consumption and public spending are discussed. Figure 3 shows the dynamic reactions of output, consumption and investment to a positive fiscal shock when the existence of a relationship of substitutability between private and public consumption is assumed. To isolate the consequences of the assumption, the hypothesis of productive government spending is temporarily dropped. The impulse responses are displayed for $\varrho = 0.23$ and $\varrho = 0.42$, the lowest and highest values taken by the parameter in the empirical study by Aschauer (1985). While output still rises, the negative effect on consumption is accentuated and the negative effect on investment is lower than in the benchmark model.
In Figure 4, the effects of a fiscal shock when private and government spending are complementary are shown for some of the values of ϱ found by Karras (1994). For all values of ϱ the percentage deviation of output from steady state following an increase in government spending is higher than in absence of complementarity. When the degree of complementarity is high ($\varrho = -1.34$), the positive effect of a fiscal shock on output is more than doubled.The presence of a certain degree of complementarity is also able to offset the negative wealth effect caused by an increase in government spending in the benchmark model, boosting consumption for high negative values

Figure 2: **Government spending shock**
Productive government spending versus benchmark model
Green line: Productive government spending. Red line: benchmark model.



of ϱ. Investment is crowded out and the decrease is stronger the higher the degree of complementarity between private and public spending.

5.3 The role of the monetary policy rule

The dynamics described in the previous sections refers to a situation in which the sole purpose of the monetary authority is to control inflation and therefore the interest rate is set without taking account of output fluctuations ($\gamma_y = 0$). However, the choice of the monetary policy rule has important implications for the way the economy reacts to a government spending shock. Figure 5 illustrates this point showing the impact response of output, consumption and investment for $\gamma_y = 0$ and $\gamma_y = 0.5$. Two alternative calibrations are considered: a combination of low values of the output elasticity of public spending and of the degree of complementarity between private and public purchases and a combination of high values of the same parameters. For both calibrations, the expansionary effect of a positive government spending shock on output is considerably weaker when the central bank reacts to variations in the real economy. Moreover, for low values of the government spending parameters, the rise in private spending which would be observed when the nominal interest rate reacts exclusively to nominal changes in the economy disappears: consumption is crowded out, even though allowing for a relatively high share of government expenditures in production and a high degree of complementarity between public and private consumption (in Figure 5, for $\xi = 0.26$ and $\varrho = -1.34$) the impact on private consumption as a consequence of a fiscal shock is still positive. Investment follows a similar dynamic: it remains almost unchanged for low values of ξ and ϱ and increases when the two parameters take high values, provided $\gamma_y = 0$. However, when the monetary authority sets the interest rate taking into account output fluctuations, investment declines sharply for all calibrations.
These results show that the positive effect on private spending caused by productive and/or complementary public spending is offset partially or totally if the central bank aims to control developments in the real economy.

6 Conclusions

This paper examined the effects of government spending shocks on the economy focusing on their impact on private spending and trying to account for

Figure 3: **Government spending shock**
Substitutability vs benchmark model
Green line: substitutability. Red line: benchmark model.

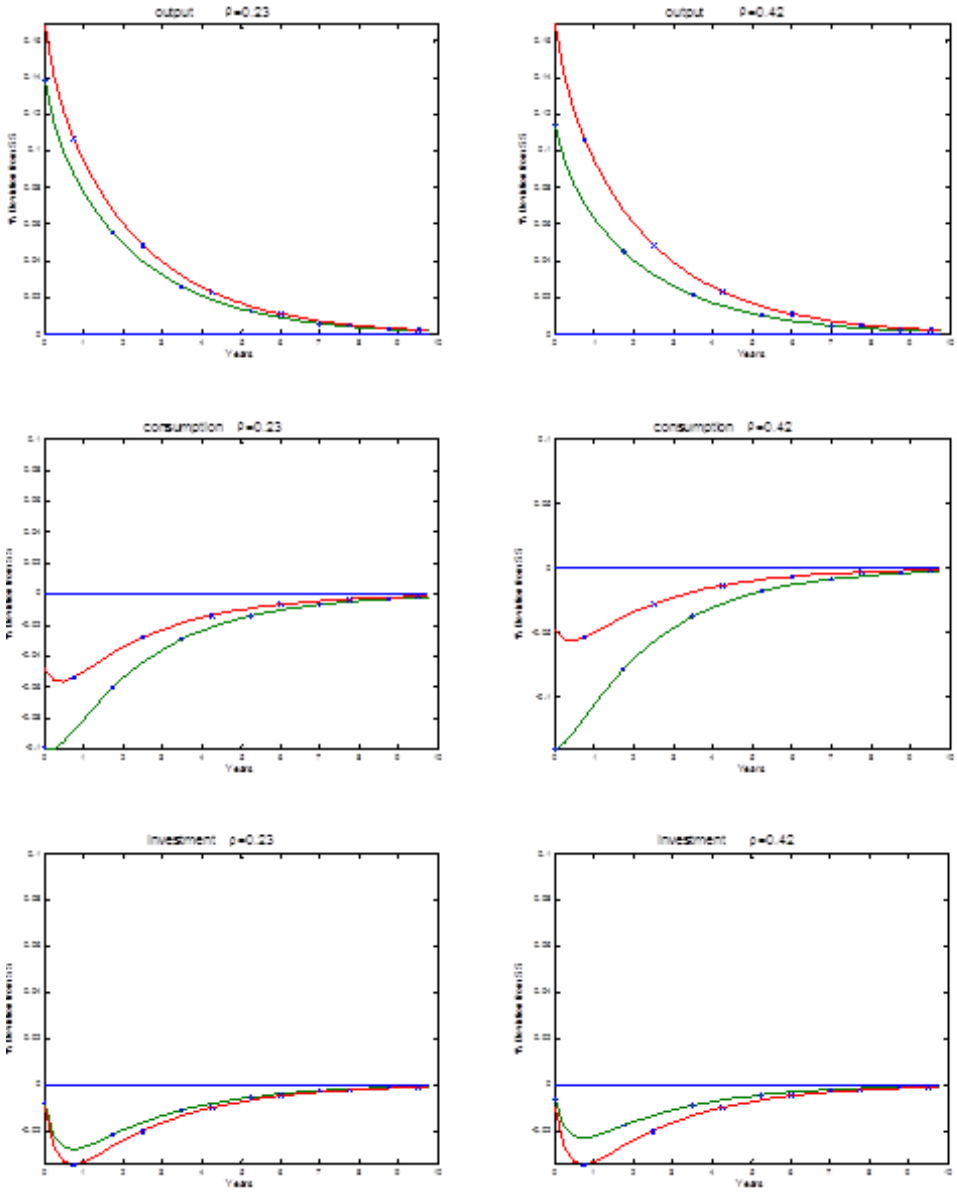


Figure 4: **Government spending shock**
Complementarity vs benchmark model
Green line: complementarity. Red line: benchmark model.

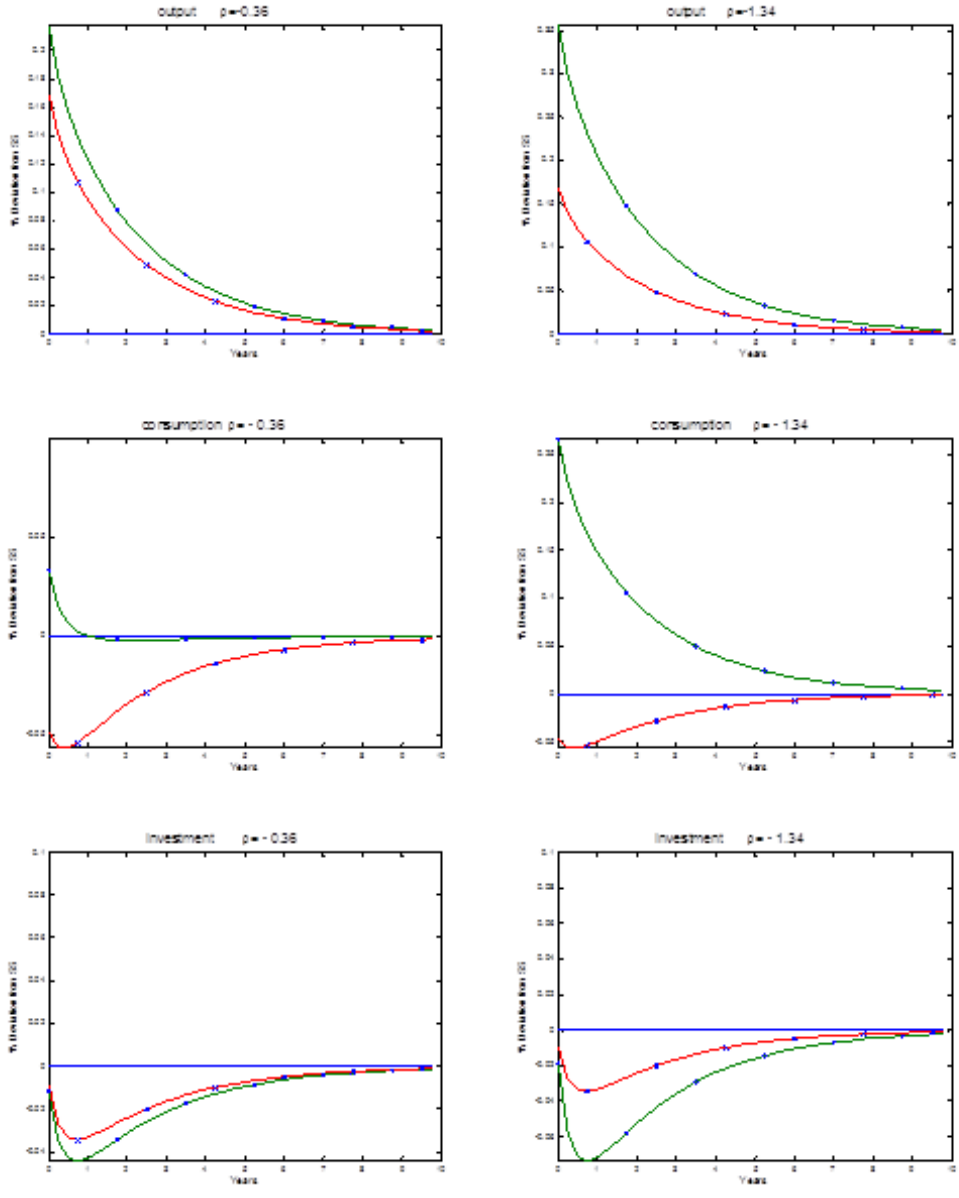
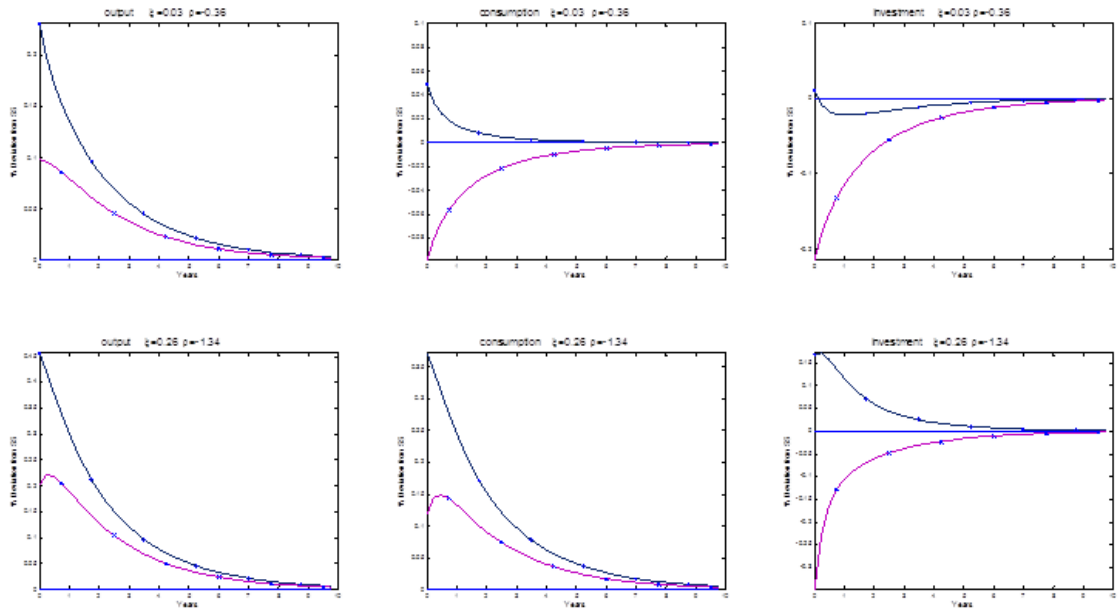


Figure 5: **Government spending shock**
$\gamma_y = 0$ versus $\gamma_y = 0.5$
Blue line: $\gamma_y = 0$. Purple line: $\gamma_y = 0.5$.



recent evidence in favor of a positive impact of increases in public purchases on private consumption.
It is found that the introduction of both price and wage rigidities in the model does not substantially change the predicted effects of a fiscal shock with respect to the standard RBC paradigm. An increase in government spending crowds in output and crowds out both private consumption and private investment. However, when government expenditures are assumed to be productive, fiscal shocks cause a dramatic increase in output and the negative effect on consumption and investment is offset. Moreover, when government spending is highly productive, private consumption increases. In this case, private consumption and investment are boosted by a positive fiscal shock as an effect of the increased productivity of the private factors.
The model also shows that the presence of a degree of complementarity between public and private consumption is capable of offsetting the negative effect on consumers' spending normally observed in RBC and NNS models. More precisely, a rise in public spending in the presence of complementarity is followed by an increase in production and private consumption and by a decrease in private investment. It must also be underlined that the choice of the monetary policy rule is not neutral. If the interest rate reacts to variations in output, the expansionary effect of an increase in government spending is considerably reduced.
In conclusion, a model allowing for a contribution of public expenditures to the production process and for a certain degree of complementarity between private and government spending seems to capture some of the features of real economies better than a model in which government expenditures do not affect agents' behavior.

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