Centre for Energy Economics Research and Policy

Can Public Spending Boost Private Consumption?

Stylianos Asimakopoulos, Marco Lorusso and Luca Pieroni

CEERP Working Paper No. 5
December 2016

Heriot-Watt University
Edinburgh, Scotland
EH14 4AS
ceerp.hw.ac.uk

Can Public Spending Boost Private Consumption?

Stylianos Asimakopoulos
University of Stirling

Marco Lorusso
Heriot-Watt University

Luca Pieroni
University of Perugia

December 1, 2016

Abstract

This paper analyses the effects on private consumption from an increase in productive and unproductive public spending. A new Keynesian model incorporating price and wage rigidities, monetary policy and various fiscal rules is developed and estimated, using Bayesian techniques, to capture the key cyclical characteristics of the US economy. We find that price and wage rigidities along with a positive shock to the part of public spending that is productive are sufficient to boost private consumption. Moreover, we show that this initial positive reaction of private consumption is adequate to create a positive present value consumption multiplier for more than five years. Finally, we show that our main results remain robust to changes in the monetary rule and the various methods of deficit financing.

Keywords: fiscal rules, price rigidities, taylor rule, bayesian estimation
JEL Classification: C11, E27, E52, E62, H30
Corresponding author: stylianos.asimakopoulos@stir.ac.uk

1. Introduction

The recent financial and sovereign debt crisis has pivoted the attention of the policy-makers towards fiscal policy. In the United States, the introduction of the new fiscal package to stimulate demand, mainly through higher spending and lower taxes, according to "The 2015 Long-Term Budget Outlook" of the Congressional Budget Office, has lead to a deficit of about \$5.6 trillion over the period 2008-2012, leading to a debt to output ratio of about 74% in 2015.[1] The projection over the next 25 years for the U.S. is to increase federal spending to about 25.3% as share of output, which is significantly higher compared to the 50 years average of 20.1%, with a more gradual increase on the revenue side compared to spending.[2]

Therefore, under this environment, determining the effect of the increase in government spending to the economy is of paramount importance. In particular, in this paper we examine the effect of changes to productive and unproductive government spending on private consumption. Accordingly, we aim at identifying which part of government spending could lead to an increase of private consumption. In this regard, we contribute to previous economic literature by adopting a new Keynesian Dynamic Stochastic General Equilibrium (DSGE) model with price rigidities and monetary policy which includes: i) productive and unproductive government spending; ii) distortive and lump-sum taxation; iii) several fiscal policy rules.

It is widely accepted that an expansionary fiscal policy through higher government spending will increase output. However, there is no consensus regarding the effects of changes to government spending on private consumption. In particular, the standard neoclassical approach predicts that an increase in government spending will cause a decline in private consumption due to the anticipation of higher debt financing taxes, leading to a negative wealth effect. On the other hand, new Keynesian models are able to reproduce the crowding-in effect on private consumption under certain assumptions, e.g. regarding the share of non-Ricardian agents (where their consumption equals their after-tax labour income) and price rigidities.

Moreover, there is a vast empirical literature on the impact on private

[1] This is the highest level of debt for the US in the post WWII period.

[2] For more details see "The 2015 Long-Term Budget Outlook" of the Congressional Budget Office.

consumption of a positive government spending shock. Most of the empirical literature utilises structural VAR models with various identification schemes. These papers find a positive correlation between private consumption and government spending, but they do not agree on the magnitude of the effect (i.e. Blanchard and Perotti, 2002 and Galí et al., 2007). Accordingly, our work presents three main contributions with respect to this literature: firstly, we use a dataset that allows us to decompose total public spending into productive and unproductive government expenditures; secondly, we estimate our model for a relative long sample period (more than 40 years) at quarterly frequency covering the most recent period; lastly, we use Bayesian methods in order to estimate the model parameters including the fiscal rules.

There has also been a strand of literature that examines the effects of government spending on economic growth. On the one hand, neoclassical growth models, like Solow (1956) and Swan (1956), show that government spending does not have any impact on growth. On the other hand, endogenous growth models, like Barro (1990) and King and Rebelo (1990), show that fiscal variables have an impact on growth. The empirical results are rather inconclusive (i.e. Stokey and Rebelo, 1995 and Kneller et al., 1999) with more recent papers suggesting a non-linear relationship between government spending and economic growth (Asimakopoulos and Karavias, 2016). However, the focus of this paper is on the effect of higher government spending on the level of consumption and not on its long-run growth.

In a similar work to ours, Leeper et al. (2010) emphasize on the importance of several fiscal rules in the U.S. economy. In particular, they use a real business cycle model with productive government spending to assess the effects of various delays on the implementation of pre-announced public spending. They also show the importance of debt financing and its implications to the economy suggesting that lump-sum taxes/transfers do not have a significant effect on consumption.[3] Therefore, their findings suggest that the introduction of non-Ricardian agents is not a necessary condition

[3]In this regard a vast empirical literature suggests that the assumptions made on how the increased government spending is financed matters for the response of private consumption and output (i.e. Mountford and Uhlig 2009 and Leeper et al., 2010).

causing a positive response in private consumption. On the contrary, the assumption of a sufficiently productive government capital may lead to the crowding-in effect on private consumption.

Galí et al. (2007) show the importance of incorporating rule-of-thumb consumers together with price rigidities, to generate a crowding-in effect in consumption following a positive shock to government spending. More specifically, the channel through which the crowding-in effect is realised comes from: firstly, the fact that non-Ricardian agents cannot react to higher future taxes, due to the increased government spending, mitigating the negative impact on aggregate demand; and secondly price rigidities that minimise the negative impact on wage rates. Both of these effects lead to higher labour income that boosts the consumption of the non-Ricardian households leading to the crowding-in effect.[4]

Similarly to Galí et al. (2007), Linnemann and Schabert (2003) show that price rigidities alone are not sufficient to generate a positive reaction in private consumption following a positive public spending shock. In addition, Ravn et al. (2006) show that price rigidities together with deep habits can replicate the empirically relevant positive reaction of private consumption.

However, in this paper, following Baxter and King (1993), Ambler and Paquet (1996) and Linnemann and Schabert (2006), we argue that the combination of price rigidities with productive public spending can create a positive reaction in private consumption under an increase in the productive public spending.[5]

In a different work, Linnemann (2006) shows that, under a specific non-separable utility function with a sufficiently strong link between marginal utility of consumption and labour, it is possibile to find a crowding-in effect on private consumption from an increase in government spending, even if the latter is not productive. The strong assumption made by this author is that a lump-sum tax is residually determined via the government

[4] Galí et al. (2007) only allow for a lump-sum tax/transfer and not individual labour and capital taxes with fiscal rules.

[5] Baxter and King (1993) and Ambler and Paquet (1996) implement a neoclassical model without debt. In addition, Linnemann and Schabert (2006) use a new Keynesian model with a simple interest rate rule and debt is considered as a case study assuming that it follows a rule and not together with various fiscal rules as we do. Moreover, none of these papers performs a Bayesian estimation of their model.

budget constrain, thus moving away from any use of debt and distortionary taxation or even any kind of fiscal rules.

In addition, Forni et al. (2009) examine the spill-over effects to the economy of three different types of government spending, among others. However, even though they incorporate Ricardian and non-Ricardian agents and fiscal rules (only for the distortionary tax rates), they do not show any significant crowding-in effect on consumption following a positive government spending shock.

More recently, Coenen et al. (2012) show that the crowding-in effect on private consumption can be obtained only if both of the following assumptions are present: firstly, government consumption enters the utility function in a non-separable way; and secondly government and private consumption are strong complements. When they drop either of the two assumptions the crowding-in result disappears and the response of private consumption is comparable to our model under a shock to the unproductive government spending.

Finally, Kormilitsina and Zubairy (2016) are not able to reproduce the crowding-in effect on private consumption following a positive public spending shock in any of their estimated models that incorporate most of the aforementioned features.

Therefore, taking the above into consideration, we would like to identify which component of government spending has a positive effect on private consumption under a theoretical framework. Following the empirical work of Kneller et al. (1999) and the more recent theoretical paper by Leeper et al. (2010) we also split the overall government spending to productive and unproductive. In particular, our distinction assumes that expenditures with a substantial (physical or human) capital component are considered as "productive". On the hand, the major "unproductive" expenditure category relates to social security expenditures. Accordingly, we estimate different fiscal rules for the two types of government spending.

As a result, our theoretical model includes two separate channels through which public expenditure affect the economy: the productive government spending which is included in the firms' production function; and the unproductive government expenditure. We estimate our model with Bayesian techniques and we avoid VAR identification problems faced by previous empirical papers investigating the effects of government expenditure on the economy (see Galí et al. 2007 and references therein). Moreover, in our Bayesian estimation we allow for debt to be financed via labour income taxes, capital income taxes, lump-sum taxes and the two types of government spending. Thus, we also deviate from the literature that assumes that debt financing takes place only through lump-sum taxes/transfers (see, for example, Coenen and Straub, 2005 and Forni et al., 2009).

In this regard, our approach allows us to contribute to previous economic literature by analysing different fiscal policy experiments. In particular, we assess the output and consumption multipliers under different assumptions on: i) financing methods; ii) public spending share in the firms' production function; iii) speed of adjustment of different fiscal rules; iv) different weights on output and inflation in the monetary rule.

Our main findings show that private consumption responds differently to productive and unproductive government shocks. In particular, we observe a different consumption behaviour when price rigidities are present with respect to the "standard" neoclassical case. In the former case, the stronger shift in the labour demand compared to labour supply and the high inflation lead to an increase in wage rates. This is sufficient to generate a crowding-in effect on private consumption. On the contrary, unproductive public spending exhibits a high persistence. In this case the labour, capital and lump-sum taxes need to remain high, or keep increasing over time. This implies a significant crowding-out effect on private consumption because the persistent high taxes cause a significant negative wealth effect on consumers.

Regarding the output present value multipliers, under the rigid and flexible economy, our results are in line with the range of values reported in previous empirical studies. Interestingly, under the rigid economy, a positive shock to productive spending has a positive effect on the consumption present value multipliers for at least five years. Moreover, we find that in the long-run whether the government uses distortionary or non-distortionary financing methods significantly matters. In particular, different ways of financing have distinct effects on output and consumption multipliers depending on whether the economy is rigid or flexible. We also show an immediate positive reaction of private consumption when productive spending increases irrespective the method of debt financing. Finally, we find that a less aggressive monetary policy implies lower nominal and real interest rate weakening consumers' incentives to postpone consumption.

In the next section we briefly discuss our new Keynesian DSGE model. In section 3, we present the data used for the analysis and our Bayesian estimates. In Section 4, we compare the impulse responses for productive and unproductive government spending shocks. Section 5 provides the results for consumption and output present value multipliers. In section 6 we present several robustness checks. Finally, section 7 concludes the paper.

2. Theoretical Model

In this section we present our DSGE model assuming that there are two different public expenditures, namely, productive and unproductive government spending. We adopt a new Keynesian model in line with the paper of Smets and Wouters (2007) extended in order to consider distortive taxes to capital and labour incomes together with several fiscal policy rules. Moreover, we assume that our economy has both nominal and real rigidities and the central bank sets its policy rule. In what follows, we are going to describe in detail parts of the model that deviate from Smets and Wouters (2007) setup, while all the remaining equations are reported in the online Appendix.

2.1. Households

We assume that the representative household trades a risk-less one period government bond and accumulates physical capital that it rents out to firms. Moreover, it receives wage income and dividend payments from the firms. Therefore, the representative household maximizes the following utility function with two arguments, consumption (C_t) and labour (L_t):

$$\max E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left[\left(\begin{array}{c} \frac{1}{1-\sigma^c} \left(C_t - hC_{t-1} \right)^{1-\sigma^c} \cdot \\ \exp\left(\frac{\sigma^c - 1}{1+\sigma^l} \left(L_t \right)^{1+\sigma^l} \right) \end{array} \right) \right] \right\} \tag{1}$$

where β^t is the discount factor, σ^c denotes the coefficient of relative risk aversion and σ^l is the inverse of the elasticity of work with respect to the real wage. The parameter h measures the degree of external habit formation in consumption.

The representative household faces the following budget constraint:

$$\frac{B_t}{\varepsilon_t^b R_t} = B_{t-1} + (1 - \tau_t^l) W_t L_t + (1 - \tau_t^k) R_t^k + D_t - P_t C_t - P_t I_t + T_t \quad (2)$$

where P_t indicates the price level while R_t is the gross nominal return of government bonds denoted by B_t. As in Smets and Wouters (2007), ε_t^b is the exogenous risk premium shock and follows an AR(1) process. W_t denotes the wage rate while R_t^k is the rental rate and D_t are the firms dividends. C_t and I_t represent the private consumption good and investment good, respectively. The fiscal authority absorbs part of the gross income of the representative household to finance its expenditure. Accordingly, in equation (2), τ_t^l denotes the labour income tax rate while τ_t^k is the capital income tax rate. Moreover, T_t indicates the lump-sum taxes of the government.

In addition, the representative household supplies its labour services to a labour union. The union uses Calvo (1983) contracts to set the wages charged to the intermediate firms. Finally, we allow for a partial indexation of wages to past inflation rates.

2.2. Firms

We assume a continuum of monopolistically competitive firms indexed by $j \in [0, 1]$ that produces differentiated varieties of intermediate production goods, and a single final production good firm that combines the variety of intermediate production goods under perfect competition.

Each intermediate good firm j produces its differentiated output using a Cobb-Douglas technology with three input factors: private capital (K_t), labour (L_t) and productive government capital (K_t^{gp}):

$$\begin{aligned} Y_t(j) &= \varepsilon_t^a (K_t(j))^{\alpha_1} (L_t(j))^{\alpha_2} (K_t^{gp}(j))^{\alpha_3} - \Phi \\ \text{where} &: \alpha_1 + \alpha_2 = 1 \\ \text{and} &: 0 < \alpha_3 < 1 \end{aligned} \tag{5}$$

where α_1 and α_2 indicate the private capital and labour share in production respectively. With respect to the production function used by Smets and Wouters (2007), equation (5) displays an additional parameter associated with the productive government capital, that is α_3. This parameter denotes the public capital share in production.[6] Moreover, in equation (5), ε_t^a indicates the total factor productivity exogenous shock following a first order autoregressive process and Φ is a fixed cost. Firms set their prices according to current and expected marginal costs, but also according to past inflation rate. The expression for the marginal cost is different from the one of Smets and Wouters (2007) since, in our case, marginal cost does not depend only on wages and capital rental rate but also on the price of the productive government capital (see online Appendix).

In line with Baxter and King (1993) and Leeper et al. (2010), we assume that the evolution equation for productive government capital is given by:

$$K_{t+1}^{gp}(j) = (1 - \delta^g) K_t^{gp}(j) + G_t^p \tag{6}$$

where δ^g is the parameter indicating the depreciation rate of the productive government capital. In equation (6), G_t^p indicates the productive government investment.

We also assume that, in the intermediate production good sector, there is a sluggish price adjustment due to staggered price contracts à la Calvo. Finally, we allow for partial indexation of prices that cannot be adjusted to past inflation rates.

[6] In line with Baxter and King (1993), Glomm and Ravikumar (1997) and Leeper et al. (2010), we model the production function in order to exhibit increasing returns to scale with respect to public capital.

2.3. Fiscal Sector

Government budget constraint assumes that the finance of public spending takes place through lump-sum taxes, issuing bonds or adjusting distortionary taxes on labour and capital income. We separate government expenditure into productive (G_t^p) and unproductive (G_t^u) and, consequently, display a composite budget constraint as:

$$G_t^u + G_t^p + B_{t-1} + T_t = \tau_t^r + \frac{B_t}{R_t} \tag{7}$$

Moreover, total government tax revenues are given by:

$$\tau_t^r = (1 - \tau_t^l) W_t^h L_t^h + (1 - \tau_t^k) R_t^k K_{t-1} \tag{8}$$

We use fiscal policy rules that are in line with Leeper et al. (2010):

$$\begin{aligned}
\hat{\tau}_t^l &= \phi^{yl}\hat{y}_t + \gamma^{bl}\hat{b}_{t-1} + \hat{\varepsilon}_t^l && (9)\\
\text{where} &: \hat{\varepsilon}_t^l = \rho^l \hat{\varepsilon}_{t-1}^l + \sigma^l \eta_t^l && (10)\\
\hat{\tau}_t^k &= \phi^{yk}\hat{y}_t + \gamma^{bk}\hat{b}_{t-1} + \hat{\varepsilon}_t^k && (11)\\
\text{where} &: \hat{\varepsilon}_t^k = \rho^k \hat{\varepsilon}_{t-1}^k + \sigma^k \eta_t^k && (12)\\
\hat{g}_t^p &= -\phi^{yg^p}\hat{y}_t - \gamma^{bg^p}\hat{b}_{t-1} + \hat{\varepsilon}_t^{g^p} && (13)\\
\text{where} &: \hat{\varepsilon}_t^{g^P} = \rho^{g^p} \hat{\varepsilon}_{t-1}^{g^p} + \sigma^{g^p} \eta_t^{g^p} && (14)\\
\hat{g}_t^u &= -\phi^{yg^u}\hat{y}_t - \gamma^{bg^u}\hat{b}_{t-1} + \hat{\varepsilon}_t^{g^u} && (15)\\
\text{where} &: \hat{\varepsilon}_t^{g^u} = \rho^{g^u} \hat{\varepsilon}_{t-1}^{g^u} + \sigma^{g^u} \eta_t^{g^u} && (16)\\
\hat{t}_t &= \phi^{yt}\hat{y}_t + \gamma^{bt}\hat{b}_{t-1} && (17)
\end{aligned}$$

where small hatted letters denote linearized variables. Moreover, $\hat{\varepsilon}_t^l$, $\hat{\varepsilon}_t^k$, $\hat{\varepsilon}_t^{g^p}$ and $\hat{\varepsilon}_t^{g^u}$ are assumed to follow distinct AR(1) processes and each of the η's is distributed i.i.d. N (0,1). All our fiscal policy rules have two characteristics. Firstly, we assume that the fiscal variables respond to contemporaneous variations of output ($\phi^{yl} \geq 0$, $\phi^{yk} \geq 0$, $\phi^{yg^p} \geq 0$, $\phi^{yg^u} \geq 0$ and $\phi^{yt} \geq 0$). Secondly, our rules allow for dynamic responses to changes in government debt ($\gamma^{bl} \geq 0$, $\gamma^{bk} \geq 0$, $\gamma^{bg^p} \geq 0$, $\gamma^{bg^u} \geq 0$ and $\gamma^{bt} \geq 0$). Moreover, in order to capture the persistence in taxes and expenditures we allow for the shocks to be serially correlated ($\rho^l \in [0,1]$, $\rho^k \in [0,1]$, $\rho^{g^p} \in [0,1]$ and $\rho^{g^u} \in$

[0, 1]). Finally, in order to capture unexpected changes in distortionary taxes and spending we assume that fiscal rules (9), (11), (13) and (15) include exogenous processes ($\hat{\varepsilon}_t^l$, $\hat{\varepsilon}_t^k$, $\hat{\varepsilon}_t^{g^p}$ and $\hat{\varepsilon}_t^{g^u}$, respectively).

2.4. Monetary Policy

Following Smets and Wouters (2007), the central bank is assumed to set the nominal interest rate according to the following Taylor rule (Taylor, 1993):

$$\frac{R_t}{(r)^{SS}} = \left(\frac{R_t^{-1}}{(r)^{SS}}\right)^{\rho} \left[\left(\frac{\pi_t}{(\pi)^{SS}}\right)^{r^{\pi}} \left(\frac{Y_t}{Y^p}\right)^{r^y}\right]^{(1-\rho)} \left(\frac{Y_t/Y_{t-1}}{Y_t^p/Y_{t-1}^p}\right)^{r^{\Delta_y}} \varepsilon_t^r \tag{18}$$

where $(r)^{SS}$ and $(\pi)^{SS}$ are the steady states of nominal interest rate and inflation, respectively. Moreover, ρ is the nominal interest smoothing parameter, r^{π} indicates the response of nominal interest rate to lagged inflation from an inflation objective, r^y denotes the response of nominal interest rate to output gap and r^{Δ_y} is the response of nominal interest rate to changes in output gap. We also assume that the monetary policy shock is denoted by ε_t^r. Finally, Y_t^p indicates the natural output level.

2.5. Market Equilibrium

The final goods market is in equilibrium if the production of firms equals the demand by households for consumption and investment and the government. Differently from standard new Keynesian models, in the aggregate resource constraint (19) we observe that total public spending is given by the sum of productive and unproductive government expenditures:

$$Y_t = C_t + I_t + G_t^u + G_t^p \tag{19}$$

3. Estimated Results

In this section, firstly, we describe the data and the estimation technique used in order to assess the theoretical model. Secondly, we discuss how we estimate the endogenous parameters and the exogenous processes related to the structural shocks. Finally, we present the main estimation results.

3.1. Data and Estimation Technique

We estimate our model using US quarterly data for the sample period 1963:Q2-2013:Q4.[7] The length of our sample relates to the data availability of our main source, namely the OECD Economic Outlook No 90. In turn, the reason of choosing such source relates to the disaggregation of US government expenditure components that is crucial for our analysis as we will explain below.

According to our theoretical set up, we consider eight exogenous shocks so that eight data series are used in our estimation. In particular, we use data on real gross domestic product, real private consumption, real private investment, real wage compensation, inflation rate, federal funds effective rate, real labour tax revenues, real capital tax revenues, real productive government expenditure and real unproductive government spending. In order to obtain the real variables we deflate them using the US GDP deflator. Moreover, the real variables are converted in per capita terms dividing by the working age population. Following Pfeifer (2014) we also detrend the logarithm of each real variable,[8] while we demean the inflation rate and nominal interest rate. All the details about data construction are shown in the online Appendix.

In what follows, we prefer to focus on the variables that are "new" with respect to previous DSGE analysis on this topic (see for example, Coenen et al. 2012; Leeper et al. 2010), namely real productive and unproductive government expenditures. As in Leeper et al. (2010) we focus on federal government data for which comprehensive data on fiscal series exist. In particular, the OECD Economic Outlook No 90 provides a detailed disaggregation of government expenditure components. As we explained above, our aim is to disentangle between productive and unproductive government spending following Kneller et al. (1999) approach. To this end we assume that government productive expenditure is composed by government final wage consumption expenditure, government fixed capital formation, capital transfers and other capital payments and government consumption of fiscal capital. For the period 1960-2013, the average share of this series

[7]The period 1960:Q2-1963:Q1 is used as presample.

[8]In particular, we use the HP filter with smoothing parameter equal to 1,600.

on US GDP is about the 17%. We further assume that the unproductive government spending correspond to the sum of government final non-wage consumption expenditure, property income paid by government, subsidies and social security benefits paid by government. This series weights on average about the 20% of US GDP during the period 1960-2013.

As we described above we detrend both these series likewise we treat the remaining real variables. Although recent papers have used one or two common stochastic trends to estimate DSGE models (see for example Greenwood et al. 1997, 2000; Altig et al. 2005) this procedure is not straightforward. Indeed, our choice is motivated by the fact that fiscal series clearly display different trends during our sample period.[9] Therefore, following the treatment of observed variables used by Leeper et al. (2010) we prefer to detrend the series of labour tax revenues, capital tax revenues, productive government spending and unproductive government spending.

As estimation technique, we use the Bayesian approach. More specifically, the estimation of the model parameters by Bayesian maximum likelihood proceeds in two steps. First, we specify prior distributions for the parameters. Then we combine this prior information with the likelihood of the model and characterise the posterior distribution. In order to approximate the parameters posterior distribution, we use Markov Chain Monte Carlo methods. Specifically, we use the Metropolis-Hastings algorithm to generate parameter observations on which to base inference.[10]

3.2. Fixed Parameters and Prior Distributions

Before discussing the estimation results we firstly describe the choice of the prior distributions. Table 1 presents the values assigned to fixed parameters. These parameters can be viewed as very strict priors because they can be directly related to the steady-state values and are not identifiable from the data we use. For these values we assume "standard" parameters extracted from the most recent DSGE literature. In particular, the discount factor (β) is calibrated to be 0.996, in line with the value assumed

[9] In the online Appendix, Figure C1 shows the series of labour and capital tax revenues together with productive and unproductive government expenditures all expressed as shares of GDP.

[10] All our estimations are done with Dynare (http://www.dynare.org/).

Parameter	*Symbol*	*Value*	*Target/Source*
Discount Factor	β	0.996	D & S (2008)
Depreciation Rate of Priv. Cap.	δ	0.025	Ann. Cap. Depr: 0.10
Elast. Labour Supply	σ^l	0.04	Altonji (1986)
Public Cap. Share in Prod.	α_3	0.10	Leeper et al. (2010)
S.S. Mark-up in Goods Market	ϕ^p	1.5	S & W (2007)
S.S. Mark-up in Lab. Market	ϕ^w	1.5	S & W (2007)
Goods Market Agg. Cur.	ϑ^p	10	S & W (2007)
Lab. Market Agg. Cur.	ϑ^w	10	S & W (2007)
Prod. Gov. Exp. / GPD	g^{py}	0.17	From our data sample
Unprod. Gov. Exp. / GPD	g^{uy}	0.20	From our data sample
S.S. Capital Tax Rate	$\left(\tau^k\right)^{SS}$	0.28	From our data sample
S.S. Labour Tax Rate	$\left(\tau^l\right)^{SS}$	0.26	From our data sample
Depreciation Rate of Gov. Cap.	δ^g	0.005	Leeper et al. (2010)

Table 1: Fixed parameters according to quarterly data

by Del Negro and Schorfheide (2008).

The depreciation rate of private capital (δ) is set at 0.025 per quarter, which implies an annual depreciation on capital of 0.10. We set up the elasticity of labour supply (σ^l) equal to 0.04 in line with the broad range of values that have been calculated on the basis of microeconomic or macroeconomic data sets.[11] Moreover, we assume that α_3 is equal to 0.10 which is within the range applied in the related literature (see Leeper et al., 2010 and references therein).[12]

As in Smets and Wouters (2007), the steady state mark-up in the labour market (ϕ^w) is equal to 1.5, and we assume that the steady state mark-up in the goods market (ϕ^p) is equal to 1.5 as well. Moreover, as in Smets and Wouters (2007), the curvature parameters of the Kimball aggregators in the goods (ϑ^p) and labour market, (ϑ^w), are both set at 10.

Differently from Smets and Wouters (2007) and Del Negro and Schorfheide

[11] As reported by Peterman (2016), original microeconometric estimates of the elasticity of labour supply are between 0-0.54 (see MaCurdy, 1981; Altonji, 1986). In contrast, other studies calibrate the elasticity of labour supply in macroeconomic models in the range of 2-4 (Chetty et al., 2013).

[12] We would like to mention here that the parameter α_3 is dificult to estimate due to the absence of aggregate data. In addition, the related empirical literature on public spending has diverse views on the share of public spending in the production ranging from significant 0.24 (Aschauer 1989) to insignificant Kamps (2004) or even negative effects (Evans and Karras, 1994).

(2008) we have a set of fixed parameters related to fiscal sector. In particular, the relative shares of productive (g^{py}) and unproductive (g^{uy}) government expenditures on GDP are computed as average ratios for the period 1960-2013 and are equal to 0.17 and 0.20, respectively. Moreover, the steady state tax rates for capital, $\left(\tau^k\right)^{ss}$, and labour, $\left(\tau^l\right)^{ss}$, are obtained from average capital and labour income tax rates, respectively, and computed from our sample data. Finally, as in Leeper et al. (2010) we assume that the depreciation rate for the government capital expenditure (δ^g) corresponds to 0.005.[13]

Tables 2 and 3 report the remaining parameters of the model estimated with Bayesian techniques.[14] In particular, our prior mean for habit in consumption (h) is in line with the values used by Jermann (1998) and Constantinides (1990). We set the prior mean of the intertemporal elasticity of substitution ($\frac{1}{\sigma^c}$) corresponding to a coefficient of relative risk aversion equal to 5.[15] Regarding the prior for the investment adjustment costs (S'') we set it in line with Ravn et al. (2012) and Schmitt-Grohe and Uribe (2012). The prior mean for the private capital share in the production function (α_1) is set following Leeper et al. (2010) calibration.

Turning to nominal rigidities, we assume prior means for the parameters of Calvo wage (ξ^w), Calvo price (ξ^p), wage indexation (ι^w) and price indexation (ι^p) in line with Le et al. (2011).[16] Regarding the parameters of the monetary policy rule, the prior for the degree of interest rate smoothing (ρ) is similar to the one used by Del Negro and Schorfheide (2008). We assume that the priors for the long-run reaction coefficients of inflation (r^π) and output (r^y) are Gamma distributed with means equal to 4 and 2, respectively, and standard deviations of 0.25 and 0.10, respectively. In addition, we set the prior of the short-run coefficient of output (r^{Δ_y}) as Gamma distributed with mean 0.50 and standard deviation 0.10.

[13] This is also in line with the related literature, i.e. Baxter and King (1993) and Kamps (2004).

[14] The prior and posterior probability density functions for all the estimated parameters are shown in the online Appendix.

[15] This value of the risk aversion is commonly used in the macroeconomic literature (see, for example, Jermann, 1998).

[16] In their study, Le et al. (2011) estimate a model of the US economy for the post-war period, using indirect inference, the bootstrap and a VAR representation of the data. They suggest that limited nominal rigidities fit better with actual data.

Focusing on the priors for the coefficients of the fiscal sector we assume rather loose priors in order to cover a large range of parameter values. More specifically, the prior for the parameter of the labour tax rate elasticity with respect to output (ϕ^{yl}) is assumed to have Gamma distribution with a mean of 0.10 and standard deviation of 0.05 (so that it will range approximately between 0 and 0.35). We assume the same priors as in Leeper et al. (2010) for the parameters of capital tax rate (ϕ^{yk}) and lump-sum tax (ϕ^{yt}) elasticities with respect to output. Moreover, our assumed prior distributions for the responses of labour income tax (γ^{bl}), capital tax (γ^{bk}) and lump-sum tax (γ^{bt}) to government debt cover a large range of possible estimated values. In particular, γ^{bl} will range approximately between 0 and 0.25, while γ^{bk} between 0 and 5 and, finally, γ^{bt} between 0 and 2.5.

As a contribution with respect to previous studies, we distinguish between two different types of government spending. Therefore, we assume two distinct parameters that measure the responses of productive and unproductive government expenditures to output, namely, ϕ^{yg^p} and ϕ^{yg^u}. As far as we know, our study is the first that attempts to estimate the value for these parameters. Thus, our assumed prior distributions for ϕ^{yg^p} and ϕ^{yg^u} are fairly general covering the range of values found by previous papers that estimated the response of aggregate government spending to output (see for example Blanchard and Perotti, 2002; Giorno et al., 1995; Yang, 2005). Moreover, our model assumes two different parameters indicating the responses of productive and unproductive government expenditures to debt, i.e. γ^{bg^p} and γ^{bg^u}. Our analysis contributes to previous economic literature in estimating these parameters. Also, in this case we assume diffuse prior distributions in order to cover a reasonable range of parameter values.[17]

Finally, we focus on the priors of the parameters related to the exogenous processes driving the economy. As in Leeper et al. (2010), we set the persistence parameters for AR(1) exogenous processes to be Beta distributed with mean 0.70 and standard deviation 0.20. Moreover, we use Inverse Gamma distributions for standard errors of all exogenous shocks

[17] In this regard, our prior distributions cover the range of values found by Leeper et al. (2010) that have estimated the response of aggregate government spending to the debt to output ratio.

with means equal to one and infinite degrees of freedom which correspond to rather loose priors.

3.3. Posterior Estimates

In order to estimate the model we used a sample of 1,000,000 draws (dropping the first 250,000 draws), obtaining an acceptance rate of about 27%. To test the stability of the sample, we used the Brooks and Gelman (1998) diagnostic, which compares within and between moments of multiple chains. Tables 2 and 3 show the posterior means for the model parameters together with a 90% confidence interval.

In the online Appendix we report several diagnostic tests for our estimates, including the Monte Carlo Markov Chain (MCMC) univariate diagnostics and the multivariate convergence diagnostics. Moreover, in order to evaluate whether our estimated model fits with the US economy, we computed the business cycle statistics implied by our model and compared them with those deriving from actual data. The results show that our estimated model well captures the business cycle statistics of the key variables.

Our estimate of the external habit stock is about 80% of past consumption, while the posterior mean estimate for the inverse coefficient of relative risk aversion is 0.2, though it is not well identified by the data. The posterior mean estimate for S'' is higher than its prior mean suggesting an even slower response of investment to changes in the value of capital. Our estimate of α_1 is 0.28 which corresponds to a share of about 2/3 of labour to output.

In terms of nominal rigidities, the posterior mean estimates suggest that both prices and wages are flexible being changed roughly every four months on average. Moreover, the posterior estimates suggest that the degree of indexation of both prices and wages is low.

Focusing on our estimates of the monetary policy reaction function, the posterior mean of the reaction coefficient to inflation is estimated to be substantially high. Moreover, the nominal interest rate appears to react very strongly to the output gap in the long-run, but does not respond strongly to changes in the output gap in the short-run. Finally, the degree

Par.	*Description*	*Priors*			*Posteriors*		
		Distr.	Mean	St. Dev.	Mean	Conf. Inter.	
h	Cons. Habit Pers.	B	0.85	0.01	0.81	0.79	0.82
$\frac{1}{\sigma^c}$	Intertemporal Elas. of Sub.	G	0.20	0.05	0.20	0.12	0.28
S''	Inv. Adjustment Cost	G	7.00	1.50	15.53	12.87	18.11
α_1	Private Cap. Share in Prod.	G	0.35	0.02	0.28	0.26	0.30
ξ^w	Calvo Wages Prob.	B	0.20	0.01	0.23	0.21	0.24
ξ^p	Calvo Prices Prob.	B	0.20	0.01	0.24	0.23	0.26
ι^w	Degree of Wage Ind.	B	0.05	0.04	0.05	0.03	0.07
ι^p	Degree of Price Ind.	B	0.05	0.04	0.05	0.04	0.07
ρ	Int. Rate Smooth. in T.R.	G	0.60	0.01	0.64	0.62	0.66
r^π	T.R. Coef. on Inf.	G	4.00	0.25	3.62	3.27	3.96
r^y	T.R. L.R. Coef. on Output	G	2.00	0.10	1.68	1.54	1.82
r^{Δ_y}	T.R. S.R. Coef. on Output	G	0.50	0.10	0.20	0.14	0.26
ϕ^{yl}	Lab. Inc. Tax / GDP Coef.	G	0.10	0.05	0.25	0.07	0.43
ϕ^{yk}	Cap. Tax / GDP Coef.	G	1.00	0.30	2.97	2.33	3.62
ϕ^{yt}	Lump-sum Tax / GDP Coef.	G	0.20	0.10	0.23	0.05	0.41
γ^{bl}	Lab. Inc. Tax / Debt Coef.	G	0.05	0.04	0.07	0.00	0.15
γ^{bk}	Cap. Tax / Debt Coef.	G	1.00	0.80	0.60	0.00	1.21
γ^{bt}	Lump-sum Tax / Debt Coef.	G	0.60	0.40	1.17	0.29	2.04
ϕ^{yg^p}	Prod. Gov. Exp. / GDP Coef.	G	0.07	0.05	0.15	0.03	0.26
ϕ^{yg^u}	Unprod. Gov. Exp. / GDP Coef.	G	0.07	0.05	0.12	0.00	0.23
γ^{bg^p}	Prod. Gov. Exp. / Debt Coef.	G	0.40	0.20	0.24	0.06	0.42
γ^{bg^u}	Unprod. Gov. Exp. / Debt Coef.	G	0.40	0.20	0.34	0.07	0.60

Table 2: Priors and posteriors for the endogenous parameters

of interest rate smoothing is slightly higher than its prior mean.

Turning to the estimates of the fiscal policy parameters, we observe that capital tax response is much more procyclical than labour tax response. Similarly, capital tax responds more strongly than labour tax to changes in government debt. This is in line with the optimal fiscal policy literature that suggests that capital taxes should be used as a shock absorber while labour taxes should be held relatively smooth over the business cycle (Barro, 1979, Chari et al., 1994 and Angelopoulos et al., 2015). In addition, we found that lump-sum taxes respond strongly in changes to debt to output ratio, while they have low response to output deviations. As a result the estimated fiscal rules show a preference of towards the use of non-distortionary taxation to stabilise debt, while capital tax is the most reactive fiscal policy instrument for output stabilisation.

Focusing on the two different types of government expenditures, our estimated results show that both productive and unproductive government spending have similar responses to changes in output. However, the unproductive government expenditure responds more strongly than productive government spending to debt variations. In this regards, our results contribute to previous economic literature by convincingly quantifying the economic effects of the alternative methods of financing public expenditure.[18]

Finally, regarding the exogenous processes, with the exceptions of the risk premium shock, the investment shock and the wage mark-up shock, all the posterior estimates show a higher persistence than the one assumed in the prior distribution. In particular, our results show that the unproductive government spending is more persistent than the productive government expenditure. Moreover, our posterior estimates show that capital tax shock, unproductive government spending shock and labour tax shock are much more volatile than the remaining shocks.

[18] In this regard, Lorusso and Pieroni (2017) and Barro (1979 and 1981) have stressed the importance of the economic effects of government spending and its alternative financing methods. In particular, Lorusso and Pieroni (2017) have focused on different public spending components, namely civilian and military expenditures.

Parameter	*Priors*			*Posteriors*		
	Distr.	Mean	St. Dev.	Mean	Conf.	Inter.
Risk Premium Pers.: ρ^b	B	0.70	0.20	0.05	0.01	0.09
Investment Pers.: ρ^i	B	0.70	0.20	0.65	0.55	0.75
Wage Mark-up Pers.: ρ^w	B	0.70	0.20	0.10	0.04	0.16
Price Mark-up Pers.: ρ^p	B	0.70	0.20	0.75	0.61	0.90
Productivity Pers.: ρ^a	B	0.70	0.20	0.95	0.90	0.99
Productive Gov. Exp. Pers.: ρ^{g^p}	B	0.70	0.20	0.84	0.76	0.92
Unproductive Gov. Exp. Pers.: ρ^{g^u}	B	0.70	0.20	0.99	0.98	0.99
Capital Tax Pers.: ρ^k	B	0.70	0.20	0.79	0.72	0.86
Labour Income Tax Pers.: ρ^l	B	0.70	0.20	0.74	0.68	0.80
Monetary Policy Pers.: ρ^r	B	0.70	0.20	0.88	0.83	0.92
Risk Premium St. Err.: σ^b	I-G	1	Inf	0.33	0.30	0.36
Investment St. Err.: σ^i	I-G	1	Inf	0.52	0.42	0.60
Wage Mark-up St. Err.: σ^w	I-G	1	Inf	1.03	0.91	1.15
Price Mark-up St. Err.: σ^p	I-G	1	Inf	0.24	0.19	0.28
Productivity St. Err.: σ^a	I-G	1	Inf	0.30	0.21	0.39
Productive Gov. Exp. St. Err.: σ^{g^p}	I-G	1	Inf	0.82	0.67	0.98
Unproductive Gov. Exp. St. Err.: σ^{g^u}	I-G	1	Inf	2.82	2.55	3.08
Capital Tax St. Err.: σ^k	I-G	1	Inf	4.22	3.86	4.60
Labour Income Tax St. Err.: σ^l	I-G	1	Inf	2.45	2.24	2.67
Monetary Policy St. Err.: σ^r	I-G	1	Inf	0.43	0.38	0.49

Table 3: Priors and posteriors for the shock processes parameters

4. Impulse Response Analysis

This section presents the impulse responses of the key variables in our economy following an exogenous positive 1% shock to productive and unproductive government spending.[19] For the impulse response analysis, we set the values of the estimated parameters equal to their mean estimates of the posterior distribution. Moreover, in Figures 1 and 2 we include two lines: i) the solid line that represents an economy with price rigidities; ii) the dashed line that denotes the flexible economy.

4.1. Productive Government Expenditure

As we can observe from Figure 1, in response to the shock, output increases on impact and in the subsequent periods in both economies. In addition, debt increases because it is assumed to be the residual instrument for the government and due to the fact that the increase of the remaining fiscal instruments, that follow a predetermined rule, is not sufficient to fund the exogenous increase in public spending. As a result, the increased public spending does not increase debt on a one-to-one basis. In particular, all taxes increase due to their estimated positive reaction to current output gap and past debt to output gap, even though they increase at a different rate and with different patterns.[20] Moreover, unproductive government spending drops because the unproductive spending shock is assumed to be zero and, according to expression (15), $\hat{g}_t^u$ depends exclusively on countercyclical reactions to output and debt.

Private consumption behaves differently for the rigid and the flexible economy. The driving force of this result is the reaction of the wage rate. In particular, the increase in the real wage occurs when the shift in labour demand dominates the shift in labour supply. Under both economies, the increased productive government spending will increase the productivity of firms due to the assumption that productive public spending enters in

[19]Note that qualitatively the results of the impulse response analysis are the same if we use the estimated standard deviation of the shocks instead of the one percent standard deviation. We simply normalise the shock to the economy to be one percent to ease the comparison of the impulse responses between the two cases of productive and unproductive government spending.

[20]Each fiscal rule response to output and debt has been estimated and exhibits different values.

the firms' production function. This, in turn, will lead to higher labour demand. In addition, in the rigid economy, under sticky prices à la Calvo, firms that cannot change their price will adjust quantities, hence further shifting labour demand at a given wage. On the other hand, the remaining firms increase their prices, creating inflation. Moreover, under the rigid economy, firm's prices over marginal cost decrease leading to an additional upward pressure on prices.[21] Meanwhile, the change in labour supply depends on the wealth effect and the intertemporal substitution. In this case, the low persistence of the productive government spending reduces the present discounted value of taxes and the wealth effect on consumers.

Therefore, in the rigid economy, the stronger shift of labour demand compared to labour supply and the high inflation lead to an increase in wage rates. This is sufficient to create a positive reaction of private consumption for almost eight quarters. In this regard, our results are in line with the findings of Linnemann and Schabert (2003) and Ravn et al. (2006) showing that strong shifts in labour demand and counter-cyclical markups of prices over marginal cost may imply a positive reaction of private consumption under an exogenous increase in productive public spending. On the contrary, under the flexible economy, private consumption decreases. This is the standard neoclassical result where the wealth effect dominates leading to high labour supply and lower consumption due to the expected future taxation that will fund the increase in public spending (see, among others, Barro, 1990).

[Figure 1 about here]

4.2. Unproductive Government Expenditure

As we can see from Figure 2, following the shock, the reactions of output and debt are again positive. In addition, the initial reaction of all the fiscal instruments is similar to the productive public spending. However, we should note here that unproductive public spending exhibits higher persistence compared to the productive public spending. This causes a

[21]The ratio of price over marginal cost decreases following the exogenous shock because, as it can be seen from the impulse responses, marginal cost increases more than inflation.

different reaction of the economy and, in particular, of the fiscal rules. For example, in this case the labour, capital and lump-sum taxes need to remain high, or keep increasing over time (for the case of the lump-sum taxes), due to the high persistence of the shock. Even though the lump-sum taxes increase over time, they are not sufficient to control debt so as not to increase. In particular, the response of debt is twice as much as in the case of productive spending. As a result, the economy enters a spiral of higher level of output but also high level of debt for a prolonged period of time. This implies a significant crowding-out effect on private consumption because the persistent high taxes cause a significant negative wealth effect on consumers.

Comparing the reaction of private consumption to the case with a positive shock to productive public spending, we observe that even in the case of a rigid economy we cannot get the empirically relevant positive reaction of private consumption. Therefore, the assumption of price stickiness is not sufficient to drive the crowding-in effect on private consumption from an increase in public spending. In particular, positive unproductive government spending shocks do not increase firms' productivity. As a consequence, the shift in labour demand is lower than in the case of the productive public spending shock. Accordingly, the response of real wage is negative inducing a crowding-out effect on consumption.

Our results are in line with Linnemann and Schabert (2003) that argue that price rigidities alone are not sufficient to generate a positive reaction in private consumption following a positive public spending shock. Moreover, we extend the argument of Ravn et al. (2006) where they implemented a model with price rigidities and deep habits to replicate the empirically relevant positive reaction of private consumption. They also show that the same model with "superficial" habits, like in our model, cannot produce the same results. Our model shows that price rigidities with productive public spending is the combination that leads to a positive reaction in private consumption when the exogenous positive government shock is on the productive public spending.

In the next section we show the importance of public spending financing under a rigid and a flexible economy.

[Figure 2 about here]

5. Fiscal Multipliers

In this section we summarise the effects of the two types of public spending to the economy. The present value multipliers are constructed following Leeper et al. (2010) and using the following equation:

$$\frac{\sum_{i=0}^{k}\left(\prod_{j=0}^{i} r_{t+j}^{-1}\right)\Delta X_{t+i}}{\sum_{i=0}^{k}\left(\prod_{j=0}^{i} r_{t+j}^{-1}\right)\Delta G_{t+i}^{c}} \tag{20}$$

where X_{t+i}, in the tables below, represents output (Y_{t+i}) and private consumption (C_{t+i}). Moreover, we assess the effects of both categories of public spending. Thus, G_{t+i}^{c} defines productive (G_{t+i}^{p}) and unproductive public spending (G_{t+i}^{u}). In addition, ΔX_{t+i} and ΔG_{t+i}^{c} are the relative level changes of the variables with respect to their steady-state values. Finally, the discount factor (r) represents the real interest rate.

Table 4 presents the cumulative present value multipliers for output and consumption based on the mean estimates of the posterior distribution. The parameter k determines the period in quarters and is set up to 1,000 for the infinite horizon case. We also present the results on the impact of the exogenous shock, together with the results for 3, 5 and 10 years ahead.

Comparing the present value of output multipliers between the rigid and the flexible economy we can see that they are slightly higher at the rigid economy and both are close to the range of values reported in previous empirical studies (Monacelli and Perotti, 2008 and Romer and Bernstein, 2009).

Regarding consumption present value multipliers for the rigid economy we can see that it is positive for at least 5 years indicating that the initial positive reaction of private consumption observed at the impulse responses is rather long lasting.[22] In terms of flexible economy, we note that the in-

[22] The consumption present value multiplier under the productive public spending

Variable	*Impact*	*1-year*	*3-years*	*5-years*	*10-years*	∞
Rigid Economy						
Productive Government Spending Present Value Multipliers						
$\frac{\Delta Y_{t+i}}{\Delta G^p_{t+i}}$	1.018	0.959	0.846	0.764	0.627	0.442
$\frac{\Delta C_{t+i}}{\Delta G^p_{t+i}}$	0.074	0.082	0.058	0.024	-0.066	-0.234
Unproductive Government Spending Present Value Multipliers						
$\frac{\Delta Y_{t+i}}{\Delta G^u_{t+i}}$	0.962	0.913	0.848	0.807	0.745	0.550
$\frac{\Delta C_{t+i}}{\Delta G^u_{t+i}}$	0.003	-0.014	-0.040	-0.060	-0.101	-0.280
Flexible Economy						
Productive Government Spending Present Value Multipliers						
$\frac{\Delta Y^f_{t+i}}{\Delta G^p_{t+i}}$	0.909	0.810	0.681	0.600	0.483	0.358
$\frac{\Delta C^f_{t+i}}{\Delta G^p_{t+i}}$	-0.038	-0.074	-0.123	-0.160	-0.237	-0.347
Unproductive Government Spending Present Value Multipliers						
$\frac{\Delta Y^f_{t+i}}{\Delta G^u_{t+i}}$	0.920	0.851	0.769	0.721	0.652	0.464
$\frac{\Delta C^f_{t+i}}{\Delta G^u_{t+i}}$	-0.039	-0.074	-0.118	-0.147	-0.196	-0.369

Table 4: Present value multipliers for output and consumption under productive and unproductive government spending shock

stantaneous consumption multiplier assumes a slightly positive value. Indeed, real rigidities prevent consumption from adjusting immediately, as we observed in Figure 1. However, immediately after the impact of the shock the present value of the consumption multiplier becomes negative and constantly decreases.

In order to assess if the method of financing the increased level of spending matters for the positive reaction of consumption, we consider different financing methods. Table 5 presents the cumulative present value multipliers for output and consumption for two different cases. The left panel presents the case where only labour and capital taxes adjust to the exogenous public spending shock, whereas the right panel presents the case where only lump-sum taxes adjust.

Overall, we do not observe significant differences in the short-run regarding the different methods of financing. However, in the long-run it matters significantly whether the government uses distortionary (such as

shock is equal to zero six and a half years after the shock and it then turns negative.

labour and capital taxes) or non-distortionary (such as lump-sum taxes) methods of financing. This result is in line with the findings of Leeper et al. (2010) arguing that distortionary taxation creates an additional channel that negatively affects the expansionary implications of increased public spending.

Regarding the flexible economy, for both productive and unproductive expenditures we note that the present value output multipliers are constantly higher when only lump-sum taxes adjust to a positive spending shock. On the other hand, under the rigid economy case, output multipliers have very similar responses in the short-run with much more pronounced differences in the long-run. Specifically, in the long-run the present value output multipliers are positive in the case of lump-sum tax adjustment.

Turning to the present value of consumption multipliers, under the flexible economy case, we observe significantly negative values when only labour and capital taxes adjust to positive productive and unproductive spending shocks. On the contrary, under the rigid economy case, the differences between the two methods of financing are less pronounced.

In general, we observe that different financing methods have distinct effects on output and private consumption depending on whether the economy is rigid or flexible. More specifically, when prices are sticky the stronger change in labour supply compared to labour demand and the high inflation level induce a positive response of real wage. The last effect is absent in the flexible economy case.

Finally, our results also indicate that private consumption immediately increases when productive public spending rises irrespective the method of debt financing. This outcome is in contrast to Linnemann and Schabert (2006) where they argue that only under non-distortionary taxation as a method of financing may lead to a crowding-in private consumption. In this regard, our results extend significantly the work of Linnemann and Schabert (2006) since we consider different fiscal policy rules including those for capital and labour taxes.

Variable	*Impact*	*5-years*	∞	*Impact*	*5-years*	∞
Rigid Economy						
	Labour and Capital Taxes Adjust			Lump-sum Taxes Adjust		
Productive Government Spending Present Value Multipliers						
$\frac{\Delta Y_{t+i}}{\Delta G^p_{t+i}}$	1.024	0.804	-1.583	1.022	0.804	0.420
$\frac{\Delta C_{t+i}}{\Delta G^p_{t+i}}$	0.060	0.009	-1.643	0.054	-0.036	-0.376
Unproductive Government Spending Present Value Multipliers						
$\frac{\Delta Y_{t+i}}{\Delta G^u_{t+i}}$	0.969	0.848	-1.362	0.972	0.891	0.866
$\frac{\Delta C_{t+i}}{\Delta G^u_{t+i}}$	-0.013	-0.059	-1.563	-0.025	-0.104	-0.136
Flexible Economy						
	Labour and Capital Taxes Adjust			Lump-sum Taxes Adjust		
Productive Government Spending Present Value Multipliers						
$\frac{\Delta Y^f_{t+i}}{\Delta G^p_{t+i}}$	0.924	0.602	-3.380	0.938	0.713	0.382
$\frac{\Delta C^f_{t+i}}{\Delta G^p_{t+i}}$	-0.039	-0.202	-3.357	-0.030	-0.140	-0.432
Unproductive Government Spending Present Value Multipliers						
$\frac{\Delta Y^f_{t+i}}{\Delta G^u_{t+i}}$	0.938	0.717	-3.130	0.966	0.889	0.866
$\frac{\Delta C^f_{t+i}}{\Delta G^u_{t+i}}$	-0.039	-0.173	-3.223	-0.031	-0.106	-0.136

Table 5: Present value multipliers for output and consumption under productive and unproductive government spending shock when only distortive taxes adjust and when only lump-sum taxes adjust

6. Robustness Checks

In this section we provide a sensitivity analysis regarding the importance of a few key parameters in our model. Starting with the share of the productive public capital in the production process, α_3, we examine how our key results are affected if we reduce its value to 0.05. Note that there is no consensus regarding the value of this parameter in the related literature with a suggested range of values between 0.05 and 0.24 (see Leeper et al. 2010 and references therein).

Table 6 shows that when the share of public capital in the production process is reduced all the present value multipliers are lower and for every period examined (middle panel). This result is valid for both economies and for both types of public spending shocks. However, we should note here that the present value multiplier of output and consumption is mainly affected under the rigid economy and under a positive shock to productive public spending.

Regarding the speed of adjustment of the various fiscal rules (γ^j parameter, where $j = bl$, bk, bg^p, bg^u and bt), we assess the effects to our economy when all the rules adjust twice as fast in each shock compared to the benchmark case (right panel in Table 6). The results indicate that under the rigid economy there are higher present value multipliers for output and consumption, especially in the short-run. Therefore, in our model the economy benefits more in the short-run when the government does not postpone the repayment of debt leading to a lower negative wealth effect.

Monetary policy is one of the most important transmission channels of public spending shocks. Therefore, in Table 7 we consider different values for the parameters of the Taylor rule. In particular, we analyse output and consumption multipliers when r^π, ρ, r^y and r^{Δ_y} are set to the half of their respective estimated values. In general, we observe that productive and unproductive spending shocks produce similar qualitative results. A less aggressive monetary policy implies lower nominal and real interest rate weakening consumers' incentives to postpone consumption and, in turn, boosts final output.

Thus, for example, lower values of r^π and r^y cause higher values for the instantaneous output and consumption multipliers. Similarly, in the long-

Var.	*Imp.*	*5-years*	∞	*Imp.*	*5-years*	∞	*Imp.*	*5-years*	∞
Rigid Economy									
	Benchmark			α_3= 0.05			$\gamma^j_{new} = 2 * \gamma^j$		
Productive Government Spending Present Value Multipliers									
$\frac{\Delta Y_{t+i}}{\Delta G^p_{t+i}}$	1.018	0.764	0.442	1.009	0.732	0.340	1.034	0.763	0.453
$\frac{\Delta C_{t+i}}{\Delta G^p_{t+i}}$	0.074	0.024	-0.234	0.075	0.024	-0.309	0.089	0.036	-0.225
Unproductive Government Spending Present Value Multipliers									
$\frac{\Delta Y_{t+i}}{\Delta G^u_{t+i}}$	0.962	0.807	0.550	0.958	0.796	0.555	0.979	0.808	0.555
$\frac{\Delta C_{t+i}}{\Delta G^u_{t+i}}$	0.003	-0.060	-0.280	0.004	-0.059	-0.266	0.019	-0.050	-0.276
Flexible Economy									
	Benchmark			α_3= 0.05			$\gamma^j_{new} = 2 * \gamma^j$		
Productive Government Spending Present Value Multipliers									
$\frac{\Delta Y^f_{t+i}}{\Delta G^p_{t+i}}$	0.909	0.600	0.358	0.902	0.577	0.261	0.910	0.590	0.369
$\frac{\Delta C^f_{t+i}}{\Delta G^p_{t+i}}$	-0.038	-0.160	-0.347	-0.038	-0.161	-0.424	-0.038	-0.158	-0.339
Unproductive Government Spending Present Value Multipliers									
$\frac{\Delta Y^f_{t+i}}{\Delta G^u_{t+i}}$	0.920	0.721	0.464	0.916	0.713	0.472	0.921	0.712	0.469
$\frac{\Delta C^f_{t+i}}{\Delta G^u_{t+i}}$	-0.039	-0.147	-0.369	-0.038	-0.145	-0.356	-0.039	-0.147	-0.366

Table 6: Present value multipliers for output and consumption under productive and unproductive government spending shock with different share of productive capital in the production production process and faster debt adjustment for the fiscal rules

run, the present values of output and consumption multipliers are larger than in the benchmark case. On the contrary, a lower value of the interest rate smoothing parameter causes a higher response of the nominal interest rate. Therefore, in this case, we observe a lower response of output and consumption multipliers on impact and in the long-run. Finally, we note that output and consumption multipliers are not substantially different if we decrease r^{Δ_y} to half of its benchmark value. Evidently, this result depends on the low benchmark (estimated) value of the weight on short-run GDP in the Taylor rule.

		Variable			
	Rigid Economy	Productive Gov. Spend. PV Multipliers		Unproductive Gov. Spend. PV Multipliers	
		$\frac{\Delta Y_{t+i}}{\Delta G^p_{t+i}}$	$\frac{\Delta C_{t+i}}{\Delta G^p_{t+i}}$	$\frac{\Delta Y_{t+i}}{\Delta G^p_{t+i}}$	$\frac{\Delta C_{t+i}}{\Delta G^p_{t+i}}$
Impact		1.018	0.074	0.962	0.003
5-years	Benchmark	0.764	0.024	0.807	-0.060
∞		0.442	-0.234	0.550	-0.280
Impact		1.048	0.105	0.966	0.007
5-years	$r^{\pi}_{new} = 0.5 * r^{\pi}$	0.800	0.066	0.810	-0.056
∞		0.465	-0.205	0.547	-0.283
Impact		0.982	0.036	0.950	-0.009
5-years	$\rho_{new} = 0.5 * \rho$	0.739	-0.005	0.805	-0.063
∞		0.434	-0.247	0.550	-0.280
Impact		1.022	0.078	0.962	0.003
5-years	$r^{y}_{new} = 0.5 * r^{y}$	0.778	0.039	0.807	-0.060
∞		0.451	-0.223	0.551	-0.279
Impact		1.020	0.076	0.962	0.003
5-years	$r^{\Delta_y}_{new} = 0.5 * r^{\Delta_y}$	0.765	0.026	0.808	-0.060
∞		0.442	-0.234	0.550	-0.280

Table 7: Present value multipliers for output and consumption under productive and unproductive government spending shock for the rigid economy with different values of the parameters in Taylor rule

7. Conclusion

In this paper we developed and estimated a new Keynesian DSGE model with productive and unproductive government spending financed by lump-sum and distortive taxes. In particular, we have assumed that the productive government expenditure enters firms' production function. We have also taken into account several fiscal policy rules. Our model has been estimated with Bayesian techniques for the sample period 1963:Q2-2013:Q4.

Our results contribute to the related literature in several ways. Firstly, our estimated fiscal rules show that capital tax response is more procyclical than labour tax response. Similarly, capital tax responds more strongly than labour tax to changes in government debt. Thus, capital tax is used as a shock absorber while labour tax is held relatively smooth over the business cycle. Secondly, we found that lump-sum taxes exhibit a strong reaction to changes in debt to output ratio. Thirdly, our estimates show that unproductive expenditure responds more strongly than productive spending to changes in government debt indicating that policymakers are reluctant in raising taxes to finance "unpopular" public spending. Therefore, they prefer to issue new debt. Finally, we found that the estimated parameter for the persistence of the unproductive spending shock is higher than the one of productive expenditure. As we have shown, a lower persistence in the productive public spending is one of the main reasons for the crowding-in effect on private consumption.

Moreover, our approach allowed us to assess several fiscal policy experiments. In particular, our results show that when the share of public capital in the production process is reduced all the present value multipliers decrease. In addition, we found that for the rigid economy when all the fiscal rules adjust more rapidly to debt deviations than in the estimated case there are marginally higher present value multipliers for output and consumption in the short-run. Finally, our findings suggest that a less aggressive monetary policy implies lower nominal and real interest rate weakening consumers' incentives to postpone consumption and, in turn, leads to higher GDP.

Acknowledgements: We would like to thank James Malley, Francesco Ravazzolo and Ronald P. Smith for their useful comments and feedback. We gratefully acknowledge the Department of Political Science of the University of Perugia for financial support on this project. The usual disclaimer applies.

References

[1] Altig, D., L.J. Christiano, M. Eichenbaum, and J. Linde, (2005): "Firm-Specific Capital, Nominal Rigidities, and the Business Cycle," NBER Working paper no. 11034.

[2] Altonji, J.G. (1986): "Intertemporal Substitution in Labor Supply: Evidence from Micro Data," The Journal of Political Economy, 94 (3), S176–S215.

[3] Ambler, S., and A. Paquet (1996): "Fiscal Spending Shocks, Endogenous Government Spending, and Real Business Cycles," Journal of Economic Dynamics and Control, 20, 237–256.

[4] Angelopoulos, K., S. Asimakopoulos, and J. Malley (2015): "Tax smoothing in a business cycle model with capital-skill complementarity," Journal of Economic Dynamics and Control, 51, 420-44.

[5] Aschauer, D.A. (1989) "Does Public Capital Crowd Out Private Capital?" Journal of Monetary Economics, 24,171–188.

[6] Asimakopoulos S., and I. Karavias (2016): "The Impact of Government Size on Economic Growth: a threshold analysis," Economics Letters, 139, 65-68.

[7] Barro, R.J. (1979): "On the Determination of the Public Debt," Journal of Political. Economy, 87 (6), 940–971.

[8] Barro, R.J. (1981): "Output Effects of Government Purchases," Journal of Political Economy, 89(6), 1086–1121

[9] Barro, R.J. (1990): "Government Spending in a Simple Model of Endogenous Growth," Journal of Political Economy, 98, S103–S125.

[10] Baxter, M., and R.G. King (1993): "Fiscal Policy in General Equilibrium," American Economic Review, 83(3), 315–34.

[11] Bilbiie, F. O. (2009): "Nonseparable Preferences, Fiscal Policy Puzzles, and Inferior Goods," Journal of Money, Credit and Banking, 41, 443–450.

[12] Blanchard, O.J. and R., Perotti (2002): "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output,". Quarterly Journal of Economics,117 (4), 1329-1368.

[13] Brooks, S.P., and A. Gelman (1998): “General Methods for Monitoring Convergence of Iterative Simulations,” Journal of Computational and Graphical Statistics, 7(4): 434–55.

[14] Calvo, G. (1983). “Staggered Prices in a Utility Maximizing Framework.” Journal of Monetary Economics, 12, 383–398.

[15] Chari, V., C. Lawrence, and P. Kehoe (1994): “Optimal Fiscal Policy in a Business Cycle Model,” Journal.of Political. Economy, 102 (4), 617–652.

[16] Chetty, R., A. Guren, D. Manoli, and A. Weber (2013): “Does Indivisible Labor Explain the Difference between Micro and Macro Elasticities? A Meta-Analysis of Extensive Margin Elasticities,” NBER Macroeconomics Annual, University of Chicago Press, 27(1), 1–56.

[17] Christiano, L., M. Trabandt, and K. Walentin (2011): “DSGE Models for Monetary Policy Analysis.” In Handbook of Monetary Economics, ed. Benjamin Friedman and Michael Woodford, 285–367. Amsterdam: North-Holland.

[18] Coenen, G., and R. Straub (2005): “Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area,” International Finance, 8(3), 435–470.

[19] Coenen, G., R. Straub, and M. Trabandt (2012): “Fiscal Policy and the Great Recession in the Euro Area,” American Economic Review: Papers and Proceedings, 102(3): 71–76.

[20] Cogan, J. F., T. Cwik, J. B. Taylor, and V.Wieland (2010): “New Keynesian versus Old Keynesian Government Spending Multipliers,” Journal of Economic Dynamics and Control, 34(3), 281–295.

[21] Constantinides, G.,(1990): “Habit Formation: a Resolution of the Equity Premium Puzzle,” Journal of Political Economics, 104, 219–240;

[22] Del Negro, M., and F. Schorfheide: (2008) “Forming Priors for DSGE Models (and How It Affects the Assessment of Nominal Rigidities),” Journal of Monetary Economics, 55(7), 1191-1208.

[23] Evans, P., and G. Karras (1994): “Are Government Activities Productive? Evidence from a panel of U.S.states,” Review of Economic and Statistics, 76,1–11.

[24] Forni, L., L. Monteforte and L. Sessa (2009): “The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area,”. Journal of Public Economics, 93, 559-585.

[25] Galí, J., J. D. López-Salido, and J. Vallés (2007): "Understanding the Effects of Government Spending on Consumption," Journal of the European Economic Association, 5(1), 227–270.

[26] Giorno, C., P. Richardson, D. Roseveare, and P. van den Noord (1995): "Estimating Potential Output, Output Gaps and Structural Budget Balances," Economic Working Papers No. 152, OECD.

[27] Glomm, G., and B. Ravikumar (1997) "Productive Government Expenditures and Long-run Growth," Journal of Economic Dynamics and Control, 21, 183–204.

[28] Greenwood, J., Z. Hercowitz, and P. Krusell (1997): "Long-run Implications of Investment-Specific Technological Change," American Economic Review 87 (3), 342 362.

[29] Greenwood, J., Z. Hercowitz, and P. Krusell, (2000): "The Role of Investment-Specific Technological Change in the Business Cycle," European Economic Review 44 (1), 91–115.

[30] Jermann, U.J. (1998): "Asset Pricing in Production Economies," Journal of Monetary Economics, 41, 257–275;

[31] Kamps, C. (2004): "The Dynamic Macroeconomic Effects of Public," Capital Springer, Berlin, Germany.

[32] King, R., and S. Rebelo (1990): "Public Policy and Economic Growth: Developing Neoclassical Implications," Journal of Political Economy, 98(5), S126-50, October.

[33] Kneller, R., M. Bleaney and n. Gemmell (1999): "Fiscal Policy and Growth: Evidence from OECD countries," Journal of Public Economics, 74, 171-190.

[34] Kormilitsina, A., and S. Zubairy (2016): "Propagation Mechanisms for Government Spending Shocks: A Bayesian Comparison," manuscript.

[35] Le, V.P. M., D. Meenagh, P. Minford, and M. Wickens (2011): "How Much Nominal Rigidity Is There in the US Economy? Testing a New Keynesian DSGE Model Using Indirect Inference," Journal of Economic Dynamics and Control, 35(12), 2078–2104.

[36] Leeper, E., T. Walker and S.-C. Yang (2010): "Government Investment and Fiscal Stimulus," Journal of Monetary Economics, 57, 1000–1012.

[37] Linnemann, L. (2006): "The Effect of Government Spending on Private Consumption: A Puzzle?," Journal of Money, Credit and Banking, 38(7), 1715–1735.

[38] Linnemann, L., and A. Schabert (2003): "Fiscal Policy in the New Neoclassical Synthesis," Journal of Money, Credit and Banking, 35(6), 911–29.

[39] Linnemann, L., and A. Schabert (2006): "Productive Government Expenditure In Monetary Business Cycle Models," Scottish Journal of Political Economy, 53(1), 28–46.

[40] Lorusso, M. and L. Pieroni (2017): "The Effects of Military and Non-Military Government Expenditures on Private Consumption," Journal of Peace Research, Forthcoming.

[41] MaCurdy, T.E. (1981): "An Empirical Model of Labor Supply in a Life-Cycle Setting," The Journal of Political Economy, 89 (6), 1059–1085.

[42] Monacelli, T., and R. Perotti (2008): "Fiscal Policy, Wealth Effects, and Markups," NBER Working Paper No. 14584.

[43] Mountford A., and H. Uhlig (2009): "What are the effects of fiscal policy shocks?," Journal of Applied Econometrics, 24(6), 960–992.

[44] Peterman, W.B. (2016): "Reconciling Micro And Macro Estimates Of The Frisch Labor Supply Elasticity," Economic Inquiry, 54(1), 100-120.

[45] Pfeifer, J. (2015): "A Guide to Specifying Observation Equations for the Estimation of DSGE Models," https://sites.google.com/site/pfeiferecon/dynare.

[46] Ravn, M.O., S. Schmitt-Grohe, and M. Uribe (2006): "Deep Habits," Review of Economic Studies, 73(1), 195–218.

[47] Ravn, M.O., S. Schmitt-Grohé, and M. Uribe (2012): "Consumption, government spending, and the real exchange rate," Journal of Monetary Economics, 59(3), 215–234.

[48] Romer, C. and J. Bernstein (2009): "The Job Impact of the American Recovery and Reinvestment Plan," Obama Transition Team, Washington, DC.

[49] Schmitt-Grohe, S., and M. Grohe (2012): "What's News in Business Cycles," Econometrica, 80(6), 2733–2764.

[50] Smets, F., and R. Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," American Economic Review, 97(3), 586–606.

[51] Solow, R. (1956): "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, 65-94.

[52] Stokey, N.L., S. Rebelo, Sergio, (1995): "Growth Effects of Flat-Rate Taxes," Journal of Political Economy, 103(3), 519–50.

[53] Swan, T. (1956): " Economic Growth and Capital Accumulation. Economic Record 32.63: 334-361.

[54] Taylor, John B. (1993). "Discretion versus Policy Rules in Practice." Carnegie Rochester Conference Series on Public Policy, 39, 195–214.

[55] Yang, S. (2005): "Quantifying Tax Effects Under Policy Foresight," Journal of Monetary Economics, 52 (8), 1557-1568.

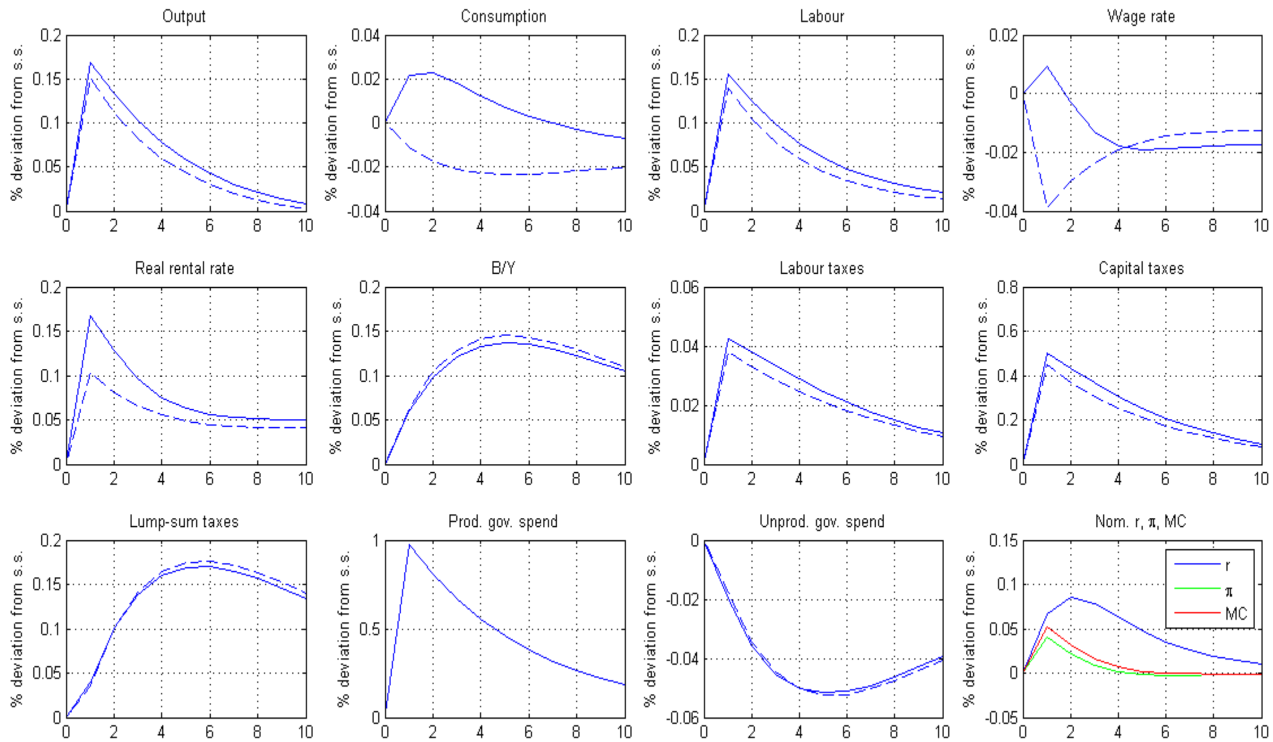

Figure 1: Impulse responses to a 1 percent increase in productive public spending. Solid lines indicate an exonomy with price rigidities. Dashed lines are for the flexible economy. All variables are in percentage deviations from their steady-state. X-axis is in quarters.

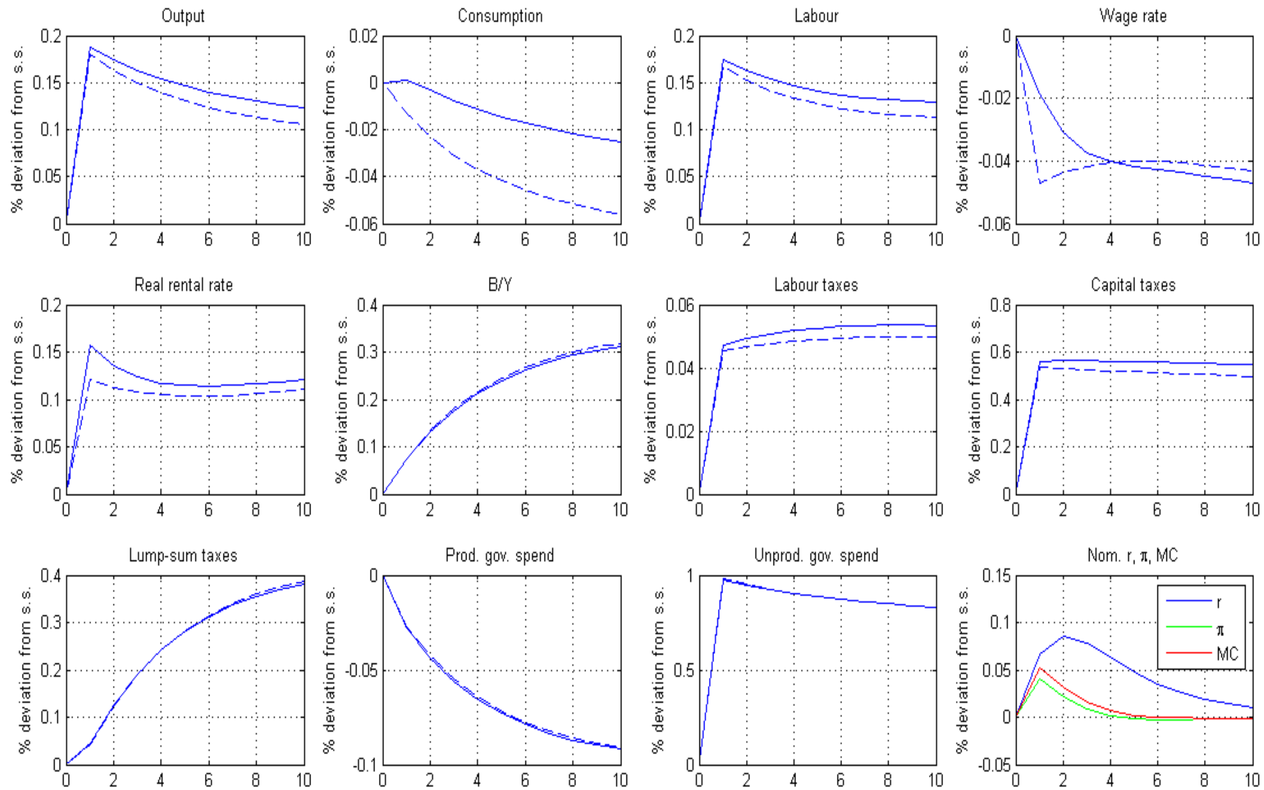

Figure 2: Impulse responses to a one percent increase in unproductive public spending. Solid lines indicate an exonomy with price rigidities. Dashed lines are for the flexible economy. All variables are in percentage deviations from their steady-state. X-axis is in quarters.