Abstract

This paper studies the impact of government consumption shocks in an estimated DSGE model of the US economy which extends the standard setup by specifying government consumption as the sum of government expenditures on goods and services and compensation of public employees. We show that accounting for the difference in spending items is key in studying the impact of spending shocks. While an increase in government purchases leads to a fall in private consumption as in standard models, a similar increase in government employment or government wages can generate a rise in private consumption even for a fairly low share of rule-of-thumb consumers in the economy. This finding qualifies some of the standard results in the literature.

1 Introduction

This paper presents estimation results for an extension to the standard New-Keynesian dynamic stochastic general equilibrium model, which allows for a breakdown of final government consumption into compensation of employees on one hand and government expenditure on goods and services on the other hand.

Compensation of employees accounts for over 60% of final government consumption in the United States and for over 50% in European Union member states. Notwithstanding, most of the theoretical literature focusing on the impact of final government consumption specifies this variable as expenditure on goods and services only, entirely ignoring the part spent on compensation of employees.
In general, models of this type generate a significant negative co-movement between public and private consumption. The reason is that an increase in government expenditure on goods and services financed by debt or taxes implies a negative wealth effect for households who then react by decreasing their consumption and increasing their labour supply. The impact of such a spending hike on the real wage differs across models depending on assumptions about price and wage rigidities.

This feature of the DSGE models seems to stand in contrast to empirical evidence on this matter. While empirical literature has not reached a clear consensus on the impact of government consumption on private consumption, a large part of results point to a significant positive or, at least, no significant negative co-movement between private and government consumption.\(^1\)

To remedy this problem, Gali et al. (2007) propose the introduction of so-called 'rule-of-thumb' consumers into an otherwise standard sticky-price model. Rule-of-thumb consumers do not have access to capital or financial markets and are constrained to consume their entire labour and transfer income in any given period. The authors argue that this empirically justified deviation from the standard permanent income hypothesis combined with sticky prices is sufficient to generate a positive co-movement between private and (partly) debt-financed public consumption.

However, the results demonstrated by these authors have not proven to be robust to different model assumptions. Most notably, frictions in the labour market prevent the model from reproducing the positive comovement between public and private consumption for plausible shares of liquidity-constrained households.\(^2\) The explanation for this is that wage rigidities reduce the demand-induced contemporaneous rise (fall) in wages in reaction to an increase (decrease) in government spending thereby dampening liquidity-constrained households’ reaction to the policy; see e.g. Coenen & Straub (2005).

The model used in this paper features liquidity-constrained consumers as well as price and wage rigidities. Accordingly, it presents a negative comovement between private and public consumption for plausible shares of liquidity-constrained households when government consumption is specified solely (and wrongly) as expenditure on goods and services.

In this paper, we argue that the correct accounting for final government consumption as the sum of expenditures on goods and services and of compensation of government employees is key in assessing the impact of government spending shocks. To make our point, we extend a standard New-Keynesian model to allow for the more exact specification of final government consumption. Households supply labour to both the public and the private sectors with less than perfect substitution between employment in the two sectors. Wages are set by economy-wide monopolistically competing trade unions in each sector separately. As we show, the optimal wage schedule in each sector takes into account labour market

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\(^{1}\)See e.g. Blanchard & Perotti (2002), Fatas & Mihov (2001), Mountford & Uhlig (2009), Ramey & Shapiro (1998) or Gali et al. (2007) and the literature review therein.

\(^{2}\)The term ‘liquidity-constrained’ consumers is used to describe ‘rule-of-thumb’ consumers. Throughout the entire paper, these terms are used interchangeably.
conditions in the total economy; this leads to the transmission of shocks across sectors.

We estimate this model for the US between 1995Q1 and 2009Q4 using Bayesian estimation methods to determine the share of liquidity-constrained households as well as Frisch and cross-sector labour supply elasticities. We then use this model to assess the impact of government consumption shocks on private consumption and output.

Our results suggest that there are significant differences between the economic impact of shocks to government spending on goods and services on the one hand and shocks to public employment on the other hand. In particular, while shocks to government spending on goods and services crowd out private consumption as in the standard models, shocks to public employment and public wages (specified as a wage mark-up shock in the government sector) tend to crowd in private consumption.

Interestingly, our model generates positive co-movement between public employment expenditures and private consumption even for fairly low shares of liquidity-constrained households. Indeed, our estimations indicate a share of rule-of-thumb consumers of less than 20%. To compare, Gali et al. (2007) calibrate the share of rule-of-thumb consumers to 50% and Coenen & Straub (2005) report a share of 25 - 37% for the euro area. What drives our results is the fact that the estimated degree of substitution between public and private employment is relatively low. Thereby, an increase in public employment does not lead to a large fall in private employment and generates stronger income effects for households.

Literature on public employment in general equilibrium models has been scarce. Earlier contributions rely on RBC or sticky-price models with perfectly competitive labour markets and perfect substitution between private and public employment (see e.g. Finn (1998), Cavallo (2005), Pappa (2009)). Unless these models allow for productive government employment or for complementarity between private and public consumption in the utility function, increases in public employment will crowd out private consumption and / or lead to a fall in total employment which are at odds with data. The less-than-perfect substitution between public and private employment in our model yields results similar to those of Ardagna (2007) who builds on unionised labour markets or Afonso & Gomes (2008) and Gomes (2010) who introduce search and matching frictions in a model with public and private employment.

To the best of our knowledge, Gomes (2010) is the only paper estimating a model including public employment. This paper focuses however on the impact of public employment shocks on the labour market only. These results are roughly in line with our findings.

The remainder of this paper is organised as follows. The next section describes QUEST III focusing on the parts relevant to the public sector extension.

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3 For another paper with public employment and search and matching frictions see also Quadrini & Trigari (2007). These authors focus, however, on the business-cycle properties of models with public sector employment.
Section 3 presents estimation results. Section 4 discusses the reaction of the economy to shocks to government consumption and section 5 concludes.

2 The QUEST III model with government employment

The QUEST III model is an open-economy New-Keynesian dynamic general equilibrium model comprising optimising households and firms, international goods and capital markets as well as monetary and fiscal policy authorities. The QUEST III model is described in detail in Ratto et al. (2009). At this place we outline the parts relevant to the government employment extension.

2.1 Households:

The economy contains a continuum of households $h \in [0; 1]$. There are two types: a share $1 - s^l$ are Ricardians. They work, consume, own the capital stock and invest into domestic and foreign financial assets. The remaining $s^l$ households are liquidity-constrained: they work and consume, however, they do not have access to capital and financial markets. They therefore have to (or can only) consume their labour and transfer income in any given period. These households are the so called 'rule-of-thumb' consumers described in Gali et al. (2007). As discussed by the authors, the introduction of such rule-of-thumb households can be motivated by substantial deviations from the permanent income hypothesis in observed consumer behaviour.

In the current extension, it will be assumed that each individual household chooses the share of its members employed and allocates them between the private and the public sectors. In addition, labour supply to the two sectors is not perfectly substitutable. This captures less than perfect mobility of workers across sectors. Wages are assumed to be set by economy-wide trade unions uniformly representing Ricardian and liquidity-constrained households. The share of household members not employed in either sector receives an unemployment benefit payment which is linked to the average wage in the total economy.

Formally, both types of households face an identical utility function:

$$\max\ U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[ U \left( C^j_t \right) - V(L^j_t) + W \left( G^j_t, Y^G_t \right) \right]$$

where $C^j_t$ stands for the average per capita consumption within a household, $L^j_t$ for the share of household members working, $G^j_t$ for per capita government

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4The specification used in this paper follows Iacoviello & Neri (2010). See also M. Horvath (2000). Frictions in workers’ mobility between sectors might also be captured by adjustment costs for firms in hiring workers from the other sector. However, since government employment decisions are exogenous, this would not have permitted a symmetric treatment of frictions across sectors.
purchases of privately produced goods and services and \( Y^G \) for per capita goods and services provided by the government. Variables indexed \( r \) denote values across Ricardian households; the index \( l \) stands for variables related to liquidity-constrained households.

The specific functional forms are:

\[
U(C^r_t) = \exp(u^r_c t) \left( 1 - \text{hab}^r_c \right) \log \left( C^r_t - \text{hab}^r_c C_{t-1} \right),
\]

\[
V(L^l_t) = \omega \exp(u^l t) \left( L^l_t \right)^{\kappa + 1},
\]

where \( \kappa > 0 \) is the inverse of the Frisch labour supply elasticity; \( \omega \) denotes the relative importance of the disutility of labour relative to the utility of consumption. We allow for external habit persistence in consumption, with \( \text{hab}^r_c \) denoting the degree of persistence; \( u^r_c t = \rho_u u^r_{c, t-1} + \varepsilon^r_{c, t} \) for \( i = r, l \), and \( u^l t = \rho_l u^l_{c, t-1} + \varepsilon^l t \) are serially correlated shocks to preferences.

Total labour supply is a CES aggregate of labour supplied to the private sector \( L^p^r_j \) and to the public sector \( L^g^j \), respectively:

\[
L^j_t = \left[ s p^{-\frac{\Xi}{\kappa}} \left( L^p^r_j \right)^{\frac{\Xi + 1}{\kappa}} + (1 - s p)^{-\frac{\Xi}{\kappa}} \left( L^g^j \right)^{\frac{\Xi + 1}{\kappa}} \right]^{\frac{\kappa}{\Xi}};
\]

the elasticity of substitution across sectors \( \xi \in (0; \infty) \), with \( \xi \rightarrow 0 \) corresponding to perfect complementarity and \( \xi \rightarrow \infty \) to perfect substitution.

Utility over goods and services supplied by the government enters the utility function in an additively separable way. As discussed in Pappa (2009), complementarity between government and private consumption is one way to reproduce the observed positive co-movement between these two aggregates. By letting government consumption and government output entering households’ utility function separably we eliminate this channel. As will be shown later, such a pattern can still arise if government consumption is specified correctly as the sum of compensation of public employees and government purchases of goods and services.

2.1.1 Ricardian households:

Ricardian households maximise their life-time utility with respect to consumption, capital stock \( K^r_t \), investment in physical capital \( I^r_t \) as well as investment in domestic bonds \( B^r_t \) and foreign bonds \( B^{sr}_t \) subject to

1. the period budget constraint:

\[
p^C_t (1 + T^C_t) C^r_t + p^K_t I^r_t + B^r_t + \text{rer}_t B^{sr}_t + \frac{\gamma^f}{2} \left( \frac{L^p_r}{K_{t-1}} - \delta \right)^2 + \frac{\gamma^{I^2}}{2} (I^r_t - I^{r, t-1})^2 + \frac{\gamma^p}{2} \left( \frac{W^p_t}{W^{r, t-1} - 1} \right)^2 L^p^r_t + \frac{\gamma^g}{2} \left( \frac{W^g_t}{W^{r, t-1} - 1} \right)^2 L^g^r_t + T^L^S_r =
\]
\[ = (1 - T_t^L) W_t^{r_p} L_t^{r_p} + (1 - T_t^L) W_t^{r_g} L_t^{r_g} + \]
\[ + \text{benr} W_t^r (1 - L_t^{r_p} - L_t^{r_g}) + [(1 - T_t^k) r_t^k + T_t^k \delta] p_t^K K_t^r + \]
\[ + (1 + r_{t-1}) B_{t-1}^r + (1 + r_{t-1}^* + \text{risk} (B_{t-1}^r - B^*)) \text{rer}_t B_{t-1}^r + \text{Tr}_t^r, \]

where \( p_t^C \) and \( p_t^K \) denote the price of consumption and capital goods relative to the GDP deflator; \( \text{rer}_t \equiv \frac{\text{E}^*}{\text{E}} \) stands for the real exchange rate; \( \delta \) denotes the depreciation rate; \( W_t^p \) and \( W_t^g \) denote private and public nominal wages, respectively, with the real wage in each sector being \( W_t^{r,i} = \frac{W_t^i}{P_t} \), \( i = p, g \); average wage is defined as the weighted average of private and public sector wages: \( W_t = \frac{L_t^p W_t^p + L_t^g W_t^g}{L_t} \). Each household receives an unemployment benefit for the share of its non-working members \( 1 - L_t^{r_p} - L_t^{r_g} \); the benefit is defined as a constant share \( \text{benr} \) of the after-tax average wage in the economy. Households pay taxes on consumption, \( T_t^C \), labour income \( T_t^L \), corporate profit (net of capital depreciation) \( T_t^k \); they also pay lump-sum taxes receive transfers \( T_{t}^{LS,r} \) and receive transfers from the government, \( \text{Tr}_t^r \). The term \( \text{risk} (B_{t-1}^r - \bar{B}^*) \) stands for a risk premium term which allows to close down the small-open economy model; see Schmitt-Grohe & Uribe (2003); the parameter \( \delta \) stands for the depreciation rate;

2. and to the capital accumulation equation:

\[ K_t^r = (1 - \delta) K_{t-1}^r + I_t^r. \]

The first-order conditions describing Ricardian households’ decisions are standard. In the estimations, two additional shocks will be allowed for: the discount factor of the Q equation (derivative with respect to \( K_t^r \)) is subject to a serially correlated risk premium shock denoted: \( u_t^{\text{prekm}} = \rho_t^{\text{prekm}} u_{t-1}^{\text{prekm}} + \varepsilon_t^{\text{prekm}} \); and the uncovered interest parity condition can be shifted by a serially correlated exchange rate risk premium shock: \( u_t^{\text{preme}} = \rho_t^{\text{preme}} u_{t-1}^{\text{preme}} + \varepsilon_t^{\text{preme}}. \)

### 2.1.2 Liquidity-constrained households:

Liquidity-constrained households do not have access to capital markets. Therefore they face the following budget constraint:

\[ p_t^C (1 + T_t^C) C_t^l + \gamma_{wp} \left( \frac{W_t^p}{P_{t-1}^l} - 1 \right)^2 L_t^{r,p} + \gamma_{wg} \left( \frac{W_t^g}{P_{t-1}^l} - 1 \right)^2 L_t^{r,g} = \]
\[ = (1 - T_t^L) W_t^{r,p} L_t^{r,p} + (1 - T_t^L) W_t^{r,g} L_t^{r,g} + \text{benr} W_t^r (1 - L_t^{r,p} - L_t^{r,g}) + \text{Tr}_t^r - T_{t}^{LS,l}. \]
The problem of liquidity-constrained households is restricted to the current period. The only decision they could take is the optimal consumption-labour decision given their period income. The wage setting is referred to economy-wide unions and is described below.

2.1.3 Aggregation

The economy-wide aggregate of any household-specific variable in per capita terms is given by:

\[ X_t = \int_0^1 X_t(h) \, dh = \int_0^{s^l} X_t(h) \, dh + \int_{s^l}^1 X_t(h) \, dh. \]

The average per capita value of a variable across the liquidity-constrained and the Ricardian households is:

\[ X^{l}_t = \frac{1}{s^l} \int_0^{s^l} X_t(h) \, dh; \quad X^{r}_t = \frac{1}{1-s^l} \int_{s^l}^1 X_t(h) \, dh. \]

Thereby

\[ X_t = s^l X^{l}_t + (1-s^l) X^{r}_t. \]

2.2 Wage setting

Wage setting is similar to that described in Gali et al. (2007, Appendix A) with modifications made for sectoral price setting.

In both private and public sectors, there is a continuum of economy-wide trade unions, each of which represents a certain type of workers \( i \) in a centralised manner. The fraction of Ricardian and liquidity-constrained households is uniformly distributed across types of labour, and hence across trade unions, in both sectors. Trade unions set the wage to maximise their members’ average utility given the demand for effective labour input hired by firms in the private and the public sectors:

\[
L^p_t = \left( \int_0^{1} L^p_t(i) \frac{\theta^{wp}_{0} - 1}{\theta^{wp}_{0} + 1} \, di \right)^{\frac{\theta^{wp}_{0} - 1}{\theta^{wp}_{0}}} ; \quad L^g_t = \left( \int_0^{1} L^g_t(i) \frac{\theta^{wg}_{0} - 1}{\theta^{wg}_{0} + 1} \, di \right)^{\frac{\theta^{wg}_{0} - 1}{\theta^{wg}_{0}}},
\]

where \( \theta^{wp}_0 \) and \( \theta^{wg}_0 \) denote the elasticity of substitution across labour types in the private and the public sector, respectively. The elasticities are subject to serially correlated shocks: \( \theta^{wp}_t = \theta^{wp} + \eta_{0}^{wp} \) for \( j = wp, wg \), with \( \eta_{0}^{wp} = \rho_{0}^{wp} \eta_{t-1}^{wp} + \xi_{t}^{wp} \). These shocks will be referred to as wage mark-up shocks.

Consumption levels may differ between the two types of households. When setting the wage, trade unions weigh labour income with the average marginal utility of consumption across household types. Also, they take into account that private firms and the government allocate labour demand uniformly across
labour types \(i\), independently of their household type while households are willing to supply the employment demanded in each sector under the assumption that wages always remain above all households’ marginal rate of substitution. Consequently, in both sectors the employment share of Ricardian and liquidity-constrained households is equal: \(L^r_i = L^j_i = L_i^j\), for \(j = p, g\).

Specifically, each period trade unions set the wage to maximise the average utility of their members given labour demand and wage adjustment costs:

\[
L^j_i (i) = \left( \frac{W^j_i (i)}{W^j_i} \right)^{-\theta^j_i} L^j_i; \quad j = wp, wg.
\]

The wage set in the private sector is then:

\[
(1 - T^L_i) W^{rp}_t = \frac{\theta^wp}{\theta^rp - 1} \left( \frac{\omega L^p_t \left( \frac{sp L^p_t}{L^p_t} \right)^{\frac{1}{\pi^p}}}{\lambda_t} + \text{benr} W^r_t \right) - \\
- \frac{\gamma^wp}{\theta^rp - 1} \pi^wp (1 + \pi^wp) + \frac{\gamma^wp}{\theta^rp - 1} \frac{\lambda_{t+1} L^p_{t+1} \pi^wp}{\lambda_t L^p_t} \pi^p (1 + \pi^p),
\]

where \(\bar{\lambda}_t = s^l \lambda^l_t + (1 - s^l) \lambda^p_t\) is the average Lagrange multiplier across Ricardian and liquidity-constrained households (i.e. the average real marginal utility across households). This is the adapted form of a standard monopolistic competition wage setting model with Rotemberg-type wage adjustment costs: after-tax wages are set as a mark-up over the marginal rate of substitution between labour and consumption with time varying mark-up due to the adjustment costs. Note that instead of the usual marginal disutility of labour \(\omega L^p_t\) in standard models, here the disutility of labour in the private sector is more complex: \(\omega L^p_t \left( sp L^p_t \right)^{\frac{1}{\pi^p}}\), and, via total employment, it also depends on employment in the other sector. Finally, unemployment benefits also enter the wage setting equation by increasing the household’s income earned by non-working members.

Symmetrically, the wage set in the government sector follows:

\[
(1 - T^L_i) W^{rg}_t = \frac{\theta^wg}{\theta^rg - 1} \left( \frac{\omega L^g_t \left( (1 - sp) \frac{L^g_t}{L^g_t} \right)^{\frac{1}{\pi^g}}}{\lambda_t} + \text{benr} W^r_t \right) - \\
- \frac{\gamma^wg}{\theta^rg - 1} \pi^wg (1 + \pi^wg) + \frac{\gamma^wg}{\theta^rg - 1} \frac{\lambda_{t+1} L^g_{t+1} \pi^wg}{\lambda_t L^g_t} \pi^g (1 + \pi^g).
\]
Employment in the private sector is determined by the firms based on their profit-maximising decision; to capture non-profit maximising behaviour in the public sector, public employment is set exogenously by the government.

2.3 Trade

QUEST III is an open economy model. Trade equations are derived from households’ demand for domestic and foreign produced goods given prices set by producers in their own currency. Various parameters, such as elasticities of substitution and markups are estimated for the external trade. The details of QUEST III’s external dimension are not directly relevant to our discussion. Details can be found in Ratto et al (2009).

2.4 Production

2.4.1 Private firms

There is an infinite number of monopolistically competing firms in the economy whose size is normalised to 1. They sell goods to domestic and foreign households as well as to the domestic and the foreign government for consumption and investment purposes.

Firm sets their price to maximise their future discounted flow of profits:

$$\max_{P_t(i)} P_t(i)\left(\sum_{j=0}^{\infty} \beta^j \frac{X_{t+j}^{\text{real}}}{X_t} \left[ \frac{P_{t+j}(i)}{P_{t+j}} Y_{t+j}^p(i) - \frac{MC_{t+j}}{P_{t+j}} Y_{t+j}^p(i) - \frac{\gamma_p}{2} \left( \frac{P_{t+j}(i)}{P_{t+j-1}(i)} - 1 \right) Y_{t+j}^p \right] \right)$$

where

$$Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\theta} Y_t,$$

$MC_{t+j}$ stands for the marginal cost given the production technology:

$$Y_t^P = A(K_t)^{\alpha g} (ucap_t K_t)^{1-\alpha} \left( \exp(u_t^{TFP}) L_t^P \right)^{\alpha} - fcy \exp(u_t^{TFP})$$

and the last term in the brackets captures quadratic price adjustment costs. The labour augmenting productivity shock denoted $u_t^{TFP}$ follows a random walk process; $fcy$ denotes fixed production costs.

Firms act as price takers in the input markets. They choose the level of the capital stock, employment and capacity utilisation facing costs of adjusting employment:

$$\frac{\gamma}{2} \left( \frac{L_t^p}{L_{t-1}^p} - 1 \right)^2 W^{rp},$$
and capacity utilisation:

\[
\left( \pi_t^{ucap} \left( u_{cap(t)} - 1 \right) + \frac{\Delta^{ucap,2}}{2} \left( u_{cap(t)} - 1 \right)^2 \right) \rho_t^K K_t.
\]

Given firms’ problem, the price is set as a mark-up \( \frac{\partial}{\pi_t} \) over the marginal cost. This mark-up may be affected by auto-regressive mark-up shocks denoted \( u_t^\theta \). Firms labour demand can also be shifted by shocks denoted \( u_t^{ldem} \).

The first-order conditions describing the firms’ optimality conditions are standard.

### 2.4.2 Public sector

The definition of public sector output largely follows the cost-based accounting adopted by statistical offices:\(^5\)

\[
Y_{tg} = W_{tg}^L L_{tg}^L.
\]

Further, the level of public employment \( L_{tg}^L \) is chosen exogenously by the government; similarly to the private wages, public wages are set by economy-wide trade unions.

### 2.4.3 Total

Total GDP is the aggregate of sectoral output:

\[
Y_t = Y_t^p + Y_t^g,
\]

where, given that there is no explicit market demand for public production, the deflator of public output is assumed to be equal to the private production deflator.

### 2.5 Monetary policy

As is standard in literature, monetary policy sets the nominal interest rate \( i_t \) according to a simple log-linear policy rule:

\[
i_t = \phi_1 i_t + \left( 1 - \phi_1 \right) \left( \bar{\pi} + \rho_{\pi} \left( \pi_t^c - \bar{\pi} \right) + \rho_{y_{gap}} y_{gap(t-1)} + \rho_{\Delta_y} \left( y_{gap(t)} - y_{gap(t-1)} \right) + u_t^{mm} \right),
\]

where all variables are expressed in logarithms and \( u_t^{mm} = \rho_m u_t^{mm} + \epsilon_t^{mm} \) denotes the monetary policy shock.

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\(^5\)To precisely follow statistical accounting practices, this definition should also take into account the depreciation of public capital. However, since this is only a small share of government output, for the sake of simplicity we have abstracted from this.
The particular form of this policy function is motivated by empirical considerations. In particular, monetary policy is allowed to react to both the output gap and the change in the output gap, where output gap itself is defined as $ygap_t = (1 − \alpha) \log \left( \frac{ucap_t}{ucap_{t-1}} \right) + \alpha \log \left( \frac{L_t}{L_{t-1}} \right)$ following the output gap calculations used in policy making.

### 2.6 Fiscal policy

QUEST III features a rich set of fiscal instruments. Fiscal revenues consist of taxes on consumption, labour income, corporate income (net of depreciation) and lump-sum taxes:

$$REV_t = T^C_t p^C_t C_t + T^L_t (W^{r^p}_t L^p_t + W^{r^g}_t L^g_t) + T^k_t (r^k_t - \delta) p^K_t K_t + T^{LS}_t.$$  

Primary expenditures stem from final government consumption, government investment $IG_t$, benefit payments and lump-sum transfers. In contrast to standard models, final government consumption here is the sum of compensation of public employees $W^{r^g}_t L^g_t$ and government purchases of goods and services $G^C_t$:

$$EXP_t = p^C_t \left( G^C_t + IG_t \right) + benr_t W^r_t (1 - L^p_t - L^g_t) + W^{r^g}_t L^g_t + Tr_t.$$  

Total government consumption is then $G_t = p^C_t G^C_t + W^{r^g}_t L^g_t$.

Public debt evolves as:

$$B^{r^G}_t = (1 + r_{t-1}) B^{r^G}_{t-1} + EXP_t − REV_t.$$  

When setting government purchases of goods and services and government investment, the government is assumed to follow the following simple log-linear policy rules:

$$\log \left( \frac{G^C_t}{G^C_{t-1}} \right) = \phi_{glag} \log \left( \frac{G^C_{t-1}}{G^C_{t-2}} \right) + \phi_{gvecm} \left( \log \frac{G^C_t}{Y_t} - \log \frac{G^C_{t-1}}{Y_{t-1}} \right) + \phi_{gy1} ygap_t + \phi_{gy2} ygap_{t-1} + u^g_t$$  

and

$$\log \left( \frac{IG_t}{IG_{t-1}} \right) = \phi_{iglag} \log \left( \frac{IG_{t-1}}{IG_{t-2}} \right) + \phi_{igvecm} \left( \log \frac{G_t}{Y_t} - \log \frac{G_{t-1}}{Y_{t-1}} \right) + \phi_{igy1} ygap_t + \phi_{igy2} ygap_{t-1} + u^{ig}_t.$$

with $u^g_t = \rho^g u^g_{t-1} + \varepsilon^g_t$ and $u^{ig}_t = \rho^{ig} u^{ig}_{t-1} + \varepsilon^{ig}_t$.  

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The level of government employment and transfers are exogenously set by the government and may be subject to auto-regressive shocks:

\[ TR_t = TR + u^{tr}_t \]

\[ LGOV_t = LGOV + u^{LGOV}_t \]

where \( u^{tr}_t = \rho_{tr} u^{tr}_{t-1} + \varepsilon^{tr}_t \) and \( u^{LGOV}_t = \rho_{LGOV} u^{LGOV}_{t-1} + \varepsilon^{LGOV}_t \).

The benefit replacement rate as well as the tax rates on consumption, labour and corporate income are fixed and kept constant in our estimations.

Finally, to technically exclude explosive government debt the government follows a debt rule: real lump-sum taxes react to changes in the real debt stock:

\[ \frac{T_{LS}}{Y_t} = \frac{T_{LS}}{Y_{t-1}} + tgovb_1 \left( \frac{B_{t-1}^{r,G}}{4Y_{t-1}} - B^{tar} \right) + tgovb_2 \left( \frac{B_{t}^{r,G}}{Y_t} - \frac{B_{t-1}^{r,G}}{Y_{t-1}} \right) \]

2.7 Market clearing and the current account balance

In equilibrium all markets clear. The resulting current account equation is:

\[ B_t^* = (1 + r_{t-1}^* + \text{risk} (B_{t-1}^{r,r} - B^*)) B_{t-1}^{r,r} + \frac{P_t}{\epsilon_t P} EX_t - IM_t, \]

where imports are \( IM_t = C_t^F + I_t^F + G_t^F + IG_t^F \).

3 Bayesian Estimation of the Model

3.1 Data and Prior Distributions

The model is estimated on quarterly data for US over the period 1995Q1 to 2009Q4. The time series of real and nominal values of US output, consumption, corporate investment, government spending, government investment, exports and imports used in the estimation are from the Bureau of Economic Analysis database. So are the data on nominal transfers, total compensation and government compensation. As the US policy rate the Federal funds rate recorded in monthly frequency by the Conference board is used. Both total labour (total overall civilian employment, household survey) and government labour are from the Bureau of Labour Statistics.\(^6\)

\(^6\)For the estimation of the open economy part of the model a number of additional series (world demand, world interest rates, real and nominal effective exchange rates etc.) are used. A detailed description of these variables can be found in In’t Veld et al. (2011).
All the series were seasonally and calendar-effect adjusted. Individual linear trends have been removed from the logs of all variables except for employment, which has been detrended linearly in level. The GDP series has been redefined to equal exactly the sum of consumption, total investment, government spending and trade balance. The trade balance variable used for estimation has been demeaned, as persistent deviations of trade balance from zero cannot be explained by the model.

The priors used have been reported in columns 1 – 3 of Appendix Tables 1 to 3. In most part we use the same parameter priors as in In’t Veld et al (2011). However, the prior on the inverse Frisch elasticity of labour supply \( \kappa \) was assumed to follow a gamma distribution with mean 1.5 and standard deviation 0.6 and was hence higher than in the aforementioned paper. This was done to align the prior with empirical findings. The prior on another key parameter in the model, the elasticity of substitution between the government and private employment, \( \xi \), follows a gamma distribution with mean 1 and standard deviation 0.4. While, to the best of our knowledge, there are no estimates of the private-public-sector elasticity in the literature, the order of magnitude of this prior is based on cross-sectoral elasticities reported in Iacoviello and Neri (2010) for construction and non-construction sectors. The prior on the share of liquidity-constrained consumers is assumed to be beta-distributed with mean 0.4 and standard deviation 0.1, slightly lower than in Coenen & Straub (2005). The calibrated values of non-estimated parameters as well as some steady-state ratios of the model economy are listed in the Appendix tables 4 and 5.

The estimation of the model was performed using the DYNARE toolbox for MATLAB.

### 3.2 Estimation results

[TO BE DONE FOR NEXT VERSION: evaluation of model fit with / without government employment]

At this place we present estimation results of selected parameters which are relevant to the discussion of the impact of government consumption shocks that follows this section. The posterior distribution of these parameters is listed in Table 1. The posterior distribution for other parameters can be found in columns 4 – 6 in the Appendix tables 1 to 3.

---

7 In national accounts this identity does not generally hold, due to changes in inventories and measurement discrepancies.

8 For a more detailed description of the application of the Bayesian methodology in DSGE estimation see Smets and Wouters, 2003.
Table 1: Selected Estimates

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<td>3.3697</td>
</tr>
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<td>0.0446</td>
<td>17.2883</td>
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<tr>
<td>$hab_L^C$</td>
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<td>0.1042</td>
<td>7.0148</td>
</tr>
<tr>
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<td>3.0141</td>
</tr>
<tr>
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<td>3.9275</td>
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<td>2.4281</td>
<td>3.3093</td>
</tr>
<tr>
<td>$\gamma^{wg}$</td>
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<td>5.9479</td>
<td>4.7886</td>
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The share of non-Ricardian households $s^l$ is estimated to be smaller than 20% - a value which is on the low side of estimates in the literature. To compare, Coenen & Straub (2005) report a share of non-Ricardian households of about 25 to 35% for the euro area. Also, Campbell & Mankiw (1989) estimate a share of around 50% for the U.S. for the pre-1990 period. Behind our result may stand the estimation period which overlaps with a period of financial deregulation in the U.S. when only a relatively small share of households had problems accessing financial markets and thereby smooth their consumption.

The inverse Frisch elasticity $\kappa$ is estimated to be around 1.37. This lies within the range of estimates of this parameter, on the flexible side. The elasticity of substitution between public and private employment shows a relatively low degree of substitution between employment in the two sectors suggesting that employees are rather reluctant to move between the sectors.

The estimated parameters of the wage adjustment costs imply an average duration of wage contracts of about 4 quarters in the private sector and of around twice as long in the government sector. The wage rigidity in the private sector is in line with various estimates of the average duration. To our knowledge, there exist no estimations for wage rigidity in the public sector. However, the higher degree of wage rigidity in the public sector is in line with our intuition.

Finally, crucial to our analysis are three shocks to government consumption: a shock to government purchases of goods and services, a shock to government

---

Values calculated on the basis of a conversion formula between Rotemberg and Calvo wage setting.
employment and a wage markup shock in the public sector. The posterior means of parameters determining the persistence of these shocks indicate that shocks to government purchases of goods and services are almost permanent ($\phi_{govpm}$ close to zero). The shock to government employment is also highly persistent while the public wage markup shock turns out to be relatively short-lived.

4 The Impact of Shocks to Government Consumption

This section discusses the propagation of government spending shocks in the economy with special focus on the reaction of private consumption. Figures 1 to 3 display impulse responses of shocks to government purchases of goods and services, to government employment and to public wages, each calibrated to lead to a 1%-of-initial-GDP increase in the budget deficit on impact. The persistence of the shocks is determined by the estimated auto-regression coefficients as well as endogenous propagation mechanisms in the model. As a result, the shock to government purchases is almost permanent, the shock to government employment is also highly persistent, and the shock to public wages turns out to be the least persistent among these shocks.

The figures highlight the main point of our paper: there are marked differences between the propagation of these shocks in the economy. Most importantly, private consumption increases after an increase in government employment / government wage whereas it falls in reaction to an increase in government purchases.

The fall in private consumption in response to an increase in government purchases is a standard feature of DSGE models with price and wage rigidities; see Figure 1. This is driven by the negative wealth effect such a shock has on Ricardian consumers. The high degree of persistence of this shock in our estimations leads to a relatively large negative wealth effect in the impulse responses.

Price rigidities can introduce positive demand effects which, combined with liquidity-constrained consumers, may counterbalance the shock’s negative wealth effect and thereby lead to an increase in total consumption in response to the shock to government purchases (see Gali et al., 2007). However, this finding crucially hinges on the share of liquidity-constrained consumers as well as on the assumption of perfectly flexible labour markets. As shown by Coenen & Straub (2005), once labour market frictions are introduced, the positive co-movement between government purchases and private consumption breaks down again in spite of the presence of (plausible shares of) liquidity-constrained households:

---

10The increase in public wage is captured by a corresponding increase in the markup $\theta g$ in this sector.
labour market frictions prevent wages and employment from reacting strongly
to the increase in government purchases and therefore limit the positive income
effect on liquidity-constrained households.

Note also that the positive co-movement requires a fairly high share of non-
Ricardian consumers (calibrated to 50% of all households in Gali et al., 2007).
This is in contrast to our estimations for the US: we find this share to amount
to about 16% only.

As opposed to these results, the impulse responses to public employment and
public wage shocks show that increases in government consumption via these
variables can lead to an increase in private consumption even for the moderate
share of non-Ricardian households that we find in the data; see Figures 2 and 3.
To see why note that these changes affect households' income directly and therefore
lead to a stronger positive reaction on the part of non-Ricardian households
who cannot smooth their consumption. In addition, labour supply elasticities
are also crucial to this result. In particular, we estimate the Frisch elasticity to
be close to 1 and the elasticity of substitution between private and public sector
employment to be below 1. This constellation leads to a situation in which total
employment reacts relatively flexibly to changes in labour demand while, due
to the complementarity between employment in the two sectors, an increase in
public employment only leads to a small fall in private employment. This lim-
its the fall in private production and thereby also curbs Ricardian households’
negative consumption reaction.

By construction, there are some differences between the transmission of pub-
lic employment and public wage policies in the model. Public wage hike is trans-
mitted to the private sector via the change in the average wage and the following
change in demand while public employment is left constant. Therefore, the in-
crease in public wages affects employment on the extensive margin only (i.e.
by changing total employment). In contrast, the shock to public employment
endogenously affects wages and leads to a sectoral reallocation of employment
from one sector to the other. This can be seen in the panels of total and private
employment in the figures.

According to our estimated impulse responses, the positive private consump-
tion impact of the two shocks is of the same order of magnitude; the impact
of the public wage shock is slightly larger than that of the public employment
shock. Interestingly, the demand effect generated by the public wage shock is
large enough for private employment and private production to slightly increase
on impact in spite of the increase in private wages. This is also supported by
the relatively low degree of persistence of this shock which keeps the negative
wealth effect of government spending on Ricardian households limited (see panel
Consumption - Ricardians in Figure 3).

In contrast, the increase in public employment is found to crowd out private
employment and to lead to an increase in private wages comparable in size
to that after the public wage shock. The impact of this shock on Ricardian
households’ consumption also turns out to be somewhat more negative than
that of the public wage shock. Thereby, the overall consumption impact is slightly smaller.

5 Robustness

[RESULTS TO BE ADDED]

6 Conclusions

This paper presents an extension to the public sector in the estimated QUEST III, the European Commission’s dynamic stochastic general equilibrium model. The extension introduces two fundamental distinctions that bring the model closer to the data: It distinguishes between government employment and private employment; and breaks down final government consumption into compensation of employees on the one hand and government expenditure on goods and services on the other. The frictions in mobility across the private and the public sector are captured by allowing less than perfect substitution between labour supplied to the two sectors.

We estimate the model for the US data. We use this estimated model to study the effects of shocks to government consumption. Our results suggest that there are significant differences between the economic impact of shocks to government spending on goods and services on the one hand and shocks to public employment on the other hand. In particular, while shocks to government spending on goods and services crowd out private consumption as in the standard models, shocks to public employment and public wages tend to crowd in private consumption. This positive co-movement between public employment / public wages and private consumption is even present for the relatively low share of non-Ricardian households we estimate.
References


## 7 Tables and Figures

### Appendix table 1: Prior and posterior distribution of parameters

<table>
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<th>Parameter</th>
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</tr>
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<td>$h_{ab}^e$</td>
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<tr>
<td>$\kappa$</td>
<td>gamma 1.5 0.6</td>
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Appendix table 2: Prior and posterior distribution of standard deviation of shock processes

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## Appendix table 4: Calibrated parameters

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<td>0.7098</td>
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<tr>
<td>$\alpha^q$</td>
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<td>$\gamma_{ucap}$</td>
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<td>$\delta$</td>
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<tr>
<td>consumers $\beta$</td>
<td>0.9920</td>
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<tr>
<td>$\omega$</td>
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<tr>
<td>mark-ups $\theta$</td>
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<tr>
<td>$\theta^p$</td>
<td>3.0000</td>
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<tr>
<td>$\theta^g$</td>
<td>2.1683</td>
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<tr>
<td>government $\bar{\pi}$</td>
<td>0.0050</td>
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<td>$tgovb1$</td>
<td>0.0025</td>
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<tr>
<td>$tgovb2$</td>
<td>0.0750</td>
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<tr>
<td>taxes $T_k$</td>
<td>0.3500</td>
</tr>
<tr>
<td>$T^C$</td>
<td>0.1100</td>
</tr>
<tr>
<td>$T^L$</td>
<td>0.2900</td>
</tr>
<tr>
<td>$T^I$</td>
<td>—</td>
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### Appendix table 5: Steady-state ratios

<table>
<thead>
<tr>
<th>ss ratio</th>
<th>value</th>
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<tbody>
<tr>
<td>$Y$</td>
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<tr>
<td>$C/Y$</td>
<td>0.69</td>
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<tr>
<td>$I^r/Y$</td>
<td>0.16</td>
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<tr>
<td>$G/Y$</td>
<td>0.15</td>
</tr>
<tr>
<td>$IG/Y$</td>
<td>0.03</td>
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<tr>
<td>$W^{ag}L^g/Y$</td>
<td>0.11</td>
</tr>
<tr>
<td>$G^C/Y$</td>
<td>0.04</td>
</tr>
<tr>
<td>$TR/Y$</td>
<td>0.12</td>
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<tr>
<td>$bemr$</td>
<td>0.1</td>
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<tr>
<td>$W^g/W$</td>
<td>1.19</td>
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<tr>
<td>$L$</td>
<td>0.68</td>
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<tr>
<td>$L^p/L$</td>
<td>0.84</td>
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</table>

All ratios nominal
Figure 1: Impact of a shock to government purchases. The shock is calibrated to lead to a 1%-of-initial-GDP increase in the budget deficit. Impulse responses displayed as % deviation from the steady state. Periods measured in quarters on the horizontal axis.
Figure 2: Impact of a shock to government employment. The shock is calibrated to lead to a 1%-of-initial-GDP increase in the budget deficit. Impulse responses displayed as % deviation from the steady state. Periods measured in quarters on the horizontal axis.
Figure 3: Shock to the public wage mark-up. The shock is calibrated to lead to a 1%-of-initial-GDP increase in the budget deficit. Impulse responses displayed as % deviation from the steady state. Periods measured in quarters on the horizontal axis.