IN SEARCH OF THE TRANSMISSION MECHANISM OF FISCAL POLICY IN THE EURO AREA

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ABSTRACT : This paper applies the DSGE-VAR methodology to assess the size of fiscal multipliers in the data and the relative contributions of two transmission mechanisms of government spending shocks, namely hand-to-mouth consumers and Edgeworth complementarity. Econometric experiments show that a DSGE model with Edgeworth complementarity is a better representation of the transmission mechanism of fiscal policy as it yields dynamic responses close to those obtained with the flexible DSGE-VAR model (i.e. an impact output multiplier larger than one and a crowding-in of private consumption). The estimated share of hand-to-mouth consumers is too small to replicate the positive response of private consumption.

JEL CLASS.: C32, E32, E62.

KEYWORDS: Fiscal multipliers, hand-to-mouth, Edgeworth complementarity, DSGE-VAR, Euro area, Bayesian econometrics.

RÉSUMÉ : Cet article applique la méthodologie DSGE-VAR pour évaluer la taille du multiplicateur budgétaire dans les données et les contributions relatives de deux mécanismes de transmission des chocs de dépenses publiques : les ménages non ricardiens et la complémentarité à la Edgeworth. Divers exercices économétriques montrent qu'un modèle DSGE avec complémentarité à la Edgeworth est une meilleure représentation du mécanisme de transmission de la politique budgétaire car il permet d'engendrer des réponses dynamiques proches de celles obtenues avec le modèle DSGE-VAR (i.e. un multiplicateur –à l'impact– du produit plus grand que l'unité et un effet d'éviction inversé de la consommation privée). La part estimée des ménages non ricardiens est trop petite pour permettre une réponse positive de la consommation privée.

CLASSIFICATION JEL : C32, E32, E62.

MOTS-CLÉS : Multiplicateur budgétaire, ménages non ricardiens, complémentarité à la Edgeworth, DSGE-VAR, zone euro, économétrie bayésienne.

NON TECHNICAL SUMMARY

Due to concerns about high levels of public debt, many European countries have engaged in large consolidation programs in recent years. The issue of the effectiveness of these programs has initiated a vivid debate on the evaluation of government spending multipliers. Two classes of models have been extensively used to assign a quantitative value to this concept: dynamic stochastic general equilibrium (DSGE) models and vector autoregressions (VARs). However, each approach has disadvantages. While DSGE models potentially face a misspecification problem in imposing excessive restrictions on the data, structural VARs might be sensitive to identification strategies (Ramey, 2011a). The implications drawn from one model or another might not reveal the true policy effects.

This paper combines DSGE and VAR models to provide new insights into the transmission mechanisms of fiscal shocks in the euro area. This DSGE-VAR approach relaxes the strong cross-equation restrictions created by the DSGE model and thus allows possible misspecification of the structural model to be considered (Del Negro and Schorfheide, 2004, Del Negro, Schorfheide, Smets, and Wouters, 2007, and Del Negro and Schorfheide, 2009).

Armed with this original tool, we evaluate the relative contributions to the size of estimated fiscal multipliers of two transmission mechanisms of government spending shocks advanced previously in the literature. The first relies on the presence of hand-to-mouth (HtM) consumers in the population, i.e., households that do not have access to financial markets and simply consume their disposable income in each period. Galí *et al.* (2007) and Forni *et al.* (2009) show that the interaction of such agents with both real and nominal rigidities increases the government spending multiplier. The second transmission mechanism allows government spending to enter –in a non-separable way– the household's utility function (GiU), such that government activity directly affects the marginal utility of consumption. Bouakez and Rebei (2007), Fève *et* *al.* (2013) and Coenen *et al.* (2013) show that when private consumption and public expenditures display a sufficient amount of Edgeworth complementarity, households have incentives to consume and to work more, thereby generating larger fiscal multipliers. Because each competing model nests the Smets-Wouters specification (Baseline), one can vary the magnitude of the parameter summarizing one of the mechanisms to understand how government spending shocks propagate into the model economy.

Our main findings are the following. First, the Bayesian estimation shows that a DSGE model with non-separable government spending in the utility function outperforms a model with hand-to-mouth consumers in terms of fit and yields larger fiscal multipliers. The version with Edgeworth complementarity provides a multiplier of approximately 1.75, whereas the version with hand-to-mouth consumers yields a value lower than one. Second, we use the DSGE-VAR approach to assess the performance of each version. On impact, the multiplier is approximately 1.5, and its estimated value is weakly affected by the model's specification. This result can be interpreted as suggesting that the data want a multiplier larger than one. Specifically, the DSGE-VAR framework is used to investigate whether the fiscal multipliers obtained in a constrained DSGE model are far from those obtained in a DSGE-VAR model with the same structural features. We obtain a sizable increase in the estimated value of the multiplier in the Baseline and HtM versions, while it remains very similar in the GiU specification and in the model including both mechanisms. This supports our claim that Edgeworth complementarity is a better representation of the transmission mechanism of fiscal policy in the euro area.

1. Introduction

Due to concerns about high levels of public debt, many European countries have engaged in large consolidation programs in recent years. The issue of the effectiveness of these programs has initiated a vivid debate on the evaluation of government spending multipliers. Two classes of models have been extensively used to assign a quantitative value to this concept: dynamic stochastic general equilibrium (DSGE) models and vector autoregressions (VARs).[1] However, each approach has disadvantages. While DSGE models potentially face a misspecification problem in imposing excessive restrictions on the data, structural VARs might be sensitive to identification strategies (Ramey, 2011a). The implications drawn from one model or another might not reveal the true policy effects.

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Armed with this original tool, we evaluate the relative contributions to the size of estimated fiscal multipliers of two transmission mechanisms of government spending shocks advanced previously in the literature. The first relies on the presence of hand-to-mouth (HtM) consumers in the population, i.e., households that do not have access to financial markets and simply consume their disposable income in each period. Galí *et al.* (2007) and Forni *et al.* (2009) show that the interaction of such agents with both real and nominal rigidities increases the government spending multiplier. The second transmission mechanism allows government spending to enter –in a non-separable way– the household's utility function (GiU), such that government

[1] The effects of government spending shocks have been studied by, amongst other scholars, Cogan *et al.*, 2010; Coenen *et al.*, 2012, Fève *et al.*, 2013; Erceg and Lindé, 2014, using DSGE models, and by Perotti, 2005, Caldara and Kemps, 2012, using structural VAR models.

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[2]There exist many concrete examples for which private consumption and public expenditures are complements (health care, education, etc.). As discussed in Fiorito and Kollintzas (2004), the complementarity may reveal relative inefficiency in the provision of public goods. Let us consider the case of education. One may observe the coexistence of public schools and private tutors if private agents consider the quality of public teachers to be too low. In addition, the complementarity may occur because public education allows a higher level of income and thus increases the demand for other goods (similar arguments hold for health care). Though difficult to grasp at the aggregate level, this mechanism is a useful shortcut to quantify the influence of public spending on private decisions.

This paper is related to recent studies investigating the size of fiscal multipliers, the transmission mechanism of government spending shocks, and fiscal strategies in DSGE models of the euro area (see, e.g., Cwik and Wieland, 2011, Coenen *et al.*, 2012, 2013, and Cogan *et al.*, 2013). In particular, Coenen *et al.* (2013) consider HtM consumers and government spending in the utility to gauge the effects of government activity in the euro area. Our paper extends these works in two directions. First it considers that the DSGE model (even if it includes relevant propagation mechanisms of government spending) can be misspecified and thus uses the DSGE-VAR approach to quantify the size of the fiscal multiplier and the dynamic effects of government spending shocks. Second, based on empirical evidence and the estimation of different versions of the model, it investigates how the mechanisms interact at the estimation stage and highlights the most relevant channel.

The paper is organized as follows. In the next section, we expound the Baseline DSGE model and the two competing propagation mechanisms. We also conduct a prior predictive analysis. In section 3, we present empirical results from a Bayesian estimation of different model versions. In section 4, we report the estimation of different DSGE-VAR models. The last section concludes.

2. Medium-scale models for the euro area

Our investigation is based on the canonical medium-scale New-Keynesian framework described by Christiano *et al.* (2005) and Smets and Wouters (2007), which is currently considered sufficiently rich to fit the data well. It features utility-maximizing households, profit-maximizing firms, a fiscal authority financing public spending with lump-sum taxes, and a central bank setting short-term nominal interest rates according to a Taylor-type rule. The model incorporates a number of real and nominal rigidities, including habits in consumption, investment adjustment costs, variable capacity utilization, and monopolistic competition in goods and labor markets and wage and nominal price and wage rigidities with indexation.[3]

[3]A detailed exposition of the model is offered in Section A of the online appendix.

This setup is extended in two directions: *(i)* the introduction of households being hand-to-mouth consumers and *(ii)* the introduction of government spending in the household utility function in a non-separable way.

2.1. **Alternative specifications.** A first specification (labelled 'Baseline') is similar to Justiniano *et al.* (2010). This setup is then extended to introduce different transmission mechanisms of government spending shocks.

As in Galí *et al.* (2007), we assume in a second specification (labelled 'HtM') *(i)* that a fraction ω of households, called hand-to-mouth consumers, do not have access to financial markets and simply consume their disposable income in each period, *(ii)* employment agencies do not discriminate between household types in their labor demands, such that the number of hours worked N_t is the same for all households. It follows that, in symmetric equilibrium, all households have the same wage rate W_t. Therefore, the hand-to-mouth consumers set nominal consumption expenditure $C_{r,t}$ equal to their disposable wage income less lump-sum taxes $T_{r,t}$. This results in the following period-by-period budget constraint:

$$P_t C_{r,t} \leq W_t N_t - T_{r,t}. \tag{1}$$

The consumption of households that have access to financial markets is denoted $C_{0,t}$. Accordingly, total private consumption is then defined as $C_t = (1-\omega)C_{o,t} + \omega C_{r,t}$.

A third specification (labelled 'GiU') augments the Baseline model by including government spending in the utility function. As in Bouakez and Rebei (2007), we allow for complementarity/substitutability between private consumption and public expenditures. Formally, the consumption bundle C_t^* is now defined as:

$$C_t^* = C_t + \alpha_g G_t, \tag{2}$$

where the parameter α_g measures the degree of complementarity/substitutability between private consumption C_t and public expenditures G_t. The specification adopted here follows Christiano and Eichenbaum (1992), McGrattan (1994), and Finn (1998), among others.[4] If $\alpha_g > 0$, government spending substitutes for private consumption, with perfect substitution if $\alpha_g = 1$, as in Christiano and Eichenbaum (1992). In this case, a permanent increase in government spending has no effect on output or hours but reduces private consumption, through a perfect crowding-out effect. In the special case in which $\alpha_g = 0$, we recover the standard business cycle model, with government spending operating through a negative wealth effect on labor supply (see Aiyagari *et al.*, 1992, Baxter and King, 1993). When the parameter $\alpha_g < 0$, government spending complements private consumption. Then, it can be the case (depending on the labor supply elasticity) that private consumption will react positively to an unexpected increase in government spending.

A last specification (labelled 'Full') embeds both hand-to-mouth consumers and government spending in the utility function in the Baseline model.

2.2. **State-space representation.** After normalizing trending variables by the stochastic trend component in labor factor productivity, we log-linearized the resulting systems in the neighborhood of the deterministic steady state. Let $\boldsymbol{\theta}$ denote the vector of structural parameters and $\mathbf{v}_t$ be the r-dimensional vector of model variables. Thus, the state-space form of the different model specifications is characterized by the state equation:

$$\mathbf{v}_t = \mathbb{A}(\boldsymbol{\theta})\mathbf{v}_{t-1} + \mathbb{B}(\boldsymbol{\theta})\boldsymbol{\zeta_t}, \tag{3}$$

where $\boldsymbol{\zeta_t} \sim i.i.d.N\left(0, \Sigma_\zeta\right)$ is the q-dimensional vector of innovations to the structural shocks, and $\mathbb{A}(\boldsymbol{\theta})$ and $\mathbb{B}(\boldsymbol{\theta})$ are complicated functions of the model's parameters $\boldsymbol{\theta}$. The measurement equation is given by:

$$\mathbf{x}_t = \mathbb{C}(\boldsymbol{\theta}) + \mathbb{D}\mathbf{v}_t + \mathbb{E}\mathbf{e}_t, \tag{4}$$

[4] An alternative specification is a CES function between C_t and G_t (see McGrattan *et al.*, 1997, Bouakez and Rebei, 2007, Coenen *et al.*, 2013). Note that these two specifications yield exactly the same log–linearized equation for the marginal utility of consumption.

where $\mathbf{x}_t$ is an n-dimensional vector of observed variables, $\mathbb{D}$ and $\mathbb{E}$ are selection matrices, $\mathbf{e}_t$ is a vector of measurement errors, and $\mathbb{C}(\boldsymbol{\theta})$ is a vector that is a function of the structural parameters.

2.3. **Prior predictive analysis.** Conditional on a given model specification $\mathcal{M}_i$, $i \in \{0 \text{ (Baseline)}, 1 \text{ (HtM)}, 2 \text{ (GiU)}, 3 \text{ (Full)}\}$, the prior distribution of $\boldsymbol{\theta}$ is $p(\boldsymbol{\theta}|\mathcal{M}_i)$ and the likelihood function associated with the vector of *ex ante* observables $\tilde{\mathbf{X}}_T \equiv \{\tilde{\mathbf{x}}_t\}_{t=1}^T$ is $\mathcal{L}(\tilde{\mathbf{X}}_T|\boldsymbol{\theta}, \mathcal{M}_i)$. Regardless of how the conditional distribution of observables and the prior distribution of unobservables are formulated, together they provide a distribution of observables with density:

$$\mathcal{L}\left(\tilde{\mathbf{X}}_T|\mathcal{M}_i\right) = \int_{\boldsymbol{\theta}} \mathcal{L}\left(\tilde{\mathbf{X}}_T|\boldsymbol{\theta}, \mathcal{M}_i\right) p\left(\boldsymbol{\theta}|\mathcal{M}_i\right) \mathrm{d}\boldsymbol{\theta}, \tag{5}$$

known as the *prior predictive density*. It summarizes the whole range of phenomena consistent with the model $\mathcal{M}_i$ and is very easy to access by means of simulations. The prior predictive distribution summarizes the substance of the model and emphasizes that the prior distribution and the conditional distribution of observables are inseparable components, a point forcefully argued by Box (1980). As explained by Canova (1995), Lancaster (2004) and Geweke (2005), prior predictive analysis is a powerful tool to shed light on complicated objects that depend on both the joint prior distribution of parameters and the model specification. In our context, this analysis delivers the possible range of the government spending multiplier conditional on a specific model. As our alternative versions differ only by a parameter, prior predictive analysis offers precise statements concerning how a particular mechanism affects the multiplier.

In all model specifications, we calibrate few parameters: The discount factor β is set to 0.99, the inverse of the Frisch labor supply elasticity $\nu = 2$, the capital depreciation rate δ is equal to 0.025, the parameter α in the Cobb–Douglas production function is set to 0.30 to match the average capital share in net (of fixed costs) output (McAdam and Willman, 2013), the steady–state price and wage markups ε_p and ε_w are set to 1.20 and 1.35, respectively (Everaert and

Schule, 2008), and the steady–state share of government spending in output is set to 0.20 (the average value over the sample period).

Our choice of priors is in line with the literature, especially with Smets and Wouters (2007), Sahuc and Smets (2008) and Justiniano *et al.* (2010). We impose $\mathcal{B}$eta distributions for all of the parameters, the theoretical support of which is the compact [0,1]. We use $\mathcal{G}$amma distributions for positive parameters. Finally, we use $\mathcal{I}$nverse $\mathcal{G}$amma distributions for the standard errors of shocks. Importantly, we are agnostic about the share of non-Ricardian households (ω) and the degree of complementarity/substitutability between private consumption and public expenditures (α_g). We assume $\mathcal{U}$niform priors for these two parameters: ω is distributed on $[0,1]$, and α_g is distributed on $[-2,2]$.[5]

We take 1,000 draws from our prior distributions and calculate the resulting government spending multipliers. Fiscal multipliers are defined as the present value multipliers:

$$\frac{\mathrm{E}_t \sum_{i=0}^{s} \tilde{\beta}^i \Delta\Psi_{t+i}}{\mathrm{E}_t \sum_{i=0}^{s} \tilde{\beta}^i \Delta G_{t+i}}, \tag{6}$$

where E_t denotes the mathematical expectation operator conditional upon information available at t, $\tilde{\beta} \equiv \beta/\gamma_z$ is the inverse of the steady-state real interest rate, s is the selected horizon, and $\Psi_t = Y_t$ (output), C_t (private consumption), I_t (private investment). At $s = 0$, the present value multiplier equals the impact multiplier. As in Leeper *et al.* (2011), Table I compares the multiplier p-values at various horizons across the four model specifications.[6] The top panel of the table reports the probability that multipliers for output exceed unity at various horizons. The middle and lower panels report the probabilities that multipliers for consumption and investment, respectively, are positive at various horizons.

[5]The interval has been set such that the minimum value of α_g does not imply a negative value of the marginal utility of consumption around the deterministic steady state. By anticipating our estimation results, this prior ensures almost certainly that the marginal utility is positive because it depends on calibrated parameters (α, β, δ), with the only exception being the growth rate of TFP, which is estimated. However, this parameter marginally affects the great ratios (see Section B of the online appendix) and is estimated with precision.

[6]In the context of the prior predictive analysis, we follow Leeper *et al.* (2011) in choosing a prior density for ρ_g defined as $\mathcal{B}$[0.70,0.20].

Table I. Government spending multiplier probabilities implied by prior predictive analysis with informative priors

	Prob$\left(\frac{\Delta Y}{\Delta G} > 1\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
$\mathcal{M}_0$: Baseline	0.296	0.012	0.001	0.002	0.002
$\mathcal{M}_1$: HtM	0.846	0.553	0.372	0.302	0.308
$\mathcal{M}_2$: GiU	0.427	0.376	0.313	0.288	0.281
$\mathcal{M}_3$: Full	0.639	0.580	0.486	0.439	0.444
	Prob $\left(\frac{\Delta C}{\Delta G} > 0\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
$\mathcal{M}_0$: Baseline	0.000	0.000	0.000	0.000	0.000
$\mathcal{M}_1$: HtM	0.748	0.576	0.493	0.419	0.330
$\mathcal{M}_2$: GiU	0.412	0.386	0.380	0.345	0.300
$\mathcal{M}_3$: Full	0.623	0.582	0.544	0.515	0.467
	Prob$\left(\frac{\Delta I}{\Delta G} > 0\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
$\mathcal{M}_0$: Baseline	0.054	0.058	0.065	0.081	0.086
$\mathcal{M}_1$: HtM	0.058	0.071	0.077	0.088	0.099
$\mathcal{M}_2$: GiU	0.384	0.384	0.390	0.391	0.399
$\mathcal{M}_3$: Full	0.217	0.217	0.224	0.230	0.233

Note: Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function.

First, we observe that all models, even the Baseline specification, can generate impact output multipliers greater than one. This is because greater price stickiness implies that more firms respond to higher government spending by increasing production rather than prices, and hence markups respond more strongly. However, it is impossible for the Baseline model to produce positive consumption multipliers at any horizon. The negative wealth effect is indeed strong because households decrease their consumption and work more. This decline in private demand offsets most of the increased public demand, causing output to increase by less than the increase in government consumption.

Fiscal multipliers increase substantially when introducing hand-to-mouth consumers or Edgeworth complementarity/substitutability. Intuitively, as non-Ricardian households automatically consume their entire income, they ignore the wealth effects of future taxes and therefore increase their consumption when government expenditures rise. The larger the share of these agents, the lower the overall negative wealth effect on consumption. If wages are sticky, such that real wages increase in the very short run, then non-savers' consumption also increases. With sufficient non-savers in the economy, the increase in their consumption can cause total consumption to increase, leading to larger output multipliers as well. The version including Edgeworth complementarity/substitutability yields multipliers in line with the HtM consumers version, although smaller.[7] This result originates from our choice of priors for ω and α_g. Indeed, the prior mean for ω implies a sizable share of hand-to-mouth consumers, thereby allowing for a positive consumption response. Conversely, the prior uniform distribution for α_g is centered on zero (*i.e.,* the value from the Baseline model version), meaning that our prior does not favor this version. Edgeworth complementarity/substitutability allows us to cover a large range of situations for which consumption reacts positively and output multipliers are above one. These two transmission mechanisms are by themselves sufficient to generate high multipliers. Indeed, when we set all other parameters to their respective prior means and let ω and α_g be drawn from their respective prior distributions, we obtain similar probabilities as those displayed in Table 1.[8]

3. DSGE MODELS COMPARISON

In this section, we discuss the estimation results of the different specifications of the structural model and present the government spending multipliers inherited from each set of estimates.[9]

3.1. **Data description.** The quarterly euro area data run from 1980Q1 to 2007Q4 and are extracted from the AWM database compiled by Fagan *et al.* (2005), except hours worked and the working age population. The reason for ending in 2007 is not to blur the results with the zero

[7] The reason is that the prior distribution of α_g is symmetric at zero.
[8] See Table OA2 of the online appendix.
[9] A robustness analysis is provided in Section I of the online appendix.

lower bound episode in the aftermath of the financial crisis. Inflation π_t is measured by the first difference of the logarithm of the GDP deflator (YED), the short–term nominal interest rate R_t is a three-month rate (STN), and real wage growth $\Delta \log (W_t/P_t)$ is the first difference of the logarithm of the nominal wage (WRN) divided by the GDP deflator. Output growth $\Delta \log Y_t$ is obtained as the first difference of the logarithm of real GDP (YER), private consumption growth $\Delta \log C_t$ is constructed by multiplying real private consumption (PCR) by the private consumption deflator (PCD), divided by the GDP deflator and transformed into the first difference of the logarithm; private investment growth $\Delta \log I_t$ is defined as the aggregate euro area total economy gross investment minus general government investment, scaled by the GDP deflator and transformed into the first difference of the logarithm; and government spending growth $\Delta \log G_t$ is defined as the nominal general government final consumption expenditure (GCN), scaled by the GDP deflator and transformed into the first difference of the logarithm. Real variables are divided by the working age population, extracted from the OECD Economic Outlook. Ohanian and Raffo (2012) constructed a new dataset of quarterly hours worked for 14 OECD countries. We then derived a weighted (by country size) average of their series of hours worked for France, Germany and Italy to obtain a series of total hours for the euro area. Interestingly, the series thus obtained is very close to that provided by the ECB on the common sample, *i.e.* 1995–2007. Total hours worked $\log N_t$ are taken in logarithms. We use growth rates for the non-stationary variables in our data set (GDP, private consumption, private investment, government spending and the real wage) and express gross inflation, gross interest rates and the first difference of the logarithm of hours worked in percentage deviations from their sample means. The vector of eight observable variables is then given by:

$$\mathbf{x}_t = 100 \times [\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log G_t, \Delta \log (W_t/P_t), \log N_t, \pi_t, R_t]. \tag{7}$$

Our model abstracts from net exports, public investment and changes in inventories in GDP. We then introduce a measurement error $i.i.d.\mathcal{N}\left(0, \sigma_{x_e}^2\right)$ that is directly associated with output growth.

3.2. **Estimation results.** We follow the Bayesian approach to estimate the models (see An and Schorfheide, 2007, for an overview). The posterior distribution associated with the vector of observables $\mathbf{X}_T \equiv \{\mathbf{x}_t\}_{t=1}^{T}$ cannot be recovered analytically but may be computed numerically using a Monte Carlo Markov chain (MCMC) sampling approach. Specifically, we rely on the Metropolis-Hastings algorithm to obtain a random draw of size 1,000,000 from the posterior distribution of the parameters.

For the sake of comparing different model versions, we resort to the following two standard criteria. First, from $p\left(\boldsymbol{\theta}|\boldsymbol{X}_T, \mathcal{M}_i\right)$, one can compute the marginal likelihood of specification $\mathcal{M}_i$, which is defined as:

$$\mathcal{L}\left(\mathbf{X}_T|\mathcal{M}_i\right) = \int_{\boldsymbol{\theta}} \mathcal{L}\left(\mathbf{X}_T|\boldsymbol{\theta}, \mathcal{M}_i\right) p\left(\boldsymbol{\theta}|\mathcal{M}_i\right) \mathrm{d}\boldsymbol{\theta}. \tag{8}$$

Second, given a prior probability p_i on a given model specification $\mathcal{M}_i$, the posterior odds ratio is defined as:

$$\mathcal{P}_{i,T} = \frac{p_i \mathcal{L}\left(\mathbf{X}_T|\mathcal{M}_i\right)}{\sum_{j=0}^{M-1} p_j \mathcal{L}\left(\mathbf{X}_T|\mathcal{M}_j\right)} \text{ with } \sum_{j=0}^{M-1} p_j = 1, \tag{9}$$

where M is the number of competing models.

Table II reports information on the posterior distribution of the share of hand-to-mouth consumers ω and the degree of complementarity/substitutability between private consumption and government expenditures α_g for each model version: the mean and the 90 percent confidence interval for each model version.[10] Several results are worth commenting on.

[10]The rest of the parameters are reported in Section E of the online appendix.

Table II. Posterior estimates

Parameter	Model			
	$\mathcal{M}_0$: Baseline	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
HtM share, ω	–	0.291 [0.228,0.353]	–	0.137 [0.081,0.192]
Edgeworth compl., α_g	–	–	–1.638 [–1.862,–1.419]	–1.505 [–1.733,–1.272]
Marginal likelihood	–640.307	–630.203	–606.831	–603.316
Posterior odds ratio	0.000	0.000	0.029	0.971
	–	0.001	0.999	–

Note: This table reports the mean and the 90 percent confidence interval (within square brackets) of the estimated posterior distribution of ω and α_g. Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function.

The first notable result is that the two propagation mechanisms considered here are essential because they substantially improve the fit of the model (in comparison with the Baseline model). For instance, the marginal likelihood increases from -640 in the Baseline model to -630 in the model with hand-to-mouth consumers. The estimated share of hand-to-mouth consumers ω is precisely estimated, with a mean of 0.29 and a 90 percent confidence interval given by $[0.228; 0.353]$, despite that we use a flat (uniform) prior.[11] The posterior mean is close to the value obtained by Coenen and Straub (2005, 2013) and is consistent with the values reported in Kaplan *et al.* (2014). Using survey data on household portfolios for Germany, France, Italy, and Spain between 2008 and 2010, Kaplan *et al.* (2014) obtain a share of hand-to-mouth consumers between 20 and 32 percent, according to the country.

However, this model version is outperformed by the model with government spending in the utility function. This can be directly verified by inspecting the marginal likelihood and posterior odds ratios. Beginning with a prior distribution on the two model versions with equal probability (1/2), we obtain that the GiU model represents the whole probability mass. The estimated value for α_g is negative, suggesting a strong complementarity between private

[11]See Table OA5 of the online appendix for a sensitivity analysis to the set of observables.

consumption and public expenditures. This result is in line with that obtained in Coenen *et al.* (2013) for the euro area.[12] Using again an uninformative prior with zero mean, we obtain the confidence interval $[-1.86; -1.42]$ for α_g.

The largest marginal likelihood is obtained when the two mechanisms are combined (see also the high posterior odds ratio in Table 2). In this Full model version, we obtain a lower share of hand-to-mouth consumers ($\omega = 0.14$) and a slightly lesser complementarity between private consumption and public expenditures ($\alpha_g = -1.51$). Thus, the estimation of the Full model specification on actual data highlights a substitution between these two mechanisms. It is worth noting that the mean value of ω in the HtM specification is outside the 90 percent confidence interval of the Full model version. This is not the case when we consider the GiU specification. Therefore, we can infer that a model version with Edgeworth complementarity suffers less than a specification with hand-to-mouth consumers from the presence of a competing propagation mechanism.[13]

To better illustrate the trade–off between the two transmission mechanisms of fiscal shocks, we plot draws from the posterior distributions of ω and α_g in the Full model version. Figure 1 reports the outcome of this exercise. The thick plain line is the nonparametric regression, and the thick dashed lines delineate the 90 percent confidence interval obtained by standard bootstrap techniques. The scatter diagram corresponds to the estimation of the Full model. Crosses indicates the average parameter values for ω and α_g. This figure clearly reveals, in the neighborhood of the posterior means ($\omega = 0.14$ and $\alpha_g = -1.51$), that the two mechanisms substitute. Importantly, a small variation in α_g has strong implications for the estimated share of hand-to-mouth consumers. For example, moving α_g from -1.51 to -1.60 implies a change in

[12]Notice that our estimated degree of Edgeworth complementarity is equivalent to an elasticity of substitution between private and public expenditures in a CES aggregate of $\mu_{ces} = 0.172$, when assuming a private consumption share of $\varkappa = 0.75$. Indeed, $\mu_{ces} \equiv (1-\varkappa)\left(s_c/(s_c+\alpha_g s_g) - \varkappa\right)$, where s_c and s_g denote the consumption to output ratio and government expenditures to output ratio, respectively.

[13]Comparing a set of moments from actual data to those generated by alternative specifications yields additional evidence. We observe that the Full model yields a better fit than the Smets-Wouters type model, especially with respect to the volatility and persistence of aggregate variables (output, consumption, government expenditures, inflation, etc.).

ω from 0.14 to 0.07. In other words, the GiU specification appears more robust to a model's perturbation, *i.e.,* the introduction of a competing transmission mechanism, than does the HtM specification.

Moreover, the estimated share of hand-to-mouth consumers is too low to generate a positive private consumption multiplier for government consumption shocks in a standard New-Keynesian DSGE model (see, *e.g.,* Coenen and Straub, 2005; Galí *et al.*, 2007). This is confirmed by Panel (a) of Figure 2. This figure reports the posterior distribution of ω and a grey area representing the range of values that allow private consumption to respond positively to a government spending shock. One obtains that ω must exceed 0.5 to generate this pattern, a value that is far from its posterior distribution and the empirical evidence reported by Kaplan *et al.* (2014). This means that the posterior estimation dramatically changes the conclusions from the Bayesian prior predictive analysis. Conversely, the GiU model has no difficulty in creating a positive response of private consumption (see Panel (b) of Figure 2): Nearly all of the posterior distribution lies within the grey area. The Baseline and HtM models on one side and GiU and Full models on the other side are very similar. Consequently, the HtM specification appears to add very little both to the Baseline model and to the GiU model. Panel (c) reports the joint distribution of α_g and ω for which the response of consumption is positive, together with the contour of their posterior distribution. Combining the two transmission mechanisms into the Full model shows that the model can display a positive response of consumption, but this is essentially due to the non-zero value of α_g.

3.3. **Distributions of the impact output multiplier.** The value of the government spending multiplier derives from the estimated values of ω and α_g. Figure 3 reports the empirical distribution of the impact output multiplier for the Full specification, and the average value of this multiplier for the Baseline, HtM and GiU models. The figure makes clear that the estimated multiplier differs considerably between the two model versions. In the presence of hand-to-mouth consumers, the average output multiplier is approximately 0.80, while it is twice larger (approximately 1.75) when government expenditures enter the household utility function. The estimated multiplier in the HtM case slightly exceeds that obtained in the Baseline model (approximately 0.60). Moreover, the GiU and Full models yield similar multiplier values.[14]

Furthermore, the four model versions display nearly identical estimated values for the common structural parameters. Most of the parameter estimates are in line with previous results (Smets and Wouters, 2003, Sahuc and Smets, 2008, Coenen *et al.*, 2013). Neither the parameters related to real rigidities nor those related to nominal rigidities are affected by the presence of ω and α_g.[15] In addition, the parameters that govern the driving force and those describing the monetary policy are left unaffected. This means that our additional features improve the fit of a standard DSGE model without altering its propagation mechanisms.[16]

4. The size of the multiplier: A DSGE-VAR approach

The DSGE-VAR approach has been suggested as a tool for studying the misspecification of a DSGE model and allowing the cross-equation restrictions of the DSGE model to be relaxed in a flexible manner (Del Negro and Schorfheide, 2004, Del Negro *et al.*, 2007).[17] The basic idea is to *(i)* use a VAR model as an approximating model for the DSGE model and *(ii)* construct a mapping from the DSGE model to the VAR parameters, leading to a set of cross-restrictions for the VAR model. Deviations from these restrictions may be interpreted as evidence for DSGE model misspecification. In a Bayesian framework, one can specify a prior distribution for deviations from the DSGE model restrictions, the tightness of which is scaled by a single hyperparameter λ. By varying this parameter from infinity to zero, we create a continuum of models with the VAR approximation of the DSGE model at one end and an unrestricted VAR at the other end. The marginal likelihood function of this parameter then provides an overall assessment of the

[14] The contribution of the government spending shock to the short-run aggregate volatility illustrates these findings, see Table OA4 in Section G of the online appendix.

[15] See Table OA3 of the online appendix.

[16] Section H of the online appendix reports the dynamic responses of output, consumption, investment and the real interest rate to productivity and monetary policy shocks for the Baseline and Full specifications. Figures OA2 and OA3 illustrate that, whatever the specification adopted, the responses are similar.

[17] See also Adolfson *et al.*, 2008, Lees *et al.*, 2011, Warne *et al.*, 2013, and Cole and Milani, 2014, for recent applications of the DSGE-VAR approach to forecasting exercises and misspecification analysis in DSGE models.

DSGE model restrictions that is more robust and informative than a comparison of the two polar cases (unconstrained VAR model *vs.* DSGE model).[18]

4.1. **Assessing the fiscal multiplier from DSGE-VARs.** The first step consists in selecting the best DSGE-VAR(λ, p) model, where p denotes the number of lags. An approach consists in choosing the model with the largest marginal likelihood over all pairs (λ, p) and the specification of the DSGE model. We consider lag orders ranging from one to four. Several features emerge. First, the data favor the Full specification.[19] Second, for any value of λ, the log-marginal likelihood with one lag is always greater than that with two, three or four lags, indicating that reducing the number of lags, and hence the number of free parameters, increases the fit of the empirical model.[20] Third, the estimates of λ are positively related to the selected lag order. The DSGE model restrictions help in part because they reduce the number of free parameters, and this reduction becomes more valuable the larger the lag length. In the following, we therefore decide to examine the usefulness of DSGE-VAR models with two lags.[21]

As before, we take draws from the posterior distributions of the DSGE-VAR model with two lags and calculate the resulting government spending multipliers. Following Del Negro and Schorfheide (2004), it is natural to use the theoretical DSGE model to provide the prior information that enables the identification of shocks. Indeed, the contemporaneous relationships between the DSGE model variables allow us to orthogonalize the shocks that affect the model dynamics. The mapping between the canonical residuals and the structural shocks is obtained by multiplying the Choleski decomposition of the covariance matrix of the canonical residuals

[18] Section J of the online appendix offers a presentation of the DSGE-VAR methodology.

[19] See Figure OA4 of the online appendix.

[20] The estimated log-marginal likelihood values for a range of DSGE-VAR models are displayed in Figure OA5 of the online appendix.

[21] In Figure OA6 of the online appendix, we report the empirical distribution of the DSGE-VAR with two and four lags and show that the two posterior means are very close. To assess the invertibility issue, we plot the response functions to a government spending shock associated with the DSGE-VAR(∞,2) and with DSGE models and show that they are nearly identical (Figure OA8 of the online appendix).

by the factorization of a standardized version of the matrix $\mathbb{B}(\boldsymbol{\theta})$ in the DSGE state-space representation.[22] With such a mapping and the moving-average representation of the VAR model, dynamic responses of endogenous variables to structural shocks (especially the government spending shock) can be computed.

Figure 3 displays the empirical distribution of the impact output multiplier for the DSGE-VAR(0.6,2) model. The posterior mean is rather large, at 1.56, supporting the GiU and Full versions of the DSGE model. Conversely, the Baseline and HtM specifications yield output multipliers far below the empirical distribution obtained from the DSGE-VAR model.[23]

To assess the relative performance of the alternative DSGE specifications, we compare their impulse response functions after a 1-percent increase in government spending to those obtained from the flexible DSGE-VAR. We concentrate our analysis on the estimated impulse responses of output, consumption, investment and the (ex-post) real interest rate, as we are searching for a proper transmission mechanism. Figure 4 reports the dynamic responses in the DSGE-VAR(0.6,2) together with the 90 percent confidence interval. It also includes the estimated dynamic response in the four alternative specifications. As is clear from the figure, the GiU and Full versions properly match the positive and persistent response of private consumption after a government spending shock. This is not the case for the Smets-Wouters and HtM versions, which yield a persistent negative consumption response. For the HtM version, this is due to the small estimated value of ω. Moreover, these two versions under-estimate the response of output, especially in the short run. The response of investment in each version does not well match that obtained from the DSGE-VAR(0.6,2), as investment does not respond

[22]See Del Negro and Schorfheide (2009) for a refinement of the identification procedure.

[23]Notice that the unit-root technology shock in the theoretical DSGE model induces a common stochastic trend in the levels of all real variables. We also estimated a vector error correction model (VECM) with a DSGE-based prior by simply adding the cointegrating relations of the DSGE model to the VAR model. Although the VECM helps to improve the approximation of the DSGE model (via a slightly higher marginal likelihood), we found that the DSGE model maps quite well into the VAR model. Figure OA7 of the online appendix displays the empirical distributions of the output multiplier associated with DSGE-VECMs with 2 and 4 lags. The estimated impact multipliers are very close to those obtained from the DSGE-VARs.

sufficiently to a government shock. Notice again that the GiU and Full versions must be preferred, as the response of investment is more pronounced. Finally, the responses of the real interest rate are fairly well reproduced by the GiU and Full versions, whereas this is not the case for models that do not include this feature.

Why do the GiU and/or Full versions match these responses well? Part of the answer lies in the dynamics of the marginal utility of consumption.[24] In the presence of government spending in the utility function, Edgeworth complementarity between private and public consumption plays the same role as a positive preference shock that increases private consumption after a positive government spending shock. While a government spending shock makes households persistently poorer (the estimated persistence of the shock is large), they seek to consume more. The only choice they have is then to offer more labor to sustain their consumption plan. This is why output can increase substantially in the short run. For their part, firms use more labor input such that the marginal productivity of capital increases, creating incentives to invest more.[25] The large increase in the real interest rate simply reflects the persistent rise in capital productivity. The Baseline and HtM versions cannot generate these patterns because private consumption falls and the increase in labor supply is not sufficient to yield a large positive response of the marginal productivity of capital.

4.2. **DSGE misspecification and fiscal multipliers.** The DSGE-VAR approach allows us to determine whether the fiscal multipliers obtained in a constrained DSGE model are far from those obtained in a DSGE-VAR model. If they are close, this means that the features included in the DSGE model are consistent with empirical evidence. We complete the previous exercise by comparing each DSGE specification with the associated DSGE-VAR model, (*i.e.*, incorporating the same structural features).

[24]To simplify the exposition, we abstract from nominal rigidities.

[25]See Dupaigne and Fève (2015) for the analytics of the investment channel in small-scale DSGE models.

Table III. Government spending multiplier in DSGE-VAR models

Model	DSGE	DSGE-VAR	$\frac{\text{DSGE-VAR}}{\text{DSGE}}$
$\mathcal{M}_0$: Baseline	0.590	1.013	1.717
$\mathcal{M}_1$: HtM	0.768	1.064	1.385
$\mathcal{M}_2$: GiU	1.756	1.543	0.879
$\mathcal{M}_3$: Full	1.695	1.556	0.918

Note: This table reports the impact output multiplier. Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function. The DSGE-VAR model includes two lags.

Table III reports the estimated government spending multiplier in both the DSGE case and the DSGE-VAR case for each model version. The estimated value of the multiplier increases substantially in the Baseline and HtM versions, while it remains very similar in the GiU and Full model versions.[26] For example, the estimated multiplier in the DSGE-VAR model increases by 40 percent relative to the constrained HtM model version. This is in contrast to the GiU specification, for which the relative change is only 12 percent. This finding supports our claim that Edgeworth complementarity is a better representation of the transmission mechanism of fiscal policy in the euro area.

5. Concluding remarks

This paper uses the DSGE-VAR approach to assess the relative contributions to the size of estimated fiscal multipliers of two transmission mechanisms of government spending shocks, namely hand-to-mouth consumers and Edgeworth complementarity. Although a Bayesian prior predictive analysis highlights that the presence of hand-to-mouth consumers yields larger multipliers than the introduction of Edgeworth complementarity, our posterior estimates suggest the opposite. A model with Edgeworth complementarity provides a better fit and enriches the propagation mechanism of government spending shocks. In fact, a small change in the

[26]Figure OA9 of the online appendix displays the dynamic responses of output, consumption, investment and the real interest rate to a government spending shock for each DSGE-VAR specification. The four responses are much closer than those obtained with pure DSGE models.

degree of Edgeworth complementarity substantially impacts the estimated share of hand-to-mouth consumers. We also obtain that Edgeworth complementarity yields dynamic responses close to those obtained with the flexible DSGE-VAR model, i.e., a large output multiplier and a positive private consumption response. Conversely, the estimated share of hand-to-mouth consumers is too small to replicate the positive response of private consumption.

In our quantitative assessment, we deliberately abstracted from relevant details to concentrate on the two competing mechanisms. However, the relevant literature has emphasized other modeling and policy issues that might affect and enrich our findings. We mention two of them. First, we only concentrated our analysis on hand-to-mouth consumers and Edgeworth complementarity. There are other relevant mechanisms (externalities, deep habits, productive government investment), and a systematic evaluation of their relative merits may help to improve our understanding of the effects of government activity. Second, we assumed lump-sum taxes to finance the government deficit, but a more realistic representation would consider distortionary taxes with feedback rules. The way in which government expenditures are financed by distortionary taxes could impact the transmission mechanism of fiscal shocks in the euro area.

Acknowledgements

We are grateful to Stéphane Adjémian, Fabio Canova (co-editor), Eric Leeper, Julien Matheron, Paolo Surico, Mathias Trabandt, Rafael Wouters, and participants in several conferences for helpful comments. Special thanks to three anonymous referees, whose suggestions greatly improved the paper. Patrick Fève acknowledges funding from ANR-13-BSH1-0002-AMF. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Banque de France or the Eurosystem.

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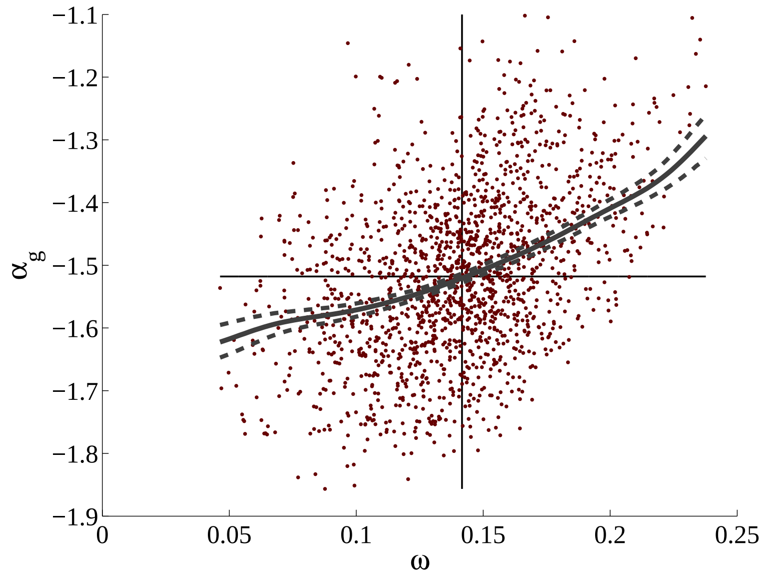


FIGURE 1. Empirical relationship between ω and α_g. The thick line is the nonparametric regression and the thick dashed lines delineate the 90 percent confidence interval obtained by standard bootstrap techniques. The cross indicates the average parameter values for α_g and ω.

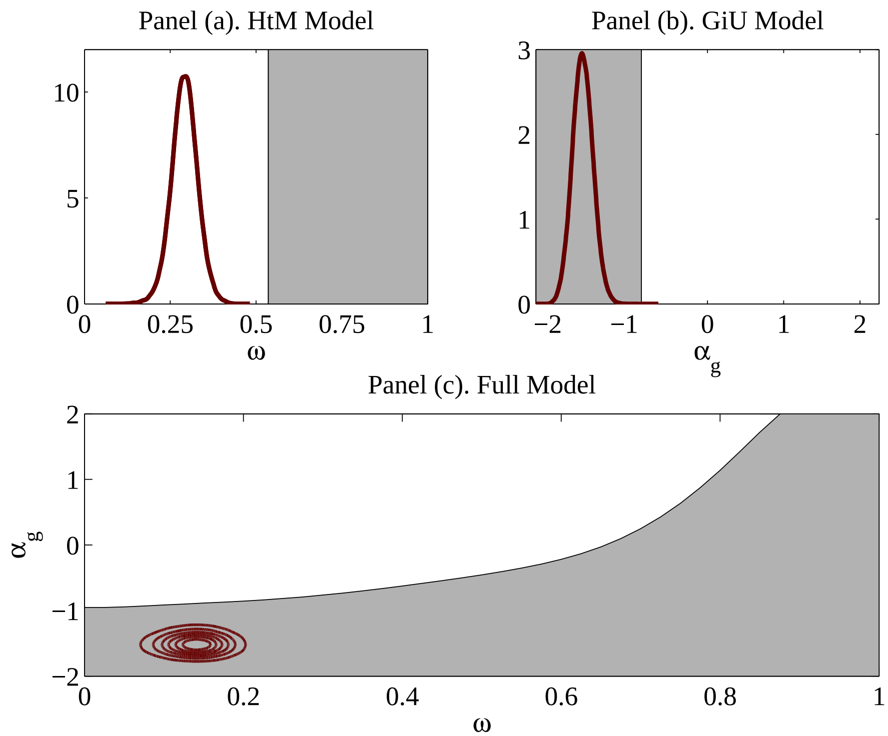


FIGURE 2. Posterior distribution of ω and α_g and area for a positive consumption response. The red lines correspond to the posterior distributions, panels (a) and (b), and to the constant elevation of the joint posterior distributions, panel (c); the grey area reflects the range of values for which the instantaneous response of consumption is positive after a government spending shock.

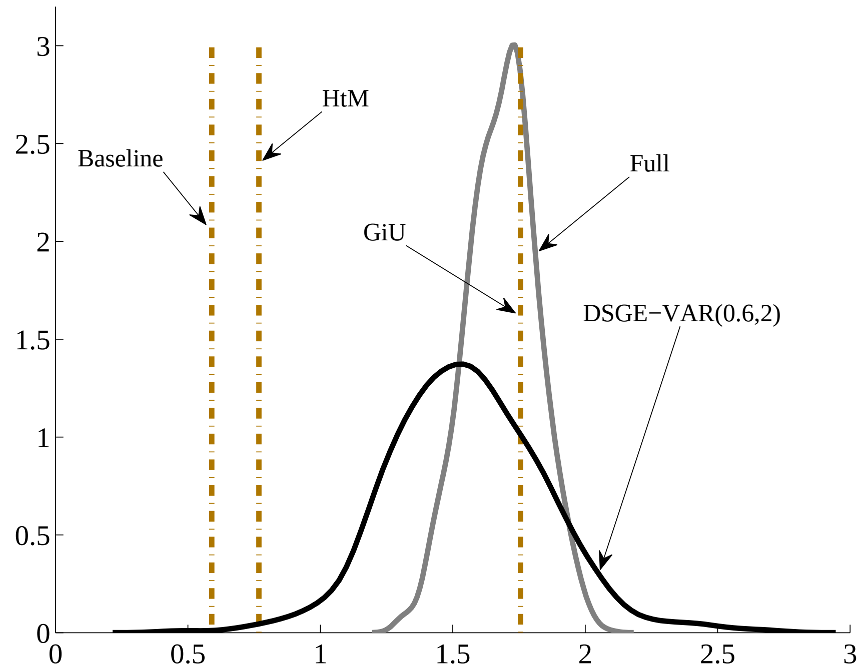


FIGURE 3. Empirical distributions of the impact output multiplier. Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function; DSGE-VAR(0.6,2): combination of a Full-DSGE model with a VAR.

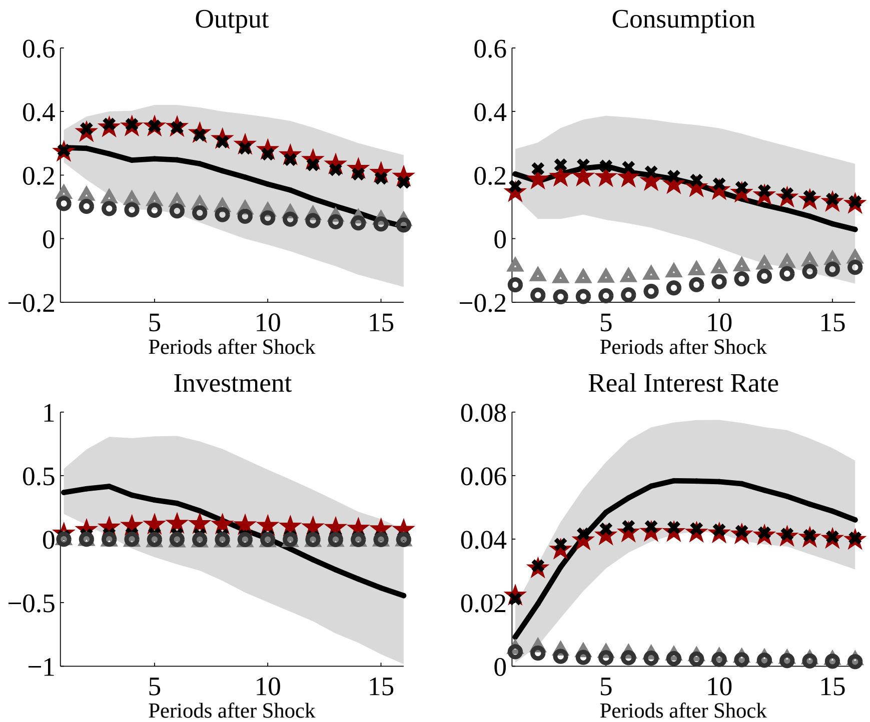


FIGURE 4. Impulse response functions to a government spending shock. The solid line corresponds to the mean of the dynamic responses obtained from the DSGE-VAR(0.6,2) model. The light grey area corresponds to the 90 percent confidence interval. Circle: Smets-Wouters type model (Baseline); Triangle: model with hand-to-mouth consumers (HtM); x-mark: model with government spending in the utility function (GiU); Pentagram: model with both hand-to-mouth consumers and government spending in the utility function (Full).

Online Appendix

A. MEDIUM-SCALE DSGE MODELS

In this section we describe the DSGE models of the euro area economy with distinct transmission mechanisms for government spending shocks. All these models have a common core which is close to Smets and Wouters (2007) and Justiniano, Primiceri and Tambalotti (2010). In particular, each model includes features such as habit formation, investment adjustment costs, variable capital utilisation, monopolistic competition in goods and labor markets, and nominal price and wage rigidities. This setup is extended in two directions: *(i)* the introduction of households being hand-to-mouth consumers and *(ii)* the introduction of government spending in the household utility function in a non-separable way.

A.1. Baseline model

The economy is populated by five classes of agents: producers of a final good, intermediate goods producers, households, employment agencies and the public sector (government and monetary authorities).

A.1.1. Household sector

Employment agencies–. Each household indexed by $j \in [0,1]$ is a monopolistic supplier of specialised labor $N_{j,t}$. At every point in time t, a large number of competitive "employment agencies" combine households' labor into a homogenous labor input N_t sold to intermediate firms, according to $N_t = \left[\int_0^1 N_{j,t}^{\frac{1}{\varepsilon_{w,t}}} \mathrm{d}j\right]^{\varepsilon_{w,t}}$. Profit maximization by the perfectly competitive employment agencies implies the labor demand function $N_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\frac{\varepsilon_{w,t}}{\varepsilon_{w,t}-1}} N_t$, where $W_{j,t}$ is the wage paid by the employment agencies to the household supplying labor variety j, while $W_t \equiv \left(\int_0^1 W_{j,t}^{\frac{1}{\varepsilon_{w,t}-1}} \mathrm{d}j\right)^{\varepsilon_{w,t}-1}$ is the wage paid by intermediate firms for the homogenous labor input sold to them by the agencies. The exogenous variable $\varepsilon_{w,t}$ measures the substitutability across labor varieties and its steady-state is the desired steady-state wage mark-up over the marginal rate of substitution between consumption and leisure.

Household's preferences–. The preferences of the jth household are given by

$$\mathrm{E}_t \sum_{s=0}^{\infty} \beta^s \varepsilon_{b,t+s} \left(\log\left(C^*_{t+s} - hC^*_{t+s-1}\right) - \frac{N_{j,t+s}^{1+\nu}}{1+\nu} + \mathcal{V}\left(G_{t+s}\right) \right),$$

where E_t denotes the mathematical expectation operator conditional upon information available at t, $\beta \in (0,1)$ is the subjective discount factor, $h \in [0,1]$ denotes the degree of habit formation, and $\nu > 0$ is the inverse of the Frisch labor supply elasticity. C^*_t is a consumption measure ($C^*_t = C_t$, where C_t is real consumption, in the baseline version), $N_{j,t}$ is labor of type j, and $\varepsilon_{b,t}$ is a preference shock.

As we explain below, households are subject to idiosyncratic shocks about whether they are able to re-optimise their wage. Hence, the above described problem makes the choices of wealth accumulation contingent upon a particular history of wage rate decisions, thus leading to the heterogeneity of households. For the sake of tractability, we assume that the momentary utility function is separable across consumption, real balances and leisure. Combining this with the assumption of a complete set of contingent claims market, all the households will make the same choices regarding consumption and money holding, and will only differ by their wage rate and supply of labor. This is directly reflected in our notations. Finally, $\mathcal{V}(G_t)$ is a positive concave function, meaning that agents do not necessarily feel worse off when public expenditures increase. Notice that this term has no effect on the equilibrium.

Household j's period budget constraint is given by

$$P_t(C_t + I_t) + T_t + B_t \leq R_{t-1}B_{t-1} + A_{j,t} + D_t + W_{j,t}N_{j,t} + \left(R_t^k u_t - P_t\vartheta(u_t)\right)\bar{K}_{t-1},$$

where I_t is investment, T_t denotes nominal lump-sum taxes (transfers if negative), B_t is the one-period riskless bond, R_t is the nominal interest rate on bonds, $A_{j,t}$ is the net cash flow from household's j portfolio of state contingent securities, D_t is the equity payout received from the ownership of firms. The capital utilisation rate u_t transforms physical capital $\bar{K}_t$ into the service flow of effective capital K_t according to $K_t = u_t\bar{K}_{t-1}$, and the effective capital is rented to intermediate firms at the nominal rental rate R_t^k. The costs of capital utilization per unit of capital is given by the convex function $\vartheta(u_t)$. We assume that $u = 1$, $\vartheta(1) = 0$, and we define $\eta_u \equiv [\vartheta''(1)/\vartheta'(1)]/[1 + \vartheta''(1)/\vartheta'(1)]$.[27] The physical capital accumulates according to

$$\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \varepsilon_{i,t}\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t,$$

where $\delta \in [0,1]$ is the depreciation rate of capital, and $S(.)$ is an adjustment cost function which satisfies $S(\gamma_z) = S'(\gamma_z) = 0$ and $S''(\gamma_z) = \eta_k > 0$, γ_z is the steady-state (gross) growth rate of technology, and $\varepsilon_{i,t}$ is an investment shock. Households set nominal wages according to a staggering mechanism. In each period, a fraction θ_w of households cannot choose its wage optimally, but adjusts it to keep up with the increase in the general wage level in the previous period according to the indexation rule $W_{j,t} = \gamma_z\pi^{1-\gamma_w}\pi_{t-1}^{\gamma_w}W_{j,t-1}$, where $\pi_t \equiv P_t/P_{t-1}$ represents the gross inflation rate, π is steady-state (or trend) inflation and the coefficient $\gamma_w \in [0,1]$ is the degree of indexation to past wages. The remaining fraction of households chooses instead an optimal wage, subject to the labor demand function $N_{j,t}$.

A.1.2. Business sector

Final good producers–. At every point in time t, a perfectly competitive sector produces a final good Y_t by combining a continuum of intermediate goods $Y_t(\varsigma)$, $\varsigma \in [0,1]$, according to the technology $Y_t = \left[\int_0^1 Y_{\varsigma,t}{}^{\frac{1}{\varepsilon_{p,t}}} d\varsigma\right]^{\varepsilon_{p,t}}$. Final good producing firms take their output price, P_t, and their input prices, $P_{\varsigma,t}$, as given and beyond their control. Profit maximization implies $Y_{\varsigma,t} = \left(\frac{P_{\varsigma,t}}{P_t}\right)^{-\frac{\varepsilon_{p,t}}{\varepsilon_{p,t}-1}} Y_t$ from which we deduce the relationship between the final good and the prices of the intermediate goods $P_t \equiv \left[\int_0^1 P_{\varsigma,t}{}^{\frac{1}{\varepsilon_{p,t}-1}} d\varsigma\right]^{\varepsilon_{p,t}-1}$. The exogenous variable $\varepsilon_{p,t}$ measures the substitutability across differentiated intermediate goods and its steady state is then the desired steady-state price markup over the marginal cost of intermediate firms.

Intermediate-goods firms–. Intermediate good ς is produced by a monopolist firm using the following production function

$$Y_{\varsigma,t} = K_{\varsigma,t}{}^{\alpha}\left[Z_t N_{\varsigma,t}\right]^{1-\alpha} - Z_t F,$$

where $\alpha \in (0,1)$ denotes the capital share, $K_{\varsigma,t}$ and $N_{\varsigma,t}$ denote the amounts of capital and effective labor used by firm ς, F is a fixed cost of production that ensures that profits are zero in steady state, and Z_t is an exogenous labor-augmenting productivity factor whose growth-rate is denoted by $\varepsilon_{z,t} \equiv Z_t/Z_{t-1}$. In addition, we assume that intermediate firms rent capital and labor in perfectly competitive factor markets.

Intermediate firms set prices according to a staggering mechanism. In each period, a fraction θ_p of firms cannot choose its price optimally, but adjusts it to keep up with the increase in the

[27] Later, we estimate η_u rather than the elasticity $\vartheta''(1)/\vartheta'(1)$ to avoid convergence issues.

general price level in the previous period according to the indexation rule $P_{\varsigma,t} = \pi^{1-\gamma_p}\pi_{t-1}^{\gamma_p}P_{\varsigma,t-1}$,where the coefficient $\gamma_p \in [0,1]$ indicates the degree of indexation to past prices. The remaining fraction of firms chooses its price $P^{\star}_{\varsigma,t}$ optimally, by maximizing the present discounted value of future profits

$$\mathrm{E}_t \sum_{s=0}^{\infty} \left(\beta\theta_p\right)^s \frac{\Lambda_{t+s}}{\Lambda_t} \left\{ \Pi^p_{t,t+s} P^{\star}_{\varsigma,t} Y_{\varsigma,t+s} - \left[W_{t+s} N_{\varsigma,t+s} + R^k_{t+s} K_{\varsigma,t+s} \right] \right\},$$

where

$$\Pi^p_{t,t+s} = \begin{cases} \prod_{v=1}^{s} \pi^{1-\gamma_p} \pi^{\gamma_p}_{t+v-1} & s > 0 \\ 1 & s = 0, \end{cases}$$

subject to the demand from final goods firms and the production function. Λ_{t+s} is the marginal utility of consumption for the representative household that owns the firm.

A.1.3. Public sector

Real (unproductive) government purchases G_t is set according to

$$\frac{G_t}{Z_t} = g\tilde{G}_t \varepsilon_{g,t},$$

where g denotes the deterministic steady-state value of G_t/Z_t, $\varepsilon_{g,t}$ is a government spending shock, and $\tilde{G}_t$ is an endogenous component of the policy, assumed to follow the simple rule

$$\tilde{G}_t = \left(\frac{Y_t}{\gamma_z Y_{t-1}} \right)^{\varphi_g}.$$

The parameter φ_g is the policy rule parameter linking the stationary component of government policy to demeaned output growth. If $\varphi_g > 0$, the policy rule contains a procyclical component that triggers an increase in government expenditures whenever output growth is above its average value. In contrast, if $\varphi_g < 0$, the policy rule features a countercyclical component, and thus reflects automatic stabilizers. When $\varphi_g = 0$, the stationary component of government policy is exogenous.

The monetary authority follows a generalised-Taylor rule by gradually adjusting the nominal interest rate in response to inflation, the output gap and a change in the output gap:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\varphi_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\varphi_\pi} \left(\frac{Y_t}{Y_{f,t}} \right)^{\varphi_y} \left(\frac{Y_t Y_{f,t-1}}{Y_{t-1} Y_{f,t}} \right)^{\varphi_{\Delta y}} \right]^{(1-\varphi_r)} \varepsilon_{r,t},$$

where R is the steady state of the gross nominal interest rate and $\varepsilon_{r,t}$ is a monetary policy shock. The output gap is defined as the ratio of actual to potential output $Y_{f,t}$ (*i.e.* the level of output that would prevail under flexible prices and constant elasticity of substitution among intermediate goods and labor types). The parameter φ_r captures the degree of interest-rate smoothing.

A.1.4. Market clearing and stochastic processes

Market clearing conditions on final goods market are given by

$$Y_t = C_t + I_t + G_t + \vartheta\left(u_t\right)\bar{K}_{t-1},$$
$$\Delta_{p,t} Y_t = \left(u_t \bar{K}_{t-1}\right)^{\alpha} \left(Z_t N_t\right)^{1-\alpha} - Z_t F,$$

where $\Delta_{p,t} = \int_0^1 \left(\frac{P_{\varsigma,t}}{P_t} \right)^{-\frac{\varepsilon_{p,t}}{\varepsilon_{p,t}-1}} \mathrm{d}\varsigma$ is a measure of the price dispersion.

Regarding the properties of the stochastic variables, productivity and monetary policy shocks evolve according to $\log(\varepsilon_{x,t}) = \zeta_{x,t}$, with $x \in \{z, r\}$. The remaining exogenous variables follow an AR(1) process $\log(\varepsilon_{x,t}) = \rho_x \log(\varepsilon_{x,t-1}) + \zeta_{x,t}$, with $x \in \{b, i, g, p, w\}$. In all cases, $\zeta_{x,t} \sim i.i.d.\mathcal{N}\left(0, \sigma_x^2\right)$.

A.2. Introducing two transmission mechanisms of government spending shocks

We consider extended versions in order to introduce different transmission mechanisms of government spending shocks.

As in Galí, Lopez-Salido and Vallès (2007), we assume in a first specification (labelled 'HtM') *(i)* that a fraction ω of households, called hand-to-mouth consumers, do not have access to financial markets and simply consume their disposable income in each and every period, *(ii)* the employment agencies do not discriminate between household types in their labor demands, such that the number of hours worked N_t is the same for all households. It follows that, in a symmetric equilibrium, all households have the same wage rate W_t. Therefore, the hand-to-mouth consumers set nominal consumption expenditure $C_{r,t}$ equal to their disposable wage income less lump-sum taxes $T_{r,t}$. This results in the following period-by-period budget constraint:

$$P_t C_{r,t} \leq W_t N_t - T_{r,t}$$

The consumption of households who have access to financial markets is denoted $C_{0,t}$. Accordingly, total private consumption is then defined as $C_t = (1-\omega) C_{o,t} + \omega C_{r,t}$.

A second specification (labelled 'GiU') augments the baseline model with government spending in the utility function. As in Bouakez and Rebei (2007), we allow for complementarity/substitutability between private consumption and public expenditures. Formally, the consumption bundle C_t^* is now defined as

$$C_t^* = C_t + \alpha_g G_t,$$

where the parameter α_g measures the degree of complementarity/substitutability between private consumption and public expenditures. The specification adopted here follows Christiano and Eichenbaum (1992), McGrattan (1994), Finn (1998), among others. If $\alpha_g > 0$, government spending substitutes for private consumption, with perfect substitution if $\alpha_g = 1$, as in Christiano and Eichenbaum (1992). In this case, a permanent increase in government spending has no effect on output and hours but reduces private consumption, through a perfect crowding-out effect. In the special case $\alpha_g = 0$, we recover the standard business cycle model, with government spending operating through a negative wealth effect on labor supply (see Aiyagari, Christiano and Eichenbaum, 1992, Baxter and King, 1993). When the parameter $\alpha_g < 0$, government spending complements private consumption. Then, it can be the case (depending on the labor supply elasticity) that private consumption will react positively to an unexpected increase in government spending.

A last specification (labelled 'Full') embeds both hand-to-mouth consumers and government spending in the utility function in the baseline model.

B. Equilibrium conditions, steady-state and log-linearization

B.1. Equilibrium conditions

This section reports the first-order conditions for the agents' optimizing problems and the other relationships that define the equilibrium of the models.

Effective capital:

$$K_t = u_t \bar{K}_{t-1}$$

Capital accumulation:

$$\bar{K}_t = (1-\delta)\,\bar{K}_{t-1} + \varepsilon_{i,t}\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t$$

Marginal utility of consumption:

$$\begin{aligned}\Lambda_t &= \frac{\varepsilon_{b,t}}{C_t^* - hC_{t-1}^*} - \beta h \mathrm{E}_t\left\{\frac{\varepsilon_{b,t+1}}{C_{t+1}^* - hC_t^*}\right\}\\ C_t^* &= C_t\end{aligned}$$

Consumption Euler equation:

$$\Lambda_t = \beta R_t \mathrm{E}_t\left\{\Lambda_{t+1}\frac{P_t}{P_{t+1}}\right\}$$

Investment equation:

$$\begin{aligned}1 = {} & Q_t\varepsilon_{i,t}\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}}S'\left(\frac{I_t}{I_{t-1}}\right)\right]\\ & + \beta\mathrm{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}Q_{t+1}\varepsilon_{i,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 S'\left(\frac{I_{t+1}}{I_t}\right)\right\}\end{aligned}$$

Tobin's Q:

$$Q_t = \beta\mathrm{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\left[\frac{R_{t+1}^k}{P_{t+1}}u_{t+1} - \vartheta\left(u_{t+1}\right) + (1-\delta)\,Q_{t+1}\right]\right\}$$

Capital utilization:

$$R_t^k = P_t\vartheta'\left(u_t\right)$$

Production function:

$$Y_{i,t} = K_{i,t}{}^{\alpha}\left[Z_t N_{i,t}\right]^{1-\alpha} - Z_t F$$

Labor demand:

$$W_t = (1-\alpha)\,Z_t\left(\frac{K_t}{Z_t N_t}\right)^{\alpha} MC_t$$

where MC_t is the nominal marginal cost.
Capital renting:

$$R_t^k = \alpha\left(\frac{K_t}{Z_t N_t}\right)^{\alpha-1} MC_t$$

Price setting:

$$\mathrm{E}_t\sum_{s=0}^{\infty}\left(\beta\theta_p\right)^s\frac{\Lambda_{t+s}}{\Lambda_t}Y_{t,t+s}^{\star}\left[P_t^{\star}\Pi_{t,t+s}^{p} - \varepsilon_{p,t+s}MC_{t+s}\right] = 0$$

Aggregate price index:

$$P_t = \left[\left(1-\theta_p\right)\left(P_t^{\star}\right)^{1/\left(\varepsilon_{p,t}-1\right)} + \theta_p\left(\pi^{1-\gamma_p}\pi_{t-1}^{\gamma_p}P_{t-1}\right)^{1/\left(\varepsilon_{p,t}-1\right)}\right]^{\left(\varepsilon_{p,t}-1\right)}$$

Wage setting:

$$\mathrm{E}_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \Lambda_{t+s} N^{\star}_{t,t+s} \left[\frac{W^{\star}_t}{P_{t+s}} \Pi^w_{t,t+s} - \varepsilon_{b,t+s}\varepsilon_{w,t+s} \frac{\left(N^{\star}_{t,t+s}\right)^{\nu}}{\Lambda_{t+s}} \right] = 0$$

Aggregate wage index:

$$W_t = \left[(1-\theta_w) \left(W^{\star}_t\right)^{1/(\varepsilon_{w,t}-1)} + \theta_w \left(\gamma_z \pi^{1-\gamma_w} \pi^{\gamma_w}_{t-1} W_{t-1} \right)^{1/(\varepsilon_{w,t}-1)} \right]^{(\varepsilon_{w,t}-1)}$$

Government spending:

$$\frac{G_t}{Z_t} = g \times \left(\frac{Y_t}{\gamma_z Y_{t-1}} \right)^{\varphi_g} \varepsilon_{g,t}$$

Monetary policy rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\varphi_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\varphi_\pi} \left(\frac{Y_t}{Y_{f,t}} \right)^{\varphi_y} \left(\frac{Y_t Y_{f,t-1}}{Y_{t-1} Y_{f,t}} \right)^{\varphi_{\Delta y}} \right]^{(1-\varphi_r)} \varepsilon_{r,t}$$

Resource constraint:

$$Y_t = C_t + I_t + G_t + \vartheta(u_t)\bar{K}_{t-1}$$

$$\Delta_{p,t} Y_t = \left(u_t \bar{K}_{t-1}\right)^{\alpha} \left[Z_t N_t\right]^{1-\alpha} - Z_t F$$

Model with hand-to-mouth consumers:

$$P_t C_{r,t} = W_t N_t - T_{r,t}$$

$$C_t = (1-\omega) C_{o,t} + \omega C_{r,t}$$

Model with government spending in the utility function:

$$C^*_t = C_t + \alpha_g G_t$$

B.2. Stationary equilibrium

To find the steady state, we express the model in stationary form. Thus, for the non-stationary variables, let lower-case denote their value relative to the technology process Z_t:

$$\begin{array}{lllll} y_t \equiv Y_t/Z_t & k_t \equiv K_t/Z_t & \bar{k}_t \equiv \bar{K}_t/Z_t & i_t \equiv I_t/Z_t & c_t \equiv C_t/Z_t \\ g_t \equiv G_t/Z_t & \lambda_t \equiv \Lambda_t Z_t & w_t \equiv W_t/(Z_t P_t) & w^{\star}_t \equiv W^{\star}_t/(Z_t P_t) & c^*_t \equiv C^*_t/Z_t \\ c_{o,t} \equiv C_{o,t}/Z_t & c_{r,t} \equiv C_{r,t}/Z_t & & & \end{array}$$

where we note that the marginal utility of consumption Λ_t will shrink as the economy grows, and we express the wage in real terms. Also, we denote the real rental rate of capital and real marginal cost by

$$r^k_t \equiv R^k_t/P_t \text{ and } mc_t \equiv MC_t/P_t,$$

and the optimal relative price as

$$p^{\star}_t \equiv P^{\star}_t/P_t.$$

Then we can rewrite the model in terms of stationary variables as follows.
Effective capital:

$$k_t = \frac{u_t \bar{k}_{t-1}}{\varepsilon_{z,t}}$$

Capital accumulation:

$$\bar{k}_t = (1-\delta)\frac{\bar{k}_{t-1}}{\varepsilon_{z,t}} + \varepsilon_{i,t}\left(1 - S\left(\frac{i_t}{i_{t-1}}\varepsilon_{z,t}\right)\right) i_t$$

Marginal utility of consumption:

$$\lambda_t = \frac{\varepsilon_{b,t}}{c_t^* - h\dfrac{c_{t-1}^*}{\varepsilon_{z,t}}} - \beta h \mathrm{E}_t \left\{ \frac{\varepsilon_{b,t+1}}{\varepsilon_{z,t+1}\left(c_{t+1}^* - h\dfrac{c_t^*}{\varepsilon_{z,t+1}}\right)} \right\}$$

$$c_t^* = c_t$$

Consumption Euler equation:

$$\lambda_t = \beta R_t \mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\varepsilon_{z,t+1}\pi_{t+1}} \right\}$$

Investment equation:

$$\begin{aligned} 1 = {} & q_t \varepsilon_{i,t} \left[1 - S\left(\frac{i_t}{i_{t-1}}\varepsilon_{z,t}\right) - \frac{i_t}{i_{t-1}}\varepsilon_{z,t} S'\left(\frac{i_t}{i_{t-1}}\varepsilon_{z,t}\right)\right] \\ & + \beta \mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t \varepsilon_{z,t+1}} q_{t+1}\varepsilon_{i,t+1} \left(\frac{i_{t+1}}{i_t}\varepsilon_{z,t+1}\right)^2 S'\left(\frac{i_{t+1}}{i_t}\varepsilon_{z,t+1}\right) \right\} \end{aligned}$$

Tobin's Q:

$$q_t = \beta \mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t \varepsilon_{z,t+1}} \left[r_{t+1}^k u_{t+1} - \vartheta\left(u_{t+1}\right) + \left(1-\delta\right) q_{t+1} \right] \right\}$$

Capital utilization:

$$r_t^k = \vartheta'\left(u_t\right)$$

Production function:

$$y_{i,t} = k_{i,t}^{\alpha} N_{i,t}^{1-\alpha} - F$$

Labor demand:

$$w_t = \left(1-\alpha\right)\left(\frac{k_t}{N_t}\right)^{\alpha} mc_t$$

Capital renting:

$$r_t^k = \alpha \left(\frac{k_t}{N_t}\right)^{\alpha-1} mc_t$$

Price setting:

$$\mathrm{E}_t \sum_{s=0}^{\infty} \left(\beta\theta_p\right)^s \frac{\lambda_{t+s}}{\lambda_t} y_{t,t+s}^{\star} \left[p_t^{\star} \frac{P_t}{P_{t+s}} \Pi_{t,t+s}^{p} - \varepsilon_{p,t+s} mc_{t+s} \right] = 0$$

Aggregate price index:

$$1 = \left[\left(1-\theta_p\right)\left(p_t^{\star}\right)^{1/\left(\varepsilon_{p,t}-1\right)} + \theta_p \left(\pi^{1-\gamma_p} \pi_{t-1}^{\gamma_p} \frac{1}{\pi_t} \right)^{1/\left(\varepsilon_{p,t}-1\right)} \right]^{\left(\varepsilon_{p,t}-1\right)}$$

Wage setting:

$$\mathrm{E}_t \sum_{s=0}^{\infty} \left(\beta\theta_w\right)^s \lambda_{t+s} N_{t,t+s}^{\star} \left[w_t^{\star} \frac{P_t}{P_{t+s}} \frac{Z_t}{Z_{t+s}} \Pi_{t,t+s}^{w} - \varepsilon_{b,t+s}\varepsilon_{w,t+s} \frac{N_{t,t+s}^{\nu}}{\lambda_{t+s}} \right] = 0$$

Aggregate wage index:

$$w_t = \left[\left(1-\theta_w\right)\left(w_t^{\star}\right)^{1/\left(\varepsilon_{w,t}-1\right)} + \theta_w \left(\gamma_z \pi^{1-\gamma_w} \pi_{t-1}^{\gamma_w} \frac{w_{t-1}}{\pi_t \varepsilon_{z,t}} \right)^{1/\left(\varepsilon_{w,t}-1\right)} \right]^{\left(\varepsilon_{w,t}-1\right)}$$

Government spending:

$$g_t = g \times \left(\frac{\varepsilon_{z,t} y_t}{\gamma_z y_{t-1}} \right)^{\varphi_g} \varepsilon_{g,t}$$

Monetary policy rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\varphi_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\varphi_\pi} \left(\frac{y_t}{y_{f,t}}\right)^{\varphi_y} \left(\frac{y_t y_{f,t-1}}{y_{t-1} y_{f,t}}\right)^{\varphi_{\Delta y}}\right]^{(1-\varphi_r)} \varepsilon_{r,t}$$

Resource constraint:

$$y_t = c_t + i_t + g_t + \vartheta(u_t)\bar{k}_{t-1}/\varepsilon_{z,t}$$
$$\Delta_{p,t} y_t = \left(u_t \bar{k}_{t-1}\right)^\alpha N_t^{1-\alpha} - F$$

Model with hand-to-mouth consumers:

$$c_{r,t} = w_t N_t - t_{r,t}$$
$$c_t = (1-\omega)\, c_{o,t} + \omega c_{r,t}$$

Model with government spending in the utility function:

$$c_t^* = c_t + \alpha_g g_t$$

B.3. Steady state

We use the stationary version of the model to find the steady state, and we let variables without a time subscript denote steady-state values. First, we have that $R = (\gamma_z \pi)/\beta$ and the expression for Tobin's Q implies that the rental rate of capital is

$$r^k = \frac{\gamma_z}{\beta} - (1-\delta)$$

and the price-setting equation gives marginal cost as

$$mc = \frac{1}{\varepsilon_p}.$$

The capital/labor ratio can then be retrieved using the capital renting equation:

$$\frac{k}{N} = \left(\alpha \frac{mc}{r^k}\right)^{1/(1-\alpha)},$$

and the wage is given by the labor demand equation as

$$w = (1-\alpha)\, mc \left(\frac{k}{N}\right)^\alpha.$$

The production function gives the output/labor ratio as

$$\frac{y}{N} = \left(\frac{k}{N}\right)^\alpha - \frac{F}{N},$$

and the fixed cost F is set to obtain zero profits at the steady state, implying

$$\frac{F}{N} = \left(\frac{k}{N}\right)^\alpha - w - r^k \frac{k}{N}.$$

The output/labor ratio is then given by

$$\frac{y}{N} = w + r^k \frac{k}{N} = \frac{r^k}{\alpha}\frac{k}{N}.$$

Finally, to determine the investment/output ratio, we use the expressions for effective capital and physical capital accumulation to get

$$\frac{i}{k} = \left(1 - \frac{1-\delta}{\gamma_z}\right)\gamma_z \Longrightarrow \frac{i}{y} = \frac{i}{k}\frac{k}{N}\frac{N}{y} = \left(1 - \frac{1-\delta}{\gamma_z}\right)\frac{\alpha\gamma_z}{r^k}.$$

Given the government spending/output ratio g/y, the consumption/output ratio is then given by the resource constraint as

$$\frac{c}{y} = 1 - \frac{i}{y} - \frac{g}{y}.$$

Model with hand-to-mouth consumers:

$$c_r = wN - t_r$$

$$c = c_o = c_r$$

In what follows, t_r is assumed to be zero.

Model with government spending in the utility function:

$$c^* = c + \alpha_g g$$

B.4. Log-linearized version

We log-linearize the stationary model around the steady state. Let $\hat{\chi}_t$ denote the log deviation of the variable χ_t from its steady-state level χ: $\hat{\chi}_t \equiv \log(\chi_t/\chi)$. The log-linearized model is then given by the following system of equations for the endogenous variables.

Effective capital:

$$\hat{k}_t + \hat{\varepsilon}_{z,t} = \hat{u}_t + \widehat{\bar{k}}_{t-1}$$

Capital accumulation:

$$\widehat{\bar{k}}_t = \frac{1-\delta}{\gamma_z}\left(\widehat{\bar{k}}_{t-1} - \hat{\varepsilon}_{z,t}\right) + \left(1 - \frac{1-\delta}{\gamma_z}\right)(\hat{\imath}_t + \hat{\varepsilon}_{i,t})$$

Marginal utility of consumption:

$$\begin{aligned}
\hat{\lambda}_t = & \frac{h\gamma_z}{(\gamma_z - h\beta)(\gamma_z - h)}\hat{c}^*_{t-1} - \frac{\gamma_z^2 + h^2\beta}{(\gamma_z - h\beta)(\gamma_z - h)}\hat{c}^*_t + \frac{h\beta\gamma_z}{(\gamma_z - h\beta)(\gamma_z - h)}\mathrm{E}_t\hat{c}^*_{t+1} \\
& - \frac{h\gamma_z}{(\gamma_z - h\beta)(\gamma_z - h)}\hat{\varepsilon}_{z,t} + \frac{h\beta\gamma_z}{(\gamma_z - h\beta)(\gamma_z - h)}\mathrm{E}_t\hat{\varepsilon}_{z,t+1} \\
& + \frac{\gamma_z}{\gamma_z - h\beta}\hat{\varepsilon}_{b,t} - \frac{h\beta}{\gamma_z - h\beta}\mathrm{E}_t\hat{\varepsilon}_{b,t+1} \\
\hat{c}^*_t = & \ \hat{c}_t
\end{aligned}$$

Consumption Euler equation:

$$\hat{\lambda}_t = \mathrm{E}_t\hat{\lambda}_{t+1} + \left(\hat{R}_t - \mathrm{E}_t\hat{\pi}_{t+1}\right) - \mathrm{E}_t\hat{\varepsilon}_{z,t+1}$$

Investment equation:

$$\hat{\imath}_t = \frac{1}{1+\beta}(\hat{\imath}_{t-1} - \hat{\varepsilon}_{z,t}) + \frac{\beta}{1+\beta}\mathrm{E}_t(\hat{\imath}_{t+1} + \hat{\varepsilon}_{z,t+1}) + \frac{1}{\eta_k\gamma_z^2(1+\beta)}(\hat{q}_t + \hat{\varepsilon}_{i,t})$$

Tobin's Q:

$$\hat{q}_t = \frac{\beta(1-\delta)}{\gamma_z}\mathrm{E}_t\hat{q}_{t+1} + \left(1 - \frac{\beta(1-\delta)}{\gamma_z}\right)\mathrm{E}_t\hat{r}^k_{t+1} - (\hat{r}_t - \mathrm{E}_t\hat{\pi}_{t+1})$$

Capital utilization:

$$\hat{u}_t = \frac{1-\eta_u}{\eta_u}\hat{r}^k_t$$

Production function:

$$\hat{y}_t = \frac{y+F}{y}\left(\alpha\hat{k}_t + (1-\alpha)\hat{n}_t\right)$$

Labor demand:

$$\hat{w}_t = \widehat{mc}_t + \alpha\hat{k}_t - \alpha\hat{n}_t$$

Capital renting:

$$\hat{r}_t^k = \widehat{mc}_t - (1-\alpha)\,\hat{k}_t + (1-\alpha)\,\hat{n}_t$$

Phillips curve:

$$\hat{\pi}_t = \frac{\gamma_p}{1+\beta\gamma_p}\pi_{t-1} + \frac{\beta}{1+\beta\gamma_p}\mathrm{E}_t\pi_{t+1} + \frac{\left(1-\beta\theta_p\right)\left(1-\theta_p\right)}{\theta_p\left(1+\beta\gamma_p\right)}\left(\widehat{mc}_t + \hat{\varepsilon}_{p,t}\right)$$

Wage curve:

$$\hat{w}_t = \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}\mathrm{E}_t\hat{w}_{t+1} + \frac{\left(1-\beta\theta_w\right)\left(1-\theta_w\right)}{\theta_w\left(1+\beta\right)\left(1+\nu\frac{\varepsilon_w}{\varepsilon_w-1}\right)}\left(\widehat{mrs}_t - \hat{w}_t + \hat{\varepsilon}_{w,t}\right)$$
$$+\frac{\gamma_w}{1+\beta}\hat{\pi}_{t-1} - \frac{1+\beta\gamma_w}{1+\beta}\hat{\pi}_t + \frac{\beta}{1+\beta}\mathrm{E}_t\hat{\pi}_{t+1} - \frac{1}{1+\beta}\hat{\varepsilon}_{z,t} + \frac{\beta}{1+\beta}\mathrm{E}_t\hat{\varepsilon}_{z,t+1}$$

Marginal rate of substitution:

$$\widehat{mrs}_t = \nu\hat{n}_t - \hat{\lambda}_t + \hat{\varepsilon}_{b,t}$$

Government spending:

$$\hat{g}_t = \varphi_g\left(\hat{y}_t - \hat{y}_{t-1} + \hat{\varepsilon}_{z,t}\right) + \hat{\varepsilon}_{g,t}$$

Monetary policy rule:

$$\hat{R}_t = \varphi_r\hat{R}_{t-1} + (1-\varphi_r)\left[\varphi_\pi\hat{\pi}_t + \varphi_y\left(\hat{y}_t - \hat{y}_{t-1}\right) + \varphi_{\Delta y}\left(\left(\hat{y}_t - \hat{y}_{f,t}\right) - \left(\hat{y}_{t-1} - \hat{y}_{f,t-1}\right)\right)\right] + \hat{\varepsilon}_{r,t}$$

Resource constraint:

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{i}{y}\hat{\imath}_t + \frac{g}{y}\hat{g}_t + \frac{r^k k}{y}\hat{u}_t$$

Model with hand-to-mouth consumers:

$$\hat{c}_{r,t} = \frac{wn}{c}\left(\hat{w}_t + \hat{n}_t\right)$$
$$\hat{c}_t = (1-\omega)\,\hat{c}_{o,t} + \omega\hat{c}_{r,t}$$

Model with government spending in the utility function:

$$\hat{c}_t^* = \frac{c}{c+\alpha_g g}\hat{c}_t + \frac{\alpha_g g}{c+\alpha_g g}\hat{g}_t$$

C. Prior distributions

Table OA1. Prior Distributions for Parameters

HtM share, ω	Edgeworth compl., α_g	Habit in consumption, h
$\mathcal{U}$[0.50,0.28]	$\mathcal{U}$[0.00,1.30]	$\mathcal{B}$[0.50,0.20]
Capital utilisation cost, η_u	Investment adj. cost, η_k	TFP growth rate, $\log(\gamma_z)$
$\mathcal{B}$[0.50,0.10]	$\mathcal{G}$[4.00,1.00]	$\mathcal{G}$[0.40,0.10]
Calvo parameters, θ_p, θ_w	Indexation parameters, γ_p, γ_w	MP–smoothing, φ_r
$\mathcal{B}$[0.66,0.10]	$\mathcal{B}$[0.50,0.15]	$\mathcal{B}$[0.75,0.10]
MP–inflation, φ_π	MP–output gap, $\varphi_y, \varphi_{\Delta y}$	Shocks persistence, $\rho_w, \rho_b, \rho_i, \rho_p, \rho_g$
$\mathcal{G}$[2.00,0.30]	$\mathcal{G}$[0.125,0.10]	$\mathcal{B}$[0.50,0.20]
Shocks volatility, $\sigma_w, \sigma_b, \sigma_i, \sigma_p, \sigma_r, \sigma_e$	Shocks volatility, σ_z, σ_g	
$\mathcal{IG}$[0.25,2.00]	$\mathcal{IG}$[1.00,2.00]	

D. A complement to the prior predictive analysis

Table OA2. Government Spending Multiplier Probabilities Implied by Prior Predictive Analysis with Informative Priors on ω and α_g

	Prob$\left(\frac{\Delta Y}{\Delta G} > 1\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
ω	0.933	0.548	0.307	0.224	0.249
α_g	0.497	0.422	0.367	0.320	0.305
ω and α_g	0.706	0.630	0.529	0.477	0.482
	Prob $\left(\frac{\Delta C}{\Delta G} > 0\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
ω	0.814	0.633	0.525	0.419	0.327
α_g	0.486	0.459	0.440	0.412	0.367
ω and α_g	0.696	0.645	0.614	0.587	0.536
	Prob$\left(\frac{\Delta I}{\Delta G} > 0\right)$				
	Impact	4 quart.	10 quart.	25 quart.	∞
ω	0.000	0.000	0.000	0.000	0.000
α_g	0.311	0.311	0.311	0.311	0.311
ω and α_g	0.127	0.127	0.127	0.127	0.127

Note: This table reports the government spending multiplier probabilities when all the parameters are set at their respective prior mean except ω and α_g that are drawn in their respective prior distributions.

E. DSGE estimation results

Table OA3. Posterior Estimates of Alternative DSGE models

	$\mathcal{M}_0$: Baseline	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
Habit in consumption, h	0.242 [0.136,0.348]	0.232 [0.098,0.360]	0.095 [0.017,0.166]	0.141 [0.037,0.244]
Gov feedback parameter, φ_g	-0.583 [-0.766,-0.403]	-0.601 [-0.784,-0.416]	-0.778 [-0.957,-0.592]	-0.733 [-0.909,-0.555]
Capital utilisation cost, η_u	0.786 [0.697,0.877]	0.777 [0.685,0.874]	0.770 [0.679,0.865]	0.779 [0.688,0.870]
Investment adj. cost, η_k	5.075 [3.852,6.323]	4.477 [3.098,5.832]	5.127 [3.813,6.446]	4.718 [3.319,6.062]
Growth rate of technology, $\log(\gamma_z)$	0.380 [0.289,0.468]	0.395 [0.309,0.484]	0.402 [0.312,0.492]	0.416 [0.325,0.507]
Calvo price, θ_p	0.950 [0.930,0.970]	0.933 [0.912,0.955]	0.931 [0.914,0.948]	0.926 [0.909,0.944]
Calvo wage, θ_w	0.748 [0.643,0.854]	0.820 [0.687,0.932]	0.743 [0.621,0.866]	0.772 [0.595,0.915]
Price indexation, γ_p	0.280 [0.048,0.454]	0.152 [0.031,0.273]	0.153 [0.041,0.262]	0.145 [0.039,0.240]
Wage indexation, γ_w	0.280 [0.106,0.447]	0.409 [0.192,0.626]	0.304 [0.129,0.479]	0.357 [0.165,0.554]
MP–smoothing, φ_r	0.865 [0.820,0.910]	0.877 [0.827,0.928]	0.868 [0.829,0.909]	0.876 [0.833,0.918]
MP–inflation, φ_π	1.581 [1.252,1.899]	1.611 [1.259,1.949]	1.398 [1.113,1.669]	1.472 [1.171,1.769]
MP–output gap, φ_y	0.018 [0.000,0.037]	0.023 [0.000,0.048]	0.054 [0.004,0.098]	0.070 [0.006,0.128]
MP–output gap change, $\varphi_{\Delta y}$	0.416 [0.334,0.493]	0.414 [0.321,0.499]	0.394 [0.297,0.495]	0.405 [0.305,0.500]
Wage markup shock persistence, ρ_w	0.686 [0.500,0.896]	0.684 [0.515,0.894]	0.843 [0.755,0.936]	0.818 [0.704,0.950]
Intertemporal shock persistence, ρ_b	0.922 [0.885,0.961]	0.716 [0.540,0.896]	0.833 [0.743,0.926]	0.629 [0.451,0.816]
Investment shock persistence, ρ_i	0.393 [0.260,0.522]	0.386 [0.265,0.509]	0.429 [0.281,0.571]	0.448 [0.302,0.594]
Price markup shock persistence, ρ_p	0.391 [0.081,0.640]	0.563 [0.332,0.816]	0.609 [0.433,0.799]	0.652 [0.501,0.813]
Government shock persistence, ρ_g	0.981 [0.968,0.994]	0.980 [0.967,0.993]	0.982 [0.971,0.993]	0.988 [0.981,0.997]

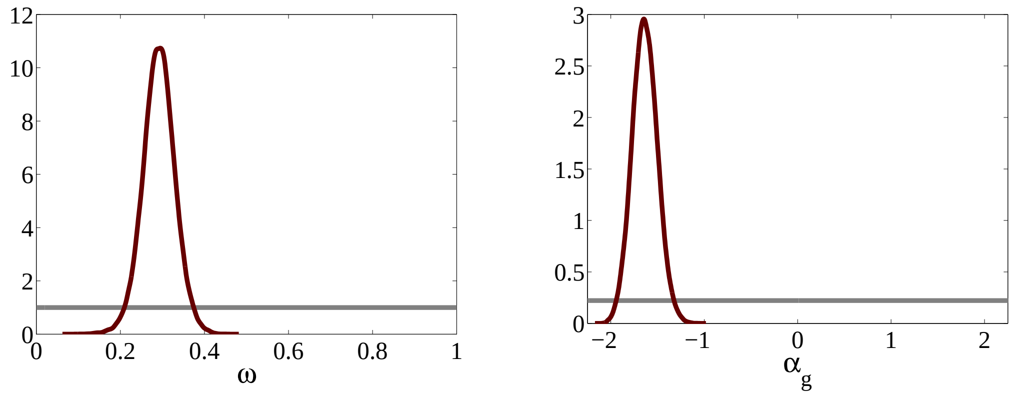
Table OA3. Posterior Estimates of Alternative DSGE models (cont'd)

	$\mathcal{M}_0$: Baseline	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
Wage markup shock volatility, σ_w	0.109 [0.071,0.146]	0.109 [0.074,0.143]	0.077 [0.059,0.094]	0.082 [0.060,0.103]
Intertemporal shock volatility σ_b	0.047 [0.036,0.057]	0.110 [0.063,0.156]	0.173 [0.086,0.259]	0.269 [0.152,0.383]
Investment shock volatility, σ_i	0.569 [0.472,0.663]	0.604 [0.503,0.705]	0.568 [0.460,0.672]	0.575 [0.474,0.681]
Price markup shock volatility, σ_p	0.140 [0.100,0.179]	0.114 [0.073,0.153]	0.102 [0.068,0.134]	0.094 [0.064,0.123]
Productivity shock volatility, σ_z	0.811 [0.720,0.903]	0.803 [0.711,0.890]	0.821 [0.727,0.910]	0.814 [0.721,0.904]
Government shock volatility, σ_g	0.849 [0.750,0.946]	0.855 [0.755,0.955]	0.871 [0.766,0.977]	0.851 [0.749,0.950]
Monetary policy shock volatility, σ_r	0.181 [0.150,0.209]	0.173 [0.144,0.199]	0.151 [0.128,0.173]	0.152 [0.129,0.174]
Measurement error volatility, σ_e	0.366 [0.326,0.408]	0.367 [0.326,0.407]	0.369 [0.328,0.411]	0.368 [0.327,0.409]

Note: This table reports the prior distribution, the mean and the 90 percent confidence interval (within square brackets) of the estimated posterior distribution of the structural parameters. Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function.

F. Prior and posterior distributions

Figure OA1. Prior and Posterior Distributions of Parameters ω and α_g



Note: The grey and red lines correspond to the prior and posterior distributions, respectively.

G. THE CONTRIBUTION OF GOVERNMENT SPENDING SHOCKS

Table OA4 reports this contribution to the variance of observables for the four model versions. As it is clear from this table, the contribution of the government spending shock to output volatility is small for the baseline and HtM model versions (less or equal to 5%), while it is around 13% for the GiU specification. The discrepancy is even larger when it comes to the volatility of hours worked: 7% for the HtM specification and 42% for the GiU version. Introducing government expenditures in the utility directly affects the marginal rate of substitution between consumption and hours worked and thus acts as a labor wedge. This government spending based labor wedge then impacts output in the short-run.

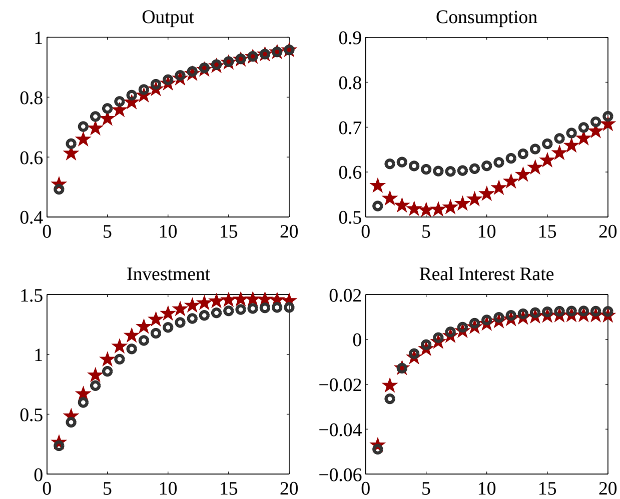
Table OA4. Contribution of the Government Spending Shock (in %)

Variable	Model			
	$\mathcal{M}_0$: Baseline	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
Output	3.72	4.84	13.24	12.57
Consumption	3.18	1.81	5.36	4.89
Investment	0.01	0.01	0.02	0.09
Government Spending	58.72	55.25	56.05	53.96
Hours Worked	5.83	7.38	42.04	49.89
Real Wages	0.00	0.00	0.00	0.02
Inflation	0.29	0.46	4.74	2.36
Interest Rate	0.79	1.37	10.56	6.65

Note: Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function.

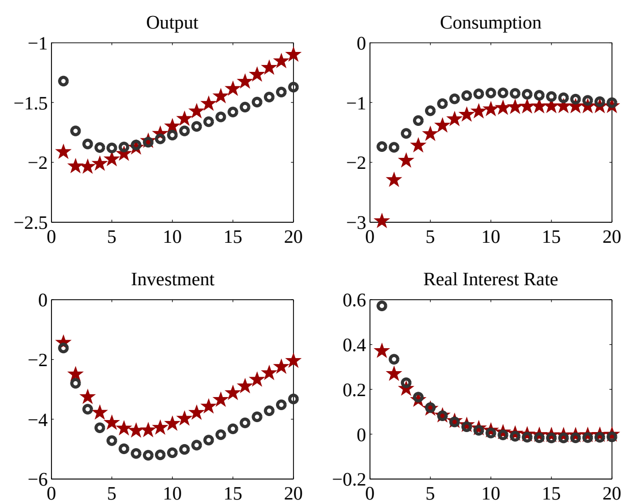
H. Impulse Response Functions (IRFs) associated with the DSGE models: Productivity and monetary policy shocks

Figure OA2. IRFs to a Productivity Shock



Note: The stars correspond to the responses associated with the model with both hand-to-mouth consumers and government spending in the utility (Full); The bullets correspond to the responses associated with the Smets-Wouters model (Baseline).

Figure OA3. IRFs to a Monetary Policy Shock



Note: The stars correspond to the responses associated with the model with both hand-to-mouth consumers and government spending in the utility (Full); The bullets correspond to the responses associated with the Smets-Wouters model (Baseline).

I. Robustness

I.1. The effects of data on estimation

One can legitimately wonder why the model with hand-to-mouth consumers differs so much from the model with Edgeworth complementarity at the estimation stage. The two propagation mechanisms can equally fit the data, as they both have the potential to yield a positive response of private consumption to a government spending shock (see Table 1 in the main text). As Guerron-Quintana (2010) has shown that the estimation of a structural model is sensitive to the set of observables, this section inspects the effect of data on the estimation of the share ω.

Table OA5. Value of ω Conditional on the Set of Observables

Observables	Calibration		
	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
Benchmark	0.284	0.324	0.333
$\{\Delta c_t, \Delta g_t\}$	0.311	0.466	0.462
$\{\Delta c_t, \Delta g_t, \Delta i_t\}$	0.367	0.481	0.469
$\{\Delta c_t, \Delta g_t, \Delta w_t\}$	0.267	0.409	0.414
$\{\Delta c_t, \Delta g_t, \Delta i_t, n_t\}$	0.324	0.398	0.412
$\{\Delta c_t, \Delta g_t, \Delta i_t, \Delta w_t\}$	0.216	0.321	0.269
$\{\Delta c_t, \Delta g_t, \Delta i_t, \Delta w_t, n_t\}$	0.280	0.342	0.325
$\{\Delta c_t, \Delta g_t, \Delta i_t, \Delta w_t, n_{t,} \pi_t\}$	0.288	0.351	0.326
$\{\Delta c_t, \Delta g_t, \Delta i_t, \Delta w_t, n_{t,} R_t\}$	0.278	0.318	0.327

Note: This table reports the mode estimates of ω under three sets of calibration (HtM, GiU and Full). Benchmark refers to the case where the eight observables are used for estimation. HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function. In all calibrations, $\alpha_g = 0$.

We consider the following experiment. We calibrate the DSGE model according to the posterior estimates in the HtM, GiU and Full model versions, respectively. For the GiU and Full models, we set $\alpha_g = 0$, *i.e.* we eliminate the propagation mechanism related to Edgeworth complementarity. In other words, the HtM, GiU and Full versions only reflect a particular calibration of the remaining models' parameters. These three calibrations are considered as simple robustness check. Given a calibration, we only estimate the share of hand-to-mouth consumers for several sets of observables. We start with the smallest relevant set and progressively add observables. The results are reported in Table OA5. For comparison purpose, the table includes our benchmark results (*i.e.* with eight observables). When we consider private consumption and government spending, including or not investment, we obtain a larger estimated value of ω (whatever the calibration) compared to the benchmark estimates. The share ω is now close to 0.5 and the HtM model version can yield more likely an output multiplier larger than one. When we progressively extend the set of observables, the estimated value is reduced, especially if we include real wages, hours worked, inflation or the nominal interest rate.

Table OA6. Robustness Analysis: Posterior Estimates

Parameter	Model			
	$\mathcal{M}_0$: Baseline	$\mathcal{M}_1$: HtM	$\mathcal{M}_2$: GiU	$\mathcal{M}_3$: Full
Panel (a). Sub–Samples (1980Q1–1993Q4 / 1994Q1–2007Q4)				
ω	–	0.229 / 0.363 (0.065) (0.055)	–	0.073 / 0.149 (0.067) (0.086)
α_g	–	–	–1.400 / –1.905 (0.176) (0.143)	–1.309 / –1.797 (0.203) (0.178)
$\mathcal{L}$	–371.622 / –267.216	–370.044 / –257.613	–358.033 / –240.971	–359.767 / –241.439
Panel (b). News Shocks				
ω	–	0.300 (0.041)	–	0.143 (0.037)
α_g	–	–	–1.612 (0.140)	–1.491 (0.146)
$\mathcal{L}$	–642.769	–634.149	–614.159	–611.817
Panel (c). Stationary Productivity Shock				
ω	–	0.414 (0.047)	–	0.217 (0.039)
α_g	–	–	–1.476 (0.154)	–1.150 (0.194)
$\mathcal{L}$	–643.646	–632.979	–627.757	–622.546
Panel (d). Non Separable Utility				
ω	–	0.228 (0.033)	–	0.130 (0.032)
α_g	–	–	–1.349 (0.152)	–1.210 (0.148)
$\mathcal{L}$	–632.890	–628.257	–610.877	–609.971

Note: This table reports the mode and the standard error (within parentheses) of HtM share ω and Edgeworth complementarity α_g. $\mathcal{L}$ denotes the marginal likelihood. Baseline: Smets-Wouters type model; HtM: model with hand-to-mouth consumers; GiU: model with government spending in the utility function; Full: model with both hand-to-mouth consumers and government spending in the utility function.

I.2. Alternative specifications

In this section, we investigate the robustness of our findings to a number of perturbations: Sub-samples, news shocks in government spending, an alternative specification of technology shocks and non-separability between consumption and leisure in the utility function. All the results are reported in Table OA6. For all experiments, we use the same prior distributions for the parameters (see Table OA1), except special comments. To save space, we only report the parameter values for ω and α_g and the marginal likelihood.

We first investigate whether our results still hold if we re-estimate the four model versions over different sub-samples. In the period between the mid-1990s and 2007, European countries enjoyed one of the greatest economic growth periods, known as the Great Moderation due to the low volatility of growth rates in those years. The mid-1990s also corresponds to the progressive realisation of Economic and Monetary Union. It seems then natural to split the overall sample in the following two parts: 1980Q1-1993Q4 and 1994Q1-2007Q4 (see Avouyi-Dovi and

Sahuc, 2016). The results are reported in Panel (a) of Table OA6. All our previous findings are robust to this sub-sample analysis: The GiU model version outperforms the HtM one, the HtM specification adds very little to both the baseline model and the GiU model versions, the share of hand-to-mouth consumers decreases when this specification is considered together with Edgeworth complementarity.

Second, as emphasised by Ramey (2011b) and Schmitt-Grohé and Uribe (2012), the expected component in public expenditures constitutes an important element of government policy. We accordingly modify our benchmark specification to allow for news shocks in the government spending rule. The stationary component of government spending still follows an AR(1) but the innovation $\zeta_{g,t}$ rewrites

$$\zeta_{g,t}^{(0)} + \zeta_{g,t-4}^{(4)} + \zeta_{g,t-8}^{(8)},$$

where $\zeta_{g,t}^{(0)}$, $\zeta_{g,t-4}^{(4)}$, and $\zeta_{g,t-8}^{(8)}$ are three independent random variables that follow a normal distribution with zero mean and variance equals to $\sigma_{g,0}^2, \sigma_{g,4}^2$ and $\sigma_{g,8}^2$, respectively. All variances have the same prior distribution, *i.e.* an inverse gamma $\mathcal{IG}[1.00,2.00]$. We obtain that government spending shocks explain around 20% of output variance, among which the expected components represent more than 30%. The estimation results are reported in Panel (b) of Table OA6. As in the previous case, none of our main results are modified.

Third, we consider a stationary version for the productivity shocks. Indeed, one can argue that the presence of a random walk (with a positive drift) specification could affect our results as it implies that government spending growth is affected by technology shocks.[28] We relax this assumption and specify a stationary AR(1) process for the logarithm of total factor productivity (in deviation from a linear trend). Government expenditures are now only explained by their own shocks. We use the same prior as before for the autoregressive parameter and the variance of innovation. The results are reported in Panel (c) of Table OA6. We obtain a larger share of the hand-to-mouth consumers (with an output multiplier around 1), but this model version is still outperformed by the GiU specification (with an output multiplier around 1.80). Even if we obtain different numbers, we reach the same conclusions about the HtM and GiU specifications.

Finally, to lower the negative wealth effect of government spending shocks when agents are forward-looking, we introduce non-separability between consumption and leisure in the utility function as in Smets and Wouters (2007),

$$\mathrm{E}_t \sum_{s=0}^{\infty} \beta^s \varepsilon_{b,t} \left[\frac{\left(C_{t+s}^* - hC_{t+s-1}^*\right)^{1-\psi}}{1-\psi} \exp\left(\frac{N_{j,t+s}^{1+\nu}}{1+\nu}\right) + \mathcal{V}\left(G_{t+s}\right) \right].$$

where ψ is the elasticity of intertemporal substitution of consumption (for constant labor).

Indeed, with non-separable preferences, an increase in hours worked has a positive effect on the marginal utility of consumption. The reason for this is that consumption and hours are complements in the utility function. Hence, unless monetary policy is very aggressive in increasing interest rates, the complementarity will work to drive up consumption with the increase in hours worked through the Euler equation. When the wealth effect on labor supply is reduced, there is no need for such a large share of HtM consumers or a large degree of Edgeworth complementarity (Panel (d) of Table OA6). For an elasticity of intertemporal substitution estimated around 1.60-1.80, we observe that ω and α_g are reduced by more than 20%. However, this alteration has no effect on the models comparison.

[28] We obtain that more than 40% of the volatility of government spending growth is explained by the permanent technology shock in the short run.

J. DSGE-VAR METHODOLOGY

To setup the DSGE-VAR(λ, p), we follow Del Negro and Schorfheide (2004). The VAR representation of the $n \times 1$ vector of endogenous variables $\mathbf{x}_t$ can be written as

$$\mathbf{x}_t = \Phi_0 + \sum_{i=1}^{p} \Phi_i \mathbf{x}_{t-i} + \varepsilon_t,$$

with $t = 1, ..., T$ and $\varepsilon_t \sim N(0, \Sigma_\varepsilon)$. Let $\mathbf{X}$ be a $T \times n$ matrix with rows given by $\mathbf{x}_t'$, $\mathbf{S}$ be the $T \times (np+1)$ matrix with rows $[1, \mathbf{x}_{t-1}', ..., \mathbf{x}_{t-p}']'$, $\Phi = [\Phi_0, \Phi_1, ..., \Phi_p]'$, and $\boldsymbol{\varepsilon}$ be a $T \times n$ matrix with rows ε_t'. The VAR model can then be written as $\mathbf{X} = \mathbf{S}\Phi + \boldsymbol{\varepsilon}$, with likelihood function

$$\mathcal{L}(\mathbf{X}|\Phi, \Sigma_\varepsilon) \propto |\Sigma_\varepsilon|^{-T/2} \exp\left\{-\frac{1}{2} tr\left[\Sigma_\varepsilon^{-1} (X - \mathbf{S}\Phi)' (X - \mathbf{S}\Phi)\right]\right\}, \qquad (10)$$

where $tr[.]$ denotes the trace of a matrix.

In the DSGE-VAR approach, the T actual observations are supposed to be augmented with $T^* = \lambda T$ artificial observations $(\mathbf{X}^*(\boldsymbol{\theta}), \mathbf{S}^*(\boldsymbol{\theta}))$ generated from the DSGE model based on the parameter vector $\boldsymbol{\theta}$. The likelihood of this artificial sample is

$$\mathcal{L}(\mathbf{X}^*(\boldsymbol{\theta})|\Phi, \Sigma_\varepsilon) \propto |\Sigma_\varepsilon|^{-\lambda T/2} \exp\left\{-\frac{1}{2} tr\left[\Sigma_\varepsilon^{-1}\left[\Sigma_\varepsilon^{-1} (X^* - \mathbf{S}^*\Phi)' (X^* - \mathbf{S}^*\Phi)\right]\right]\right\}. \qquad (11)$$

The joint likelihood of the samples of actual and artificial data is then

$$\mathcal{L}(\mathbf{X}^*(\boldsymbol{\theta}), \mathbf{X}|\Phi, \Sigma_\varepsilon) \propto \mathcal{L}(\mathbf{X}|\Phi, \Sigma_\varepsilon)\, \mathcal{L}(\mathbf{X}^*(\boldsymbol{\theta})|\Phi, \Sigma_\varepsilon)$$

The usual Bayesian approach is to specify a prior and update it with the likelihood of the data, using Bayes's rule to obtain the posterior (see An and Schorfheide, 2007, for an overview). It means that $\mathcal{L}(\mathbf{X}^*(\boldsymbol{\theta})|\Phi, \Sigma_\varepsilon)$ can be viewed as representing $p(\Phi, \Sigma_\varepsilon|\boldsymbol{\theta}, \lambda)$, *i.e.* a prior for Φ and Σ_ε. Rather than literally simulating the artificial data, the expected (scaled) population moments of the DSGE conditional on $\boldsymbol{\theta}$ are used instead of moments from simulated data, in order to avoid sampling variation. Let $\Gamma_{xx}^*(\boldsymbol{\theta}) = \mathrm{E}_{\boldsymbol{\theta}}(\mathbf{x}_t\mathbf{x}_t')/\lambda T$, $\Gamma_{xs}^*(\boldsymbol{\theta}) = \mathrm{E}_{\boldsymbol{\theta}}(\mathbf{x}_t\mathbf{s}_t')/\lambda T$, $\Gamma_{sx}^*(\boldsymbol{\theta}) = \mathrm{E}_{\boldsymbol{\theta}}(\mathbf{s}_t\mathbf{x}_t')/\lambda T$ and $\Gamma_{ss}^*(\boldsymbol{\theta}) = \mathrm{E}_{\boldsymbol{\theta}}(\mathbf{s}_t\mathbf{s}_t')/\lambda T$. If $\Gamma_{xx}^*(\boldsymbol{\theta})$ is invertible, then

$$\Phi^*(\boldsymbol{\theta}) = (\Gamma_{ss}^*(\boldsymbol{\theta}))^{-1}\Gamma_{sx}^*(\boldsymbol{\theta}),$$
$$\Sigma_\varepsilon^*(\boldsymbol{\theta}) = \Gamma_{xx}^*(\boldsymbol{\theta}) - \Gamma_{xs}^*(\boldsymbol{\theta})(\Gamma_{ss}^*(\boldsymbol{\theta}))^{-1}\Gamma_{sx}^{*\prime}(\boldsymbol{\theta}).$$

The matrices $\Phi^*(\boldsymbol{\theta})$ and $\Sigma_\varepsilon^*(\boldsymbol{\theta})$ are restriction functions that will be used to center the prior distribution of $(\Phi, \Sigma_\varepsilon)$ conditional on $\boldsymbol{\theta}$ and a hyperparameter $\lambda \geq 0$ that measures the deviation of the DSGE-VAR from the VAR approximation of the DSGE model. The joint prior distribution of the VAR and DSGE model parameters is formed hierarchically. One forms a prior for the DSGE model, and then conditional on that prior one forms a prior view for the VAR parameters, *i.e.*

$$p(\Phi, \Sigma_\varepsilon, \boldsymbol{\theta}|\lambda) = p(\Phi, \Sigma_\varepsilon|\boldsymbol{\theta}, \lambda)\, p(\boldsymbol{\theta}),$$

and the prior distribution of the VAR parameters is of the $\mathcal{I}$nverted-$\mathcal{W}$ishart–$\mathcal{N}$ormal form

$$\Sigma_\varepsilon|\boldsymbol{\theta}, \lambda \sim \mathcal{IW}(\lambda T\Sigma_\varepsilon^*(\boldsymbol{\theta}), \lambda T - (np+1), n),$$
$$\Phi|\Sigma_\varepsilon, \boldsymbol{\theta}, \lambda \sim \mathcal{N}\left(\Phi^*(\boldsymbol{\theta}), \Sigma_\varepsilon \otimes (\lambda T\Gamma_{ss}^*(\boldsymbol{\theta}))^{-1}\right).$$

The posterior density of the VAR parameters conditional on $(\boldsymbol{\theta}, \lambda)$ is proportional to the product of the prior density and the likelihood function for the VAR model, denoted $\mathcal{L}(\mathbf{X}_T|\Phi, \Sigma_\varepsilon, \boldsymbol{\theta}, \lambda)$. The DSGE-VAR prior and likelihood are conjugate and hence, it follows that the posterior distribution of Φ and Σ_ε is also of the $\mathcal{I}$nverted-$\mathcal{W}$ishart–$\mathcal{N}$ormal form. The joint posterior density of the DSGE and VAR model parameters can be factorised as

$$p(\Phi, \Sigma_\varepsilon, \boldsymbol{\theta}|\mathbf{X}_T, \lambda) = p(\Phi, \Sigma_\varepsilon|\mathbf{X}_T, \boldsymbol{\theta}, \lambda)\, p(\boldsymbol{\theta}|\mathbf{X}_T, \lambda),$$

where $\mathbf{X}_T \equiv \{\mathbf{x}_t\}_{t=1}^T$ denotes the sample of observable data, $p(\Phi, \Sigma_\varepsilon | \mathbf{X}_T, \boldsymbol{\theta}, \lambda)$ is given by the product of the conditional posterior densities for $\Phi | \Sigma_\varepsilon$ and $\Sigma_\varepsilon | \boldsymbol{\theta}$, and $p(\boldsymbol{\theta} | \mathbf{X}_T, \lambda)$, the posterior distribution of $\boldsymbol{\theta}$ for a given λ, is given by

$$p(\boldsymbol{\theta} | \mathbf{X}_T, \lambda) \propto \mathcal{L}(\mathbf{X}_T | \boldsymbol{\theta}, \lambda)\, p(\boldsymbol{\theta}),$$

where $\mathcal{L}(\mathbf{X}_T | \boldsymbol{\theta}, \lambda) = [\mathcal{L}(\mathbf{X}_T | \Phi, \Sigma_\varepsilon, \boldsymbol{\theta}, \lambda)\, p(\Phi, \Sigma_\varepsilon | \boldsymbol{\theta}, \lambda)] / p(\Phi, \Sigma_\varepsilon | \mathbf{X}_T, \boldsymbol{\theta}, \lambda)$. This posterior distribution is evaluated numerically using the Metropolis-Hastings algorithm with 1,000,000 draws. Once a posterior sample of $\boldsymbol{\theta}$ has been simulated from the DSGE-VAR(λ, p) model, one can compute the marginal likelihood which is defined as

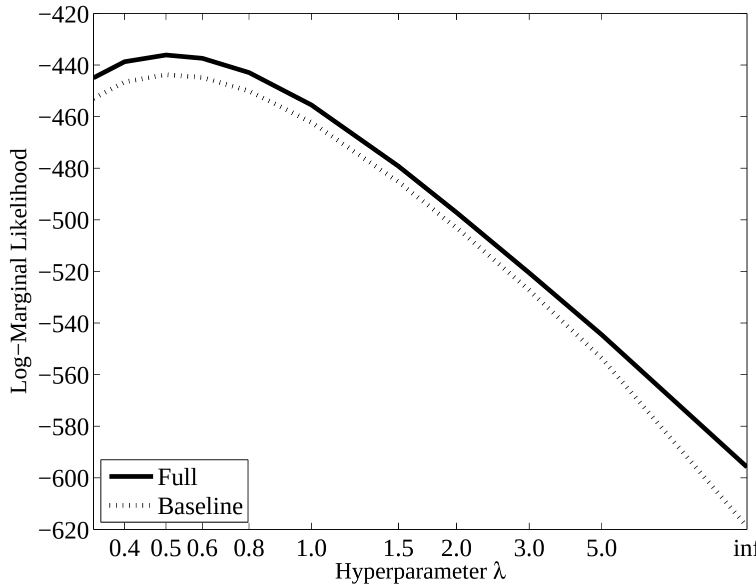
$$\mathcal{L}(\mathbf{X}_T | \lambda) = \int_{\boldsymbol{\theta}} \mathcal{L}(\mathbf{X}_T | \boldsymbol{\theta}, \lambda)\, p(\boldsymbol{\theta})\, \mathrm{d}\boldsymbol{\theta},$$

and select the hyperparameter λ such as

$$\hat{\lambda} = \underset{\lambda \in [(n(p+1)+1)/T, \infty)}{\arg\max} \mathcal{L}(\mathbf{X}_T | \lambda).$$

K. Log-marginal likelihood for alternative specifications of the DSGE-VAR model

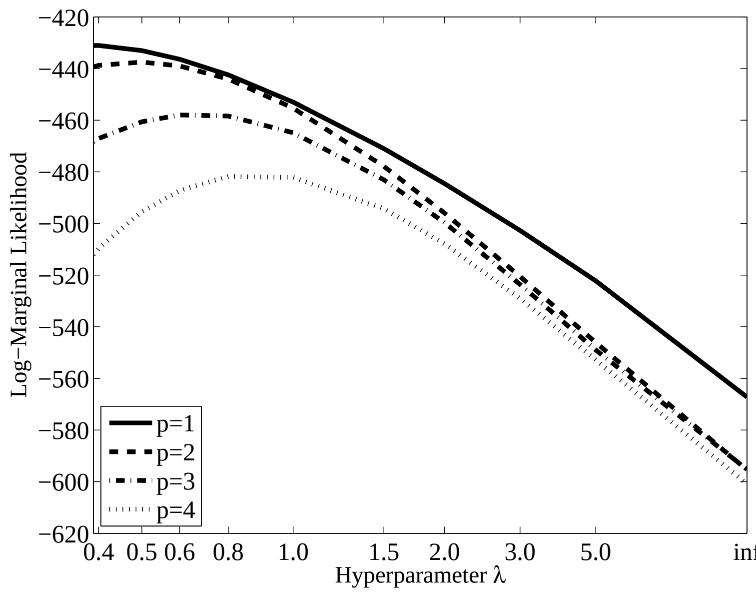
Figure OA4. Log-Marginal Likelihood for Alternative Specifications of the DSGE-VAR(λ, 2) Model



Note: The plain line corresponds to the log-marginal likelihood associated with a DSGE-VAR(λ, 2) model based on a specification with both hand-to-mouth consumers and government spending in the utility; The dashed line corresponds to the log-marginal likelihood associated with a DSGE-VAR(λ, 2) based on the baseline DSGE resctrictions.

L. Log-marginal likelihood of the DSGE-VAR model for different lag orders

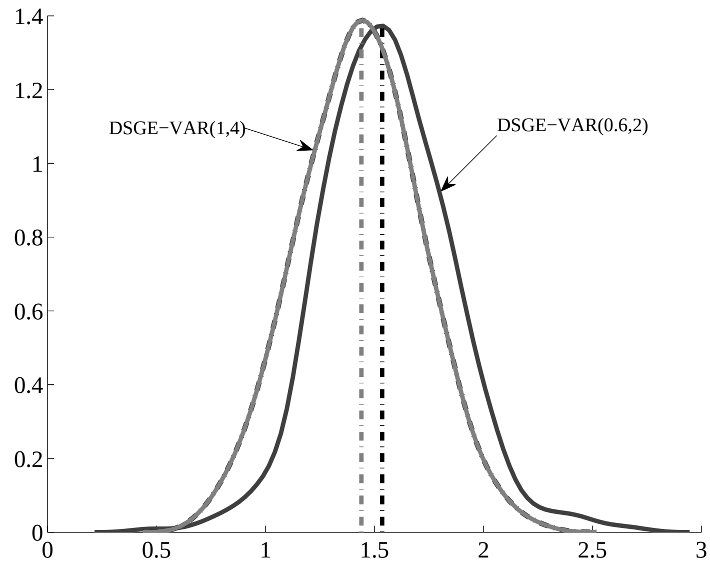
Figure OA5. Log-Marginal Likelihood of the DSGE-VAR(λ, p) Model for Different Lag Orders



Note: The DSGE-VAR(λ, p) model is based on the specification with both hand-to-mouth consumers and government spending in the utility function.

M. Empirical distribution of the DSGE-VAR output multiplier

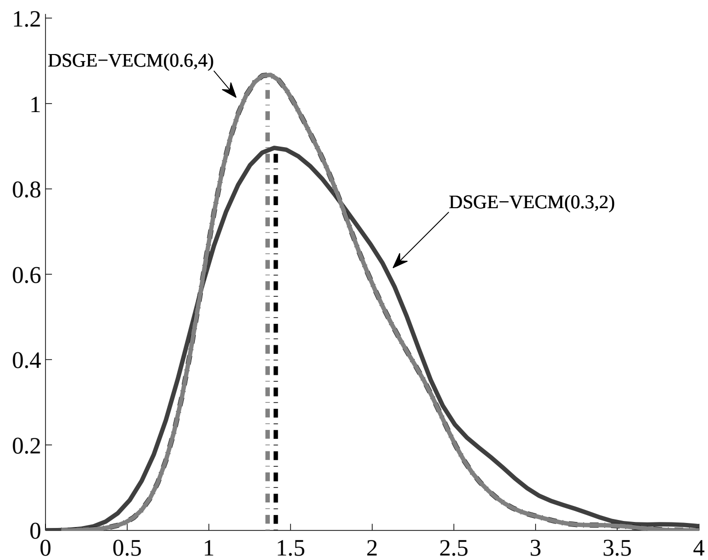
Figure OA6. Empirical Distribution of the DSGE-VAR(λ, p) Output Multiplier



Note: The DSGE-VAR model is based on the specification with both hand-to-mouth consumers and government spending in the utility function.

N. Empirical distribution of the DSGE-VECM output multiplier

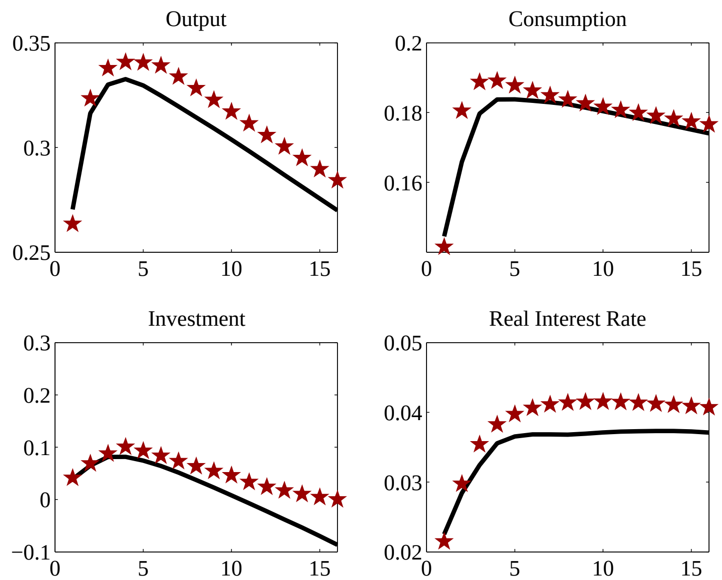
Figure OA7. Empirical Distribution of the DSGE-VECM(λ, p) Output Multiplier



Note: The DSGE-VECM model is based on the specification with both hand-to-mouth consumers and government spending in the utility function.

O. Invertibility assessment

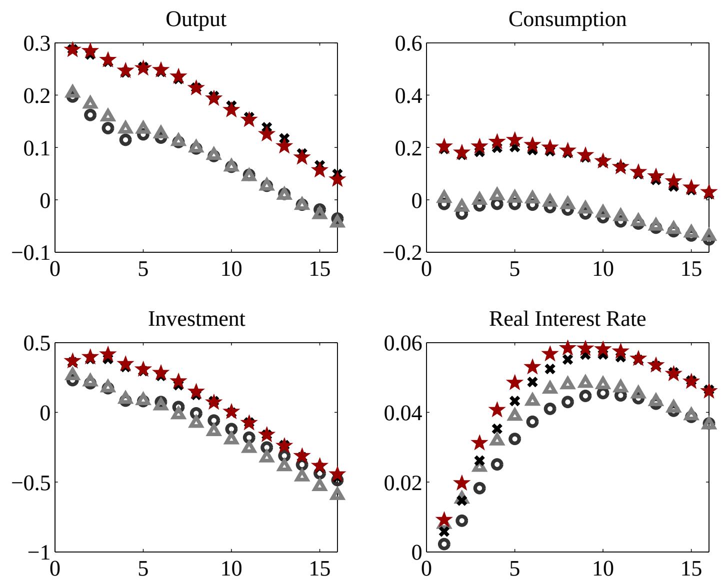
Figure OA8. Impulse Response Functions to a Government Spending Shock Associated with the DSGE-VAR(∞,2) and DSGE Models



Note: The DSGE-VAR(∞,2) model (plain line) and the DSGE model (stars) are based on the specification with both hand-to-mouth consumers and government spending in the utility function.

P. Impulse Response Functions (IRFs) associated with alternative DSGE-VAR(λ,2) specifications

Figure OA9. IRFs to a Government Spending Shock



Note: Circle: DSGE-VAR model with the Smets-Wouters specification (Baseline); Triangle: DSGE-VAR model with hand-to-mouth consumers (HtM); x-mark: DSGE-VAR model with government spending in the utility function (GiU); Pentagram: DSGE-VAR model with both hand-to-mouth consumers and government spending in the utility function (Full).