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Aggregate Tax and Spending Multipliers in a Monetary Union*

Gökhan Ider† Malte Rieth‡

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Abstract

We examine the aggregate effects of government spending and tax changes in a monetary union. We show theoretically that government consumption and government investment shocks have multipliers above 1, and consumption tax and income tax shocks have multipliers below 1. We test the predictions on quarterly euro area data, identifying the four fiscal shocks in a panel structural vector autoregression through time fixed effects and cross-country heteroskedasticity. Both spending shocks have multipliers above 1, and both tax shocks have multipliers below 1. The analysis suggests that spending policy stabilizes output more efficiently than tax policy in a monetary union.

Keywords: Fiscal policy, general equilibrium model, structural vector autoregressions, government spending, taxes, panel data, euro area.

JEL-Codes: C32, E32, E62, F45, H20, H50.

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1 Introduction

Fiscal multipliers measure the efficiency of fiscal interventions, specifically by how much output rises if the government increases spending or lowers taxes by one euro. The measurement is difficult because spending and tax changes are often a response to macroeconomic conditions, occur simultaneously, and trigger a change in monetary policy. To address these challenges, one leading empirical approach uses macroeconomic data in time-series models and identifies exogenous changes in fiscal policy through institutional knowledge or narrative instruments (Blanchard and Perotti, 2002; Ramey, 2011; Barro and Redlick, 2011; Romer and Romer, 2010). The approach gives direct estimates of aggregate tax and spending multipliers at the national level, which take into account general equilibrium effects and are usually the main interest of policy makers.

However, many macroeconomic time-series are short, instrumental variables are potentially weak, and other factors may co-move with the identified fiscal changes. Therefore, a second leading approach uses geographic cross-sectional variation in fiscal policy for identification (Nakamura and Steinsson, 2014; Chodorow-Reich, 2019; Pennings, 2021). The panel setting increases the number of observations, simplifies the search for credible instruments, and allows controlling for time-varying confounders through time fixed effects. Yet, this approach delivers regional multipliers, that is, the response of output in one region relative to others following the fiscal intervention, not the aggregate multipliers of policy interest as the general equilibrium effects are netted out.[1]

In this paper, we propose an empirical framework for measuring aggregate fiscal multipliers that combines the two approaches. We exploit the specific institutional arrangement of the euro area, where fiscal policy is determined at the country level and monetary policy at the union level. We setup a panel structural vector autoregressive model for quarterly macroeconomic data of twelve euro area countries. We identify country-specific tax and spending shocks through time fixed effects and cross-country heteroskedasticity. The framework maintains the strengths of the other two approaches, while addressing some of their limitations. It increases the number of observations, it exploits cross-sectional variation in

[1]To map regional to aggregate multipliers, researchers use theoretical models (Nakamura and Steinsson, 2014; Farhi and Werning, 2016; Chodorow-Reich, 2019). The mapping involves three steps that account for the higher openness of regions than countries, federal policy not responding to regional shocks, and outside financing. The quantitative importance of each step and, thus, the size of the aggregate multiplier remain empirical questions.

fiscal policy for identification, and it nets out common factors. Yet, it delivers estimates of aggregate tax and spending multipliers at the national level.

To guide the empirical analysis, we setup a New Keynesian model of a small open economy pertaining to a currency union. The model builds on Leeper et al. (2017). It contains a standard set of real rigidities and nominal frictions as well as a detailed fiscal sector. It includes shocks to government investment, government consumption, consumption taxes, and income taxes. To provide a plausible description of the domestic shock transmission, it features rule-of-thumb consumers, long-term public debt, government consumption in utility, productive public capital, and fiscal feedback rules. Furthermore, it allows for international trade in consumption-investment goods and riskless nominal bonds to describe the external shock transmission. It is calibrated to the average euro area country. It predicts that both spending multipliers are in the range 1 to 1.5 and that both tax multipliers are in the range 0 to 0.5 in absolute value. Key for these predictions are the presence of frictions and the absence of a monetary response to domestic inflation or output.[2]

To test the predictions, we setup a panel structural vector autoregressive model for quarterly euro area data. We differentiate between public consumption and public investment on the spending side, and between consumption taxes and income taxes on the revenue side. We identify shocks to all four fiscal instruments. Identification rests on two pillars. First, we include time fixed effects to control for common business cycle drivers of euro area countries, including monetary policy. Second, we exploit cross-sectional heteroskedasticity in the remaining country-specific fiscal innovations. Specifically, we form two groups of countries, one with low volatility and one with high volatility. We test for differences in the volatility and reject the null hypothesis that the shock volatility is the same across groups.[3]

We use the significant differences in volatility as 'probabilistic instruments' (Rigobon, 2003) for structural fiscal shocks to trace their dynamic effects on output. The underlying assumption is that the contemporaneous impacts of the shocks are equal across groups. It is the same assumption as in the geographic cross-sectional approach with regional data but

[2]Otherwise the model predicts the standard outcome in real business cycle models that spending multipliers are small and tax multipliers potentially large.

[3]Identification through heteroskedasticity has been pioneered by Rigobon (2003). It is mostly used in time-series analysis, exploiting changes in volatility over time (Rigobon and Sack, 2003; Lewis, 2021; Brunnermeier et al., 2021). The time-series approach is limitedly successful if the sampling period is short, as for the euro area, or the sampling frequency is low, as with fiscal data. Therefore, we follow the few exceptions that use cross-country heteroskedasticity (Lee et al., 2004; Rigobon and Rodrik, 2005).

unmodeled heteroskedasticity. Whether it is more or less restrictive with national data is an open question. In concreto, we assume that the contemporaneous output effect of, say, a government investment shock in Austria (low-volatility group) is the same as in Finland (high-volatility group). We perform an extensive sensitivity analysis and document that the pooling assumption is consistent with the data. We use alternative groupings, leave countries out, or estimate country-specific dynamics.

The identification approach has further appealing features. It does not rely on exclusion restrictions or outside information on tax elasticities. Exclusion restrictions can bias multiplier estimates (Caldara and Kamps, 2017) and are difficult to justify with two types of public spending in the model. Similarly, estimated tax elasticities are prone to endogeneity bias (Mertens and Ravn, 2014). Moreover, the approach gives full point-identification. It identifies four types of fiscal shocks and four corresponding multipliers in one single model. This facilitates a direct comparison of the efficacy and efficiency of the fiscal tools.

We find that government consumption and government investment shocks have large and persistent output effects. The peak cumulative multipliers are both around 1.3 and the upswings last for several years. Public investment shocks have more persistent effects than public consumption shocks. On the revenue side, tax cuts have expansionary effects, too, but these are smaller than for spending increases and less persistent. The income tax multiplier peaks at 0.4 within the first year, and output is back at trend after two years. The consumption tax multiplier is 0.3 upon impact, but the effect is gone after three quarters. These findings are robust to many sensitivity tests.[4]

To understand the transmission mechanisms, we project macroeconomic variables on the identified shocks. Spending shocks induce broad-based and persistent expansions, characterized by a crowding-in of private demand, higher employment and wages, rising inflation, an appreciating real exchange rate, and a declining trade balance. We find strong complementarities between public and private consumption on the one hand, and public and private investment on the other hand. In contrast, tax cuts have limited effects on prices and private activity. While inflation tends to fall and the real exchange rate to depreciate, the trade balance increases little and private domestic demand hardly reacts. The policy

[4]We exclude countries from the panel one by one, control for interst rates, account for possible fiscal foresight, use different definitions of taxes, vary the specification of volatility groups, include linear or quadratic trends, and test for alternative lag lengths.

rate does not respond to any of the shocks, while public deficits widen in all four cases.

Taken together, the results suggest that spending policy is more efficient at stabilizing output than tax policy in open economies where the central bank does not respond to domestic inflation or output. Specifically, the theoretical and empirical analyses consistently yield open-economy, no-monetary-policy-response, deficit-financed multipliers in the range 1 to 1.5 for public consumption and public investment and in the range 0 to 0.5 for consumption taxes and income taxes.

Apart from the general insights, the analysis informs about specific policy questions. What are the effects of fiscal shocks in the euro area? The currency union accounts for 15% of global GDP and has 350 million inhabitants, yet the empirical literature addressing the question is sparse and contradictory.[5] In early contributions using country-level panel data, Canova and Pappa (2007) identify multipliers of 0.8 and 0.6 for general spending and total revenues, respectively, with sign restrictions in quarterly data until 2003, while Beetsma and Giuliodori (2011) obtain a general spending multiplier of 1.5 with recursive identification in annual data until 2004. Using more recent regional data and the cross-sectional approach, Gabriel et al. (2023) estimate a local spending multiplier of 2.2.[6] We provide new estimates of aggregate multipliers in the euro area, finding spending multipliers in the middle of the range of previous estimates and tax multipliers at the lower end.

What are the effects of fiscal shocks in countries with limited exchange rate flexibility? As the member states of the euro fixed their exchange rate, our results inform about fiscal policy effects in countries with limited exchange rate flexibility. Globally, these regimes are the rule rather than the exception (Ilzetzki et al., 2019) but the evidence on the implications of the exchange rate regime for fiscal multipliers is limited and mixed. Ilzetzki et al. (2013) estimate a general spending multiplier of 1.4 in countries with predetermined exchange rates using recursive identification in quarterly panel data. Similarly, Sheremirov and Spirovska (2022) find a general spending multiplier of 1.5 under pegs using an instrumental variable strategy in annual panel data. In contrast, Corsetti et al. (2012) obtain a general spending multiplier of 0.6 under fixed exchange rates using recursive identification in annual panel data. We complement the evidence by documenting that both spending components have

[5] The euro area's share of global GDP is computed using the latest available World Bank data for GDP in constant U.S. dollars, for 2024.

[6] Coelho (2019) and Canova and Pappa (2025) use the geographic cross-sectional approach with annual data to estimate the regional output effects of specific EU structural and cohesion funds.

multipliers above 1, while both tax rates have multipliers below 0.5 in absolute value.

Relatedly, what are the effects of fiscal shocks when monetary policy does not respond? Central banks were constrained by a lower bound on interest rates in many advanced economies during much of the twenty-first century. Then, fiscal policy is the main stabilization tool, and New Keynesian models predict that government spending multipliers are large (Christiano et al., 2011; Bouakez et al., 2020) and tax cuts contractionary (Eggertsson, 2011). Testing the predictions is difficult because of small samples with unresponsive monetary policy. To overcome the problem, Ramey and Zubairy (2018) collect historical data for the US and estimate a general spending multiplier of 1.5 when monetary policy is fixed. Cloyne et al. (2025) collect historical data for the UK and find that tax cuts are still expansionary in such situations. The articles each rely on about 100 fixed-policy rate observations. We confirm their results based on 1200 such observations, and we complement them with a nuanced picture of the effects of different tax and spending instruments.

Finally, what are the specific effects of these different instruments? Fiscal stimulus packages typically include a variety of measures but most of the macroeconomic literature focuses on general government spending and total taxes (Blanchard and Perotti, 2002; Mountford and Uhlig, 2009; Barro and Redlick, 2011; Lewis, 2021). Only a few studies disaggregate fiscal instruments and the findings are partially contradictory. On the spending side and using recursive identification, Auerbach and Gorodnichenko (2012) and Ilzetzki et al. (2013) find that investment and consumption multipliers are similar and both above 1, whereas Boehm (2020) estimates multipliers of 0 and 1, respectively. On the revenue side and using instrumental variables, Mertens and Ravn (2013) differentiate between personal and corporate income taxes in the US, and Nguyen et al. (2021) between income and consumption taxes in the UK. Both studies find income tax multipliers above 2. Our estimates suggest that in the euro area the multipliers for government consumption and investment are both above 1 and for consumption taxes and income taxes below 0.5.

2 Theoretical analysis

In this section, we build a quantitative DSGE model to predict the sign and size of tax and spending multipliers in the euro area. The model builds on Leeper et al. (2017). It is a monetary small open economy at its cashless limit with real rigidities, nominal frictions, and a fixed exchange rate. The economy represents the typical country in the European Monetary Union. We allow for international trade in consumption-investment goods and riskless nominal bonds. We include four fiscal shocks: government investment, government consumption, consumption taxes, and income taxes. We describe the transmission of the shocks by including features that capture key channels shaping fiscal multipliers: rule-of-thumb consumers to capture a high average marginal propensity to consume, long-term public debt, government consumption in the utility function, productive public capital, steady-state distortionary taxes, and fiscal feedback rules. We close the model through a debt-elastic interest rate.

2.1 The model

The domestic economy consists of firms, households, and a public sector. It is small compared to the rest of the union. Home and foreign variables are indexed by H and F, respectively. We outline the model in the following. Details are in Appendix B.

2.1.1 Firms

The domestic production sector consists of intermediate, home composite, and final goods firms. Final goods are produced by a set of perfectly competitive firms that demand home composite goods, $x_{H,t}$, and foreign goods, $x_{F,t}$, which are combined with the CES technology $y_t = [(1-\vartheta)^{1/\gamma} x_{H,t}^{(\gamma-1)/\gamma} + \vartheta^{1/\gamma} x_{F,t}^{(\gamma-1)/\gamma}]^{\gamma/(\gamma-1)}$, with import share $\vartheta \in [0,1]$ and elasticity of substitution $\gamma > 0$.[7] Profit maximization yields demand functions for $x_{H,t}$ and $x_{F,t}$ as well as an expression for the aggregate price index P_t.

The home composite good $y_{H,t}$ is assembled by a different set of perfectly competitive firms that demand intermediate goods in quantities $x^i_{H,t}$, with $i \in [0,1]$, through the CES technology $y_{H,t} = [\int_0^1 (x^i_{H,t})^{(\epsilon-1)/\epsilon} di]^{\epsilon/(\epsilon-1)}$, where $\epsilon > 1$ denotes the elasticity of substitution. Profit maximization yields input demand for all $x^i_{H,t}$ and an expression for the price index of home composite goods $P_{H,t}$.

Intermediate goods production is conducted by a continuum of monopolistically com-

[7] In what follows, demanded and supplied quantities are denoted by the letters x and y, respectively. Nominal variables are typically capitalized and steady state values without time subscript.

petitive firms. Each firm i uses the technology

$$y_{H,t}^i = k_{it}^\alpha (n_{it}^d)^{1-\alpha}(k_t^G)^\zeta - \bar{o}, \qquad \alpha \in (0,1), \tag{1}$$

where n_{it}^d and k_{it} is the firm's demand for labor and private capital, respectively. $\bar{o} \geq 0$ are fixed costs to production. This specification assumes constant returns to private inputs. k_t^G is the stock of public capital and ζ its production elasticity. If $\zeta > 0$, public capital is productive. If $\zeta \leq 0$, it is unproductive because of congestion or waste.

As factor markets for labor and private capital are perfectly competitive, cost minimization implies that the marginal costs per unit of output are the same for all firms,

$$mc_t = (k_t^G)^{-\zeta} w_t^{1-\alpha} (r_t^k)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^\alpha, \tag{2}$$

where w_t is the real wage paid to labor packers and r_t^k the real rental rate of private capital paid to saver households. (1) and (2) highlight the supply-side effects of public investment, which increases output of intermediate firms and lowers marginal costs ceteris paribus.

We assume Calvo staggered price setting. Each period a fraction $1-\phi$ of randomly selected firms is allowed to set a new optimal price $\check{P}_{H,t}^i$. The remaining firms adjust their prices according to the indexation scheme $P_{H,t}^i = (\pi_{H,t-1})^\iota \pi^{1-\iota} P_{H,t-1}^i$, where $\iota \in [0,1]$ and $1-\iota$ measure the degree of indexation to past producer price inflation $\pi_{H,t-1} = P_{H,t-1}/P_{H,t-2}$ and steady state inflation π, respectively. Intermediate goods producers that are allowed to reset their price maximize dividend payouts to saver households:

$$E_t \sum_{s=0}^{\infty} (\phi\beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left(\check{P}_{H,t}^i Q_{t,s} - MC_{t+s}\right) y_{H,t+s}^i,$$

subject to

$$y_{H,t+s}^i = \left(\frac{\check{P}_{H,t}^i Q_{t,s}}{P_{H,t+s}}\right)^{-\epsilon} y_{H,t+s}, \tag{3}$$

where $Q_{t,s} = 1$ for $s = 0$ and $Q_{t,s} = \Pi_{l=1}^s (\pi_{H,t+l-1})^\iota \pi_l^{1-\iota}$ for $s = 1, 2, \ldots, \infty$, taking λ_{t+s}, P_{t+s}, $P_{H,t+s}$, MC_{t+s} and $y_{H,t+s}$ as given. λ_t is the real marginal utility of saver households, defined below, and MC_t nominal marginal costs.

2.1.2 Households

Domestic households. A continuum of infinitely lived domestic households is defined over the interval $[0, 1]$, consisting of a fraction μ of non-saving households indexed by N and a fraction $1 - \mu$ of saving households indexed by S. A saving household j obtains utility through composite consumption $c_t^{*S}(j)$ and disutility from hours worked $n_t^S(j)$. $c_t^{*S}(j)$ consists of private and public consumption

$$c_t^{*S}(j) = c_t^S(j) + \omega\, g_t, \tag{4}$$

where ω is the degree of substitutability between both consumption types. If $\omega < 0$, the two goods are complements; if $\omega > 0$, the two are substitutes. This consumption specification emphasizes the demand component of government consumption. Furthermore, utility from composite consumption depends on the comparison to the consumption of all saving households in the previous period $\tilde{c}_{t-1}^{*S}$, with the relative importance h:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log(c_t^{*S}(j) - h\tilde{c}_{t-1}^{*S}) - \frac{\chi(n_t^S(j))^{1+\eta}}{1+\eta} \right), \quad \beta \in (0,1), \quad \chi > 0, \tag{5}$$

where n_t^S is hours worked and $\eta \geq 0$ the inverse of the Frisch labor elasticity.

Savers can invest in private one-period risk-free discount bonds B_t^H in home currency at price $1/R_t^D$. The bonds are in zero net supply. In addition, they can invest in private one-period discount bonds in foreign currency B_t^F at price $S_t/R_t^F \Upsilon_t$, where S_t is the nominal exchange rate defined as the price of foreign currency in terms of domestic currency, such that an increase implies a depreciation of the domestic currency. Υ_t is a premium on foreign bond holdings that depends on the aggregate net foreign asset position of the country: $\Upsilon_t = \exp[-\varphi(b_t^F - b^F)/y_H]$, with $b_t^F \equiv B_t^F/P_t^*$. Furthermore, savers have access to long-term domestic government bonds B_t at the price P_t^B with zero coupon and duration $1/(1 + \rho P_t^B)$, where $\rho \in [0, 1]$ is the constant decay rate.

The budget constraint of saving household j is

$$(1+\tau_t^c)P_t c_t^S(j) + P_t i_t(j) + P_t^B B_t(j) + \frac{B_t^H(j)}{R_t^H} + \frac{S_t B_t^F(j)}{R_t^F \Upsilon_t} \leq (1+\rho P_t^B)B_{t-1}(j) + B_{t-1}^H(j)$$
$$+ S_t B_{t-1}^F(j) + (1-\tau_t^y)W_t^h n_t^S(j) + (1-\tau_t^y)R_t^k \nu_t(j)\tilde{k}_{t-1}^S(j) - \Psi(\nu_t(j))\tilde{k}_{t-1}^S + \Pi_t(j) + P_t z_t^S(j),$$

where nominal consumption expenditures include value added taxes $\tau_t^c P_t c_t^S(j)$ and $P_t i_t(j)$ is investment in the private physical capital stock owned by saving households and rented out to domestic intermediate goods firms. Expenditures are financed through income from investment in nominal assets, after tax labor income $(1-\tau_t^y)W_t^h n_t^S(j)$, effective after-tax capital income $(1-\tau_t^y)R_t^k \nu_t(j)\tilde{k}_{t-1}^S(j) - \Psi(\nu_t(j))\tilde{k}_{t-1}^S$, profits $\Pi_t(j)$, as well as from government transfers $P_t z_t^S(j)$. τ_t^y is the income tax rate, R_t^k the nominal rental rate of capital, and W_t^h the nominal wage paid by labor unions. Effective private capital is $k_t^S(j) = \nu_t(j)\tilde{k}_{t-1}^S(j)$. $\tilde{k}_{t-1}^S$ is the private capital stock and ν_t the utilization rate, which involves unit costs of $\Psi(\nu_t)$ with $\Psi' > 0$. In steady state, $\nu = 1$ and $\Psi(1) = 0$. Effective private capital evolves as $\tilde{k}_t^S(j) = (1-\delta)\,\tilde{k}_{t-1}^S(j) + i_t(j)\Phi_t(j)$, where $\Phi_t(j) = 1 - \frac{\kappa}{2}\left(1 - \frac{i_t(j)}{i_{t-1}(j)}\right)^2$. κ measures the sensitivity of the adjustment costs to changes in private investment.

In the symmetric equilibrium, the optimality conditions for savers with respect to $c_t^{*S}, n_t^S, \nu_t, \tilde{k}_t^S$ are

$$
\begin{aligned}
(1+\tau_t^c)\lambda_t &= (c_t^{*S} - hc_{t-1}^{*S})^{-1} && (6)\\
(1-\tau_t^y)\lambda_t w_t^h &= \chi n_t^\eta && (7)\\
(1-\tau_t^y)r_t^k &= \psi'(\nu_t) && (8)\\
\lambda_t\lambda_t^k &= \beta E_t\left[\lambda_{t+1}(1-\tau_{t+1}^y)r_{t+1}^k\nu_{t+1} - \lambda_{t+1}\psi(\nu_t) + \lambda_{t+1}\lambda_{t+1}^k(1-\delta)\right], && (9)
\end{aligned}
$$

where $\lambda_t\lambda_t^k$ is the Lagrange multiplier on the capital accumulation equation. The first-order conditions show that changes in consumption and income tax rates have both intratemporal and intertemporal effects. Other things equal, a temporary reduction in τ_t^c raises current consumption of savers c_t^{*S} (see 6), who pull consumption forward (see 9). A temporary but persistent reduction in τ_t^y raises the after-tax wage income and thereby hours worked (see 7), the after-tax return on physical capital and thereby the utilization rate (see 8), and the value of investing in the private capital stock (see 9).

Non-savers have the same preferences as savers but no access to capital markets. They consume all their disposable income each period, which comes from working $n_t^N(j)$ hours and receiving $P_t z_t^N(j)$ public transfers. The budget constraint of non-saver j is

$$
(1+\tau_t^c)P_t c_t^N(j) = (1-\tau_t^y)\,W_t^h n_t^N(j) + P_t z_t^N(j). \qquad (10)
$$

We assume that tax rates and nominal wages are identical for all domestic households. As the demand for savers' and non-savers' labor is the same, so are their hours worked. Hence, taking prices and transfers as given, (10) determines non-savers' consumption. Lowering τ_t^c or τ_t^y raises $c_t^N(j)$, ceteris paribus.

Foreign households. There is a continuum of infinitely lived foreign households with the same preference structure as domestic households. Analogous to domestic demand, a representative foreign household's demand for domestically produced goods satisfies

$$x_{H,t}^* = \vartheta^*(P_{H,t}^*/P_t^*)^{-\gamma^*} y_t^*, \qquad \vartheta^* \in [0,1], \qquad \gamma^* > 0,$$

where $P_{H,t}^*$ is the price of domestic goods in foreign currency and y_t^* foreign demand.

2.1.3 Labor market

The labor market is described by the sticky-wage model of Smets and Wouters (2007). Households supply homogeneous labor to monopolistically competitive intermediate labor unions that differentiate the labor services and set staggered wages. A set of perfectly competitive labor packers buys and packages the differentiated labor services n_t^l, with $l \in [0,1]$, into an aggregate labor service unit n_t^d through the technology $n_t^d = [\int_0^1 (n_t^l)^{(\epsilon_w-1)/\epsilon_w} dl]^{\epsilon_w/(\epsilon_w-1)}$, where $\epsilon_w > 1$ denotes the elasticity of substitution. Profit maximization of the labor packers yields an aggregate wage index W_t, at which the aggregate labor service is demanded by intermediate goods producers.

Unions maximize dividend payouts to households taking as given the wage desired by households W_t^h, aggregate wages, prices, and labor demand. Wage setting is subject to Calvo frictions. Each period a fraction $1-\phi_w$ of randomly selected unions is allowed to set a new optimal wage $\check{W}_t^l$. The remaining unions adjust wages according to the indexation scheme $W_t^l = (\pi_{t-1})^{\iota_w}\pi^{1-\iota_w}W_{t-1}^l$, where $\iota_w \in [0,1]$ and $1-\iota_w$ measure the degree of indexation to past and steady state CPI inflation, respectively. The unions maximize

$$\max_{\check{W}_t^l} E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{\lambda_{t+s} P_t}{\lambda_t P_{t+s}} \left(\check{W}_t^l Q_{t,s}^w - W_{t+s}^h\right) n_{t+s}^l, \tag{11}$$

subject to

$$n_{t+s}^{l} = \left(\frac{\check{W}_t^l Q_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} n_{t+s}^d, \tag{12}$$

where $Q_{t,s}^w = 1$ for $s = 0$ and $Q_{t,s}^w = \Pi_{l=1}^s (\pi_{t+l-1})^{\iota_w} (\pi_l)^{1-\iota_w}$ for $s = 1, 2, \ldots, \infty$, taking λ_{t+s}, P_{t+s}, W_{t+s}, W_{t+s}^h and n_{t+s}^d as given.

2.1.4 Public sector

The domestic public sector consists of a government in charge of fiscal policy and a monetary authority. The latter pegs the nominal exchange rate to the exchange rate of the currency union, which it takes as given.

The government collects tax revenues from income and consumption, and it issues bonds in order to finance interest rate payments, transfers z_t, as well as public investment i_t^G and consumption g_t.[8] Long-term domestic currency denominated debt is assumed to be held entirely by domestic households. The government budget constraint is

$$P_t^B B_t + \tau_t^y R_t^k k_t + \tau_t^y W_t^h n_t + \tau_t^c P_t c_t = (1 + P_t^B \rho) B_{t-1} + P_t z_t + P_{H,t}(i_t^G + g_t), \tag{13}$$

where transfers are identical across households $z_t = \int_0^1 z_t(j)dj = z_t^S = z_t^N$. The public capital stock evolves according to $k_t^G = \left(1 - \delta^G\right) k_{t-1}^G + i_t^G$ with the depreciation rate δ^G. The fiscal shocks follow independent AR(1) processes:

$$\hat{f}_t = \rho_f \hat{f}_{t-1} + \varepsilon_{f,t}, \quad \rho_f \in [0, 1), \quad \varepsilon_{f,t} \sim N(0, \sigma_f^2), \quad f = i^G, g, \tau^c, \tau^y, \tag{14}$$

where the hat over the variable denotes deviations from steady state. To stabilize debt, the government adjusts transfers according to the (linearized) rule

$$\hat{z}_t = \phi_z \hat{z}_{t-1} + (1 - \phi_z) \phi_d \hat{d}_{t-1}, \tag{15}$$

where $d_{t-1} = \frac{b_{t-1}}{y_{H,t}}$ is the public debt-to-GDP ratio and ϕ_d the strength of the feedback.

[8] The assumption that government purchases are fully allocated to domestically produced goods is motivated by empirical evidence for OECD countries of a strong home bias in government procurement, over and above that observed in private consumption.

2.1.5 Aggregation and market clearing

Consumption, hours, and transfers $e_t(j) = \{c_t(j), n_t(j), z_t(j)\}$ are aggregated according to $e_t = \int_0^1 e_t(j)dj$ and can be decomposed into household-specific components via the share of non-saving households μ: $e_t = (1-\mu)e_t^S + \mu e_t^N$. Because only the savers have access to capital markets, the aggregation for $q_t(j) = \left\{k_t(j), B_t(j), B_t^H(j), B_t^F(j), \Pi_t(j)\right\}$ is $q_t = \int_0^{1-\mu} q_t(j)dj$. Factor, goods and asset markets clear. The market clearing conditions for final goods and home composite goods are $y_t = c_t + i_t + \psi(\nu_t)\tilde{k}_{t-1}^S$ and $y_{H,t} = x_{H,t} + x_{H,t}^* + i_t^G + g_t$, respectively. The latter equation shows the direct demand effects of public investment and public consumption. Public investment has a dual role. On the one hand, it raises supply through the production function of intermediate firms (see 1) and marginal costs (see 2). On the other hand, it raises aggregate demand. For public consumption, the demand effect through the market clearing condition may be reinforced or dampened through the demand effect in the utility function (see 4 and 5) depending on $\omega \lesseqgtr 0$.

The small open economy assumption implies that the foreign producer price level, $P_{F,t}^*$, is identical to the foreign CPI, P_t^*. Furthermore, the law of one price is assumed to hold separately for each good (H and F). In addition, an equation describing the evolution of net foreign assets can be derived by combining the household and government budget constraint and substituting out aggregate payouts Π_t, which gives $S_t[B_t^F/(R_t^F\Upsilon_t) - B_{t-1}^F] = S_t\left(P_{H,t}^* x_{H,t}^* - P_{F,t}^* x_{F,t}\right)$. The risk premium Υ_t ensures that private net foreign assets B_t^F are stationary under incomplete international asset markets, while the fiscal rule ensures stationarity of public debt B_t. The fixed exchange rate assumption implies $S_t = S \;\forall\; t$.

2.2 Calibration

Table 1 summarizes the calibration. We calibrate steady state values consistent with their empirical counterparts. We collect quarterly data for the twelve founding members of the euro for the period 1999Q1-2023Q4 from Eurostat.[9] We also collect data on CPI inflation

[9]Government consumption comprises expenditures on compensation of employees and intermediate consumption. Government investment are expenditures on gross fixed capital formation. The consumption tax rate is defined as the average effective tax rate obtained by dividing total tax revenues from production, typically in the form of value-added taxes and import duties, by final consumption expenditure, which represents the corresponding tax base. The income tax rate is defined as the average effective tax rate calculated by dividing total current tax revenues on the income and wealth of households and firms by total household and firm income, which serves as the corresponding tax base. All fiscal variables refer to the general government, consisting of the federal, state, and local governments.

and interest rates. Table A.1 contains details on the data. The sample means imply $g/y_H = 0.1631, \tau^c = 0.1785, \tau^y = 0.1418, d = 0.8012 \times 4, \pi = 1.0054$. We set the bond maturity to $\mu_b = 20$ quarters, such that $\rho = 0.9548$.

We set the unobservable deep structural parameters to standard values in fiscal DSGE models (Leeper et al., 2017). Specifically, we closely follow Forni et al. (2009), Coenen et al. (2012), and Coenen et al. (2013) who estimate DSGE models with rich fiscal sectors on euro area data using Bayesian methods. For the household sector, we set $\beta = 0.995$ to yield short-term nominal interest rates of $R^H = R^F = 1.0105$. We calibrate the working time to $n = 0.3$ and set the inverse Frisch labor elasticity to $\eta = 2$. The habit parameter is $h = 0.5$, the complementarity between private and public consumption $\omega = -0.2$, and the share of non-savers $\mu = 0.2$.

For the production sector, we assume $\kappa = 5$ for investment adjustment costs. The capital utilization costs are determined by $\psi''(1)/\psi'(1) = \tilde{\psi}/(1 - \tilde{\psi})$, and we set $\tilde{\psi} = 0.15$. The elasticity of home intermediate output with respect to private and public capital is $\alpha = 0.3$ and $\zeta = 0.05$, respectively. The depreciation rates are $\delta = \delta^G = 0.025$. We normalize the public capital stock to $k^G = 1$, implying a government investment ratio of $i^G/y_H = 0.025$. The Calvo parameters are $\phi = \phi_w = 0.85$ and indexation is $\iota = \iota_w = 0.5$, implying fairly sluggish price and wage adjustments as has been documented for the euro area. The elasticity of substitution between labor services and home intermediate goods are $\epsilon = \epsilon_w = 11$ to have markups of 10%.

For the open economy features, we assume an import share of $\vartheta = 0.25$, and substitution elasticities between home and foreign composite goods of $\gamma = \gamma^* = 1.5$. The elasticity of the country premium to foreign assets is $\varphi = 0.005$. The real exchange rate is one in steady state, and foreign assets are zero. The fiscal shocks have AR(1) coefficients of $\rho_f = 0.85$. The transfer rule is parameterized with $\phi_z = 0.9$ and $\phi_d = -1$ to induce stability.

2.3 Predictions

We use the calibrated model to predict the sign and size of tax and spending multipliers in the euro area. We focus on the response of domestic output and compute the cumulative

Table 1: Parameterization for a quarterly frequency

Parameter	Notation	Value
Households		
Discount factor	β	0.995
Substitutability private/ public consumption	ω	–0.2
Inverse Frisch labor elasticity	η	2
Capital utilization costs	$\tilde{\psi}$	0.15
External habit formation	h	0.5
Share non-saving households	μ	0.2
Production and pricing		
Production elasticity private capital	α	0.3
Production elasticity public capital	$\zeta = 0.05$	0.05
Depreciation rate private and public capital	δ, δ^G	0.025
Private investment adjustment costs	κ	6
Calvo parameters	ϕ, ϕ_w	0.85
Price and wage indexation	ι, ι_w	0.5
Elasticity substitution goods and labor	ϵ, ϵ_w	11
Steady state inflation	π	1.0054
Openness		
Import share	ϑ	0.25
Substitution domestic/foreign goods	γ, γ^*	1.5
Foreign bond premium	φ	0.005
Policy		
Government consumption ratio	g/y_H	0.1631
Consumption tax rate	τ^c	0.1785
Income tax rate	τ^y	0.1418
Annual debt ratio	$4d$	4×0.8012
Transfer smoothing term	ϕ_z	0.9
Debt elasticity transfers	ϕ_d	–1
Duration long-term bonds	μ_b	20
Persistence shocks $f = i^G, g, \tau^c, \tau^y$	ρ_f	0.85

multiplier for fiscal instrument fi at horizon L as

$$MP_L^{fi} = \frac{\sum_{l=0}^{L} \Delta y_{H,t+l}}{\sum_{l=0}^{L} \Delta fi_{t+l}},$$

where $\Delta u_t = u_t - u$ is the absolute deviation of a generic variable u_t from its steady state u. fi_t is either real public investment i_t^G, government consumption g_t, consumption tax revenues $\tau_t^c c_t$, or income tax revenues $\tau_t^y(w_t^h n_t + r_t^k k_t)$. The multipliers measure the euro increase in domestic GDP per euro additional government spending or foregone taxes.

Figure 1 shows the cumulative output multipliers over four years.[10] The bars report the average per year. Both spending multipliers are positive. In the first year, one euro

[10] Figure A.1 shows the underlying impulse responses of the endogenous variables to the four fiscal shocks.

additional spending on public investment or public consumption raises domestic output by about 1.5 euro. A multiplier larger than 1 implies that some private demand is crowded-in. The government investment multiplier stays above one for the four years and exhibits a mild U-shape, reflecting increased demand in the short-run and an expanded production capacity in the medium-run. The government consumption multiplier decays slowly over the horizon and falls below one in the last year. The comparison of the two spending multipliers suggests that government investment has more persistent output effects than public consumption but that both spending components generate a strong upswing.

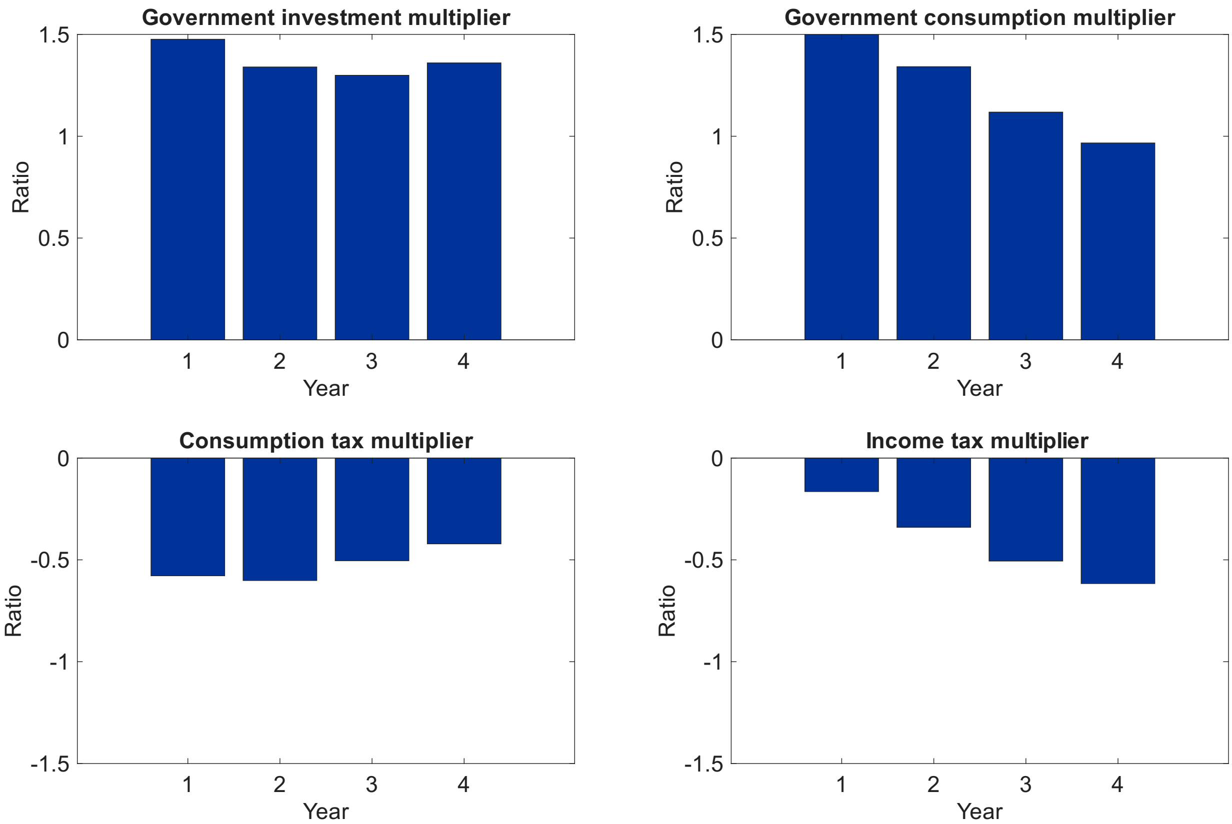

Figure 1: Cumulative output multipliers from DSGE model. *Notes*: The figure shows the cumulative output multiplier of government investment, government consumption, consumption taxes, and income taxes, respectively. It reports the average in each year 1-4 after the fiscal shock.

Both tax multipliers are negative as tax revenues fall and domestic output increases. The consumption tax multiplier is roughly –0.5 in the first two years and then slowly converges to zero. The income tax multiplier is –0.2 in the first year and –0.6 in the fourth year. The gradual buildup of the stimulus associated with the income tax cut reflects the dual role of income taxes. They affect both labor and capital income and, thus, working and investment decisions. The labor market effect materializes in the short-run and dies out quickly. The capital market effect is low initially and builds over time. The overall pattern of the income tax multiplier suggests that the capital effect dominates.

To see how robust these predictions are and what the main reasons for the stark discrepancy between the efficacy of tax and spending policies are, Figure 2 considers several alternative calibrations of the model, one at a time. The x-axis indicates the alternatives and the y-axis shows the corresponding average cumulative multiplier over four years. The first bar in each panel is the average four-year cumulative multiplier of the baseline calibration as reference.

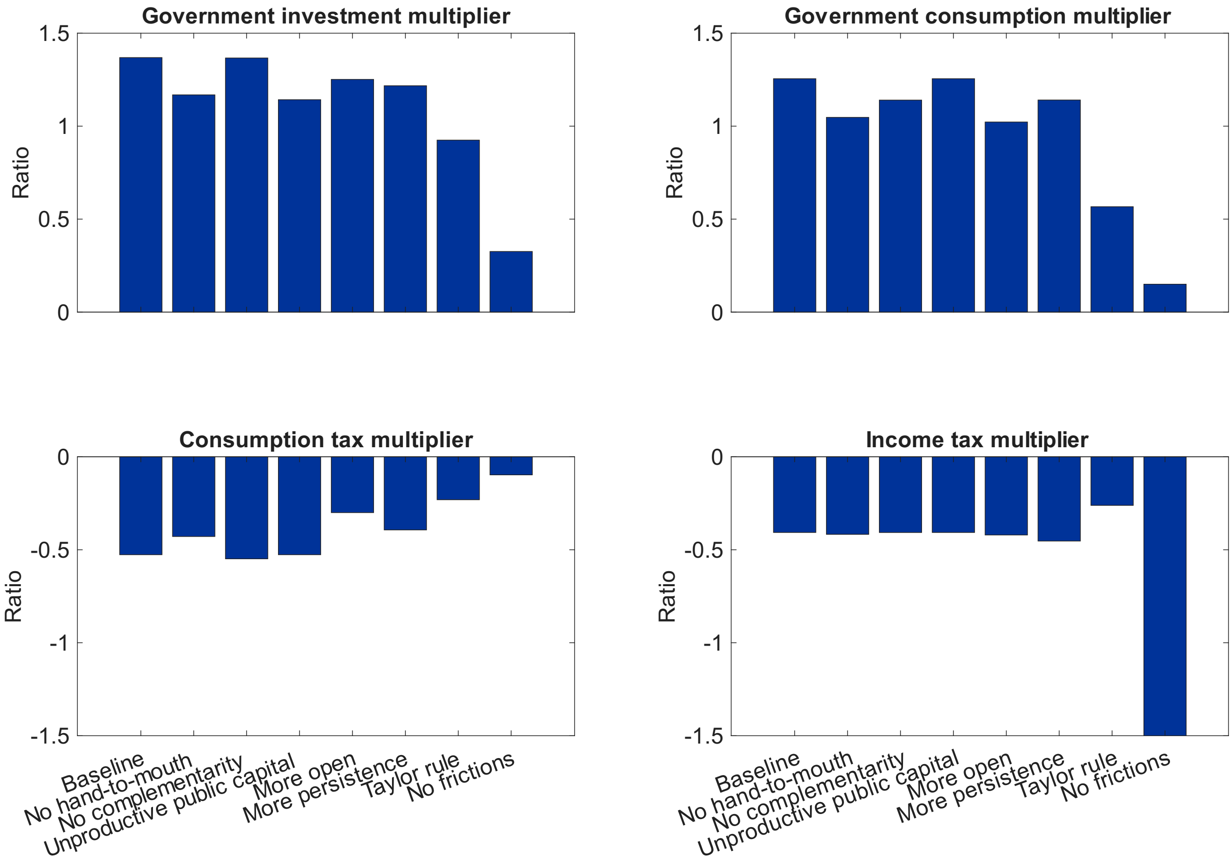

Figure 2: Cumulative fiscal multipliers for alternative calibrations. *Notes*: The figure shows the cumulative output multiplier of government investment, government consumption, consumption taxes, and income taxes, respectively, for alternative calibrations of the DSGE model. It reports the average cumulative multiplier over four years after each fiscal shock.

The second bar in each panel shows a case with the share of non-saving households set to $\mu = 0$. Both spending multipliers drop somewhat but stay above one. The consumption tax multiplier also falls a bit, whereas the income tax multiplier is virtually unaffected. The third bar shows a situation in which the complementarity in the utility function between public and private consumption is switched off, $\omega = 0$. Compared to the baseline, this change mainly affects the government consumption multiplier, which falls but stays above one. The next bar focuses on the transmission of public investment shocks. It sets the production elasticity of public capital to $\zeta = 0$. This change mainly affects the investment multiplier, which falls a bit but remains above one.

The next bar increases the openness of the economy by doubling the import share to $\vartheta = 0.5$ and increasing the elasticity of substitution between home and foreign goods at home and abroad to $\gamma = \gamma^* = 5$. Relative to the baseline, both spending multipliers and the consumption tax multiplier decrease moderately as the external demand leakage is stronger, while the income tax multiplier is hardly affected. The following bar considers more persistent shocks by setting $\rho_f = 0.95$ for $f = i^G, g, \tau^c, \tau^y$. The first three multipliers decline a bit, while income tax cuts become marginally more powerful.

The last two bars reflect modifications that change the nature of the model. First, we assume that the central bank follows a Taylor rule with $\hat{R}_t^H = 1.5\hat{\pi}_t + 0.25\hat{y}_{H,t}$, instead of pegging the nominal exchange rate. This modification describes a small open economy that conducts independent monetary policy, such as the UK or Sweden. All multipliers fall substantially in absolute value relative to the peg. The spending multipliers are now clearly below one, and the tax multipliers are yet closer to zero. The Taylor rule implies a response to domestic CPI inflation and output changes induced by the fiscal shocks. The inflation response entails that fiscal stimulus which raises inflation has smaller effects than under a peg, whereas stimulus which lowers inflation has larger effects. In our case, the first three shocks raise inflation and the last one lowers it (Figure A.1). The monetary response to output implies that all four multipliers are lower than under a peg. This effect reinforces the effect of the inflation response on the first three multipliers and dominates it in case of the income tax multiplier.

Last, we simulate an economy without frictions. We set $h = \kappa = \tilde{\psi} = \phi = \phi_w = \iota = \iota_w = \mu \approx 0$. While these are extreme and empirically unrealistic values, the calibration indicates the direction in which tax and spending multipliers may change in countries with less capital, labor, and pricing frictions than the euro area, such as the UK or US. The last bar in each panel shows that fiscal demand stimulus is substantially less effective in such situations. Both spending multipliers are well below 0.5, and the consumption tax multiplier is close to zero. In sharp contrast, supply-side stimulus is highly effective. The income tax multiplier jumps to –1.5.

To summarize, with a fixed exchange rate, spending multipliers are larger in absolute value than tax multipliers unless one assumes a frictionless world. Spending multipliers are in the range 1 to 1.5. Furthermore, public investment has more persistent output effects than government consumption. Tax multipliers are in the range 0 to 0.5. Income tax cuts have more persistent output effects than consumption tax cuts. Finally, fiscal demand stimulus is more efficient with a fixed exchange rate than with a central bank following a Taylor rule, and fiscal supply measures are less efficient in such an environment.

3 Empirical analysis

In this section, we test the theoretical predictions using euro area data. First, we describe the empirical model, the data, and the identification strategy.

3.1 Panel model and data

We use a panel vector autoregressive (VAR) model that includes macroeconomic time series by euro area country. Formally, N denotes the number of countries, K the number of country-specific variables, and T the sample length. The reduced form of the VAR model for country i and quarter t is

$$y_{it} = \eta_i + \lambda_t + \sum_{l=1}^{p} A_l y_{i,t-l} + u_{it}, \tag{16}$$

where y_{it} contains country-specific endogenous variables, $y_{it} = (y_{1,it}, ..., y_{K,it})'$, η_i denotes country fixed effects capturing time-invariant country heterogeneity, λ_t time fixed effects capturing time-varying common factors, and A_l is a $K \times K$ matrix of autoregressive parameters for lag $l = 1, ..., p$. The $K \times 1$ vector $u_{it} = (u_{1,it}, ..., u_{K,it})'$ contains serially and cross-sectionally uncorrelated country-specific reduced form errors with mean zero, that is, $\mathbb{E}[u_{it}u'_{it-1}] = \mathbb{E}[u_{it}u'_{jt}] = 0,\ i \neq j$.

The model contains five endogenous variables in y_{it}: the income tax rate, the consumption tax rate, government consumption, government investment, and GDP. The order of the variables is irrelevant as we will not rely on a recursive identification. We collect quarterly data from Eurostat (see Section 2.2 and Appendix A). The sample period is 1999Q1-2023Q4. The panel comprises 12 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. We focus on the founding members of the euro to enhance country homogeneity and to have a largely balanced panel.[11] As the sample is relatively short, we use the two-way fixed effects panel estimator in (16) with homogeneous slope coefficients.

Government consumption, government investment, and GDP are in real per capita terms. We divide them by trend GDP, following Ramey and Zubairy (2018), using a fourth-order polynomial. The scaling simplifies the computation of fiscal multipliers and makes them insensitive to scaling factors. We compute the two tax rates as average effective tax rates, that is, the ratio of total tax revenues to the respective tax base. By using tax rates rather than revenues, we aim at more closely measuring changes in the instruments under direct control of policy makers. Statutory or marginal tax rates are not consistently available for the countries in the sample.

We include four lags of the endogenous variables, as is standard with quarterly fiscal data. For inference, we use a recursive-design wild bootstrap with $u_{it}^* = \phi_t \hat{u}_{it}$, where ϕ_t is a random variable independent of y_{it} following a Rademacher distribution. Appendix C shows that the results are robust to alternative de-trending of GDP and tax definitions, changing the lag length, adding variables to the model, allowing for some country heterogeneity, and excluding countries from the sample.

3.2 Identification

For N countries, model (16) can be written in compact form as

$$Y_t = AX_t + U_t, \tag{17}$$

where Y_t is a $K \times N$ matrix of endogenous variables with $Y_t = (y_{1t}, ..., y_{Nt})$, A a $K \times (Kp + N + M)$ matrix of parameters, $A = (A_1, ..., A_p, C_1, ..., C_N, D)$, X_t a $N \times (Kp + N + M)$ matrix of lagged endogenous variables and M quarter dummies, and $U_t = (u_{1t}, ..., u_{Nt})$. The reduced form residuals U_t are linearly related to mean-zero structural shocks $\mathcal{E}_t = (\varepsilon_{1t}, ..., \varepsilon_{Nt})$, which are uncorrelated across time and space, according to $U_t = B\mathcal{E}_t$. The

[11] Greece joined in 2001. All results are robust to starting the sample in 2001.

identification problem is that the structural parameters of the model cannot be recovered from the reduced form without further assumptions.

To overcome this problem, we exploit the panel dimension of the model in two ways. First, we include time fixed effects (see 16). These control for all common business cycle drivers of the euro countries in the sample to which they are similarly exposed. The drivers can either come from outside the currency union, such as global cycles in real, financial or commodity markets, or from inside the union, such as a common euro area-specific business cycle or the monetary stance. Having the time fixed effects is a large advantage over pure time series approaches, which need to assume that all unobservable and potentially confounding factors are scattered randomly across the sample period. This is a strong assumption in short samples, which are typical for macroeconomic data.

Second, having netted out all common factors, we use the remaining country-specific heteroskedasticity in U_t for identification. Generally, heteroskedasticity can occur over time and across space. Most applications exploit volatility changes over time (Rigobon and Sack, 2003; Lewis, 2021; Brunnermeier et al., 2021). A few use differences across space (Lee et al., 2004; Rigobon and Rodrik, 2005). We follow the latter approach because we have a rich cross-section, whereas the time dimension of the sample is relatively short.

We sort countries into two groups, one with low volatility and one with high volatility, using the following steps. We estimate for each country the covariance matrix of the country-specific reduced form residuals as $\hat{\Sigma}_i = \sum_{t=1}^{T} \hat{u}_{it}\hat{u}_{it}'/(T - Kp - 1)$. Then, we compute the mean across countries: $\hat{\Sigma} = \sum_{i=1}^{N} \hat{\Sigma}_i/N$. Next, we normalize each element as $\tilde{\hat{\Sigma}}_i = \hat{\Sigma}_i \oslash \hat{\Sigma}$ so that the elements of $\tilde{\hat{\Sigma}}_i$ are in equivalent relative terms. Then, we compute a volatility score s_i for each country as the trace of the normalized country covariance matrix: $s_i = trace(\tilde{\hat{\Sigma}}_i)$. Then, we split the panel evenly and assign the six countries with the highest volatility scores to the high volatility group and the other six to the low volatility group. The countries in the low volatility group are Austria, Belgium, France, Germany, Italy, and the Netherlands. The countries in the high volatility group are Finland, Greece, Luxembourg, Ireland, Portugal and Spain. Finally, we compute the mean covariance matrix for the low volatility group L as $\Sigma_L = (N_L T - Kp - 1)^{-1} \sum_{i=1}^{L} \sum_{t=1}^{T} \hat{u}_{it}\hat{u}_{it}'$, where $i \in L$ and $N_L = 6$, and for the high volatiliy group H, Σ_H, analogously. We use an equal split to estimate the parameters of Σ_L and Σ_H, which are crucial for identification, with similar precision. The results are robust to an alternative split of countries into low- and high-volatility groups, such as based on k-means clustering.

With the two covariance matrices at hand, we can use the following matrix decomposition to identify the structural parameters of the model:

$$\Sigma_L = BB' \quad \text{and} \quad \Sigma_H = B\Lambda B', \tag{18}$$

where $\Lambda = diag(\lambda_1, \ldots, \lambda_K)$ is a diagonal matrix. The λ_k are positive elements that can be interpreted as the differences in the structural shock variances in the high volatility group relative to the low volatility group. To estimate the structural parameters in (18), we employ the GMM estimator of Kilian and Lütkepohl (2017)[p. 499].

Lanne et al. (2010) state conditions for local uniqueness of B. Local uniqueness implies that B is identified up to the signs of the parameters in each column as well as to column permutations. The conditions for local uniqueness of B are: (i) the structural shocks ε_{it} are orthogonal; (ii) the structural impact matrix B is homogeneous across groups; and (iii) there are sufficiently many and sufficiently large differences in the variances of the structural shocks across groups, that is, $\lambda_k \neq \lambda_l$ for $k, l \in \{1, \ldots, K\}$ with $k \neq l$. The first assumption is common in SVAR analysis. The second is standard in the fixed effects panel estimator. It is untestable without further assumptions. But we provide evidence that it is consistent with the data by considering alternative groupings and leaving out countries. We also show that allowing for dynamic heterogeneity does not change the main results. The third assumption relaxes the standard assumption of Gaussianity in SVAR analysis and can be tested after estimation by comparing the estimated shock variances λ_k.

Identification through cross-sectional heteroskedasticity has several advantages in our setting. Relative to recursive identification, it avoids the strong assumption of contemporaneous exogeneity of government spending. This assumption would be particularly difficult to justify with two spending components since it is unclear which one should be ordered first. Relative to sign restrictions, it yields point identification instead of set identification, where sets are often wide. Moreover, it potentially identifies all structural shocks in the model. We show below that this is the case. Then, the resulting impulse responses represent clean policy experiments of exogenous changes in one fiscal tool shutting down shocks to all others. Finally, relative to instrumental variable strategies, it does not require the availability of instruments for all countries and all fiscal shocks, nor a recursiveness assumption within the instruments.

A possible drawback is that the identified shocks can be difficult to locate as their order is not pinned down prior to estimation. Technically, B is identified only up to column permutations, and we need to assign each estimated column to the corresponding structural shock after estimation. Fortunately, this is simple in our setting as the structural shocks have a clear mapping to the fiscal variables and, thus, can be located by using the forecast error variance decomposition.

3.3 Macroeconomic effects of different fiscal tools

3.3.1 Volatility groups and identification

Table 2 presents the estimated reduced form covariance matrices to see whether volatility differs sufficiently across the two country groups for identification. All variances are substantially higher in the high-volatility group. They increase by factors of 2 to 7. This is suggestive of large differences in volatility across countries. In both groups, the residuals of the tax equations are more volatile than the residuals of the spending equations. Importantly, nearly all estimated covariances are also larger in absolute value in the high volatility group. These differences in the covariances are central to achieving identification. Together with the higher variances, they imply that when fiscal volatility is higher, we learn more about the covariance between the fiscal innovations and GDP. Rigobon (2003) calls these (co)variance shifts ‘probabilistic instruments.’

Σ_L					Σ_H				
4.84	–	–	–	–	8.20	–	–	–	–
0.36	3.06	–	–	–	−0.16	7.73	–	–	–
0.10	−0.07	0.52	–	–	0.18	−0.22	2.16	–	–
−0.12	−0.02	0.10	0.52	–	−0.01	0.06	0.44	3.69	–
−0.96	−0.45	0.26	0.10	4.28	−1.20	0.81	0.76	1.08	22.44

Table 2: Estimated group covariance matrices. *Notes:* The table shows the estimated reduced form covariance matrices in the low-volatility group (left, Σ_L) and the high-volatility group (right, Σ_H).

Table 3 reports the estimated variances of the structural shocks in the high-volatility group. The order of the λ_ks is arbitrary since the decomposition of (18) is unique up to column (and sign) permutations. To achieve identification formally, the variances of the structural shocks need to be statistically significantly different from each other (Lanne et al., 2010). All estimates are larger than 1, which is the normalized variance of each structural shock in the low-volatility group. The smallest high-volatility variance is 1.64, the largest is 7.42. All variances are precisely estimated. The standard errors are small. They appear particularly small when compared to the typical estimation precision in identification with time-varying volatility, suggesting that the identification approach works well in cross-country panel data. Two standard errors around each point estimate always exclude 1 and any of the other λ_ks. This suggests that all λ_ks are larger than 1 and distinct and, hence, that the model is statistically identified. But looking at standard errors is not a formal test of identification.

Parameter	Estimate	Standard error
λ_1	7.42	0.30
λ_2	1.64	0.06
λ_3	2.54	0.10
λ_4	4.10	0.18
λ_5	5.64	0.26

Table 3: Estimated structural shock variances. *Notes:* The table shows the estimated variances of the structural shocks in the high-volatility group, λ_k, and the bootstrapped standard errors.

Table 4 present the results of such a test, based on Lütkepohl et al. (2021). The test assumes a model with two known volatility groups. The null hypothesis is that two or more λ_ks are equal. The alternative is that they are different. The table reports the test-statistic, degrees of freedom, and p-value for each null hypothesis necessary to test the equality between the five structural parameters. The data strongly reject all null hypotheses. The largest p-value is 0.027. Together, this is statistically significant evidence against the null hypothesis that the decomposition (18) is not unique. In other words, the cross-sectional heteroskedasticity identifies all five structural shocks in the model.

As the model is fully statistically point-identified, we now label the structural shocks. As mentioned above, the decomposition in (18) is unique only up to sign changes and permutations of the elements of Λ, together with the corresponding ordering of the columns of B. To detect the location of each shock, we inspect the forecast error variance decomposition. The shock that explains the largest share of the impact forecast error variance of a given variable is labeled as the shock to that variable. For example, the shock that accounts for the largest instantaneous variation in government investment is labeled as

H_0	$Q_r(\kappa_1, \kappa_2)$	Degrees freedom	p-value
$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5$	195.93	14	0.000
$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4$	179.83	9	0.000
$\lambda_2 = \lambda_3 = \lambda_4 = \lambda_5$	120.37	9	0.000
$\lambda_1 = \lambda_2 = \lambda_3$	179.46	5	0.000
$\lambda_2 = \lambda_3 = \lambda_4$	59.55	5	0.000
$\lambda_3 = \lambda_4 = \lambda_5$	44.32	5	0.000
$\lambda_1 = \lambda_2$	149.83	2	0.000
$\lambda_2 = \lambda_3$	13.64	2	0.001
$\lambda_3 = \lambda_4$	16.23	2	0.000
$\lambda_4 = \lambda_5$	7.24	2	0.027

Table 4: Test of identification. *Notes*: The table shows the null hypothesis, Q-statistic, degrees of freedom, and p-value of a test for identification in SVAR models with two known volatility groups of Lütkepohl et al. (2021). The kurtosis parameters are $\kappa_1 = \kappa_2 = 0$, assuming group-wise Gaussianity.

the government investment shock. This strategy is close to the standard identification of government spending shocks (Blanchard and Perotti, 2002), where zero restrictions imply that government spending shocks account for all impact variation in government spending. We relax this assumption and only require that the corresponding shock explain the largest fraction of the impact forecast error variance.

	ε_t^{GI}	ε_t^{IT}	ε_t^{CT}	ε_t^{GC}	ε_t^{BC}
Income tax rate	0.15	92.86	6.99	0.00	0.00
Consumption tax rate	0.39	8.52	87.49	0.14	3.46
Government consumption	0.01	0.18	0.53	96.11	3.16
Government investment	86.79	0.53	0.04	1.79	10.85
GDP	11.69	4.85	2.83	8.99	71.63

Table 5: Forecast error variance decomposition. *Notes*: The table shows the estimated forecast error variance decomposition at horizon 1 averaged across the two volatility groups. The groups are weighted equally given an equal number of observations in each group.

Table 5 shows that spotting the location of each shock is simple. The first shock is the government investment shock ε_t^{GI}. It accounts for 87% of the impact variation in government investment. The second shock is the income tax shock, contributing 93% to the variation in income taxes. The third shock is the consumption tax shock ε_t^{CT}. It explains 87% of the forecast error variance of consumption tax rates. The next shock is the government consumption shock ε_t^{GC}. It accounts for 96% of the impact variability in public consumption. That leaves the last shock as a generic business cycle shock which drives 72% of the unexpected output fluctuations.

Figure 3 summarizes the statistical analysis visually. It shows the identified fiscal shocks by country group. The top panels depict the shocks in all the countries in the low-volatility group. The bottom panels contain the shocks in the high-volatility countries. The shocks are notably more volatile in the bottom panels. This holds especially for the two government spending shocks but also for both tax shocks. The visible differences corroborate the statistical analysis and suggests that the volatility pattern can be exploited for the identification of the dynamic effects of four types of fiscal shocks on output.

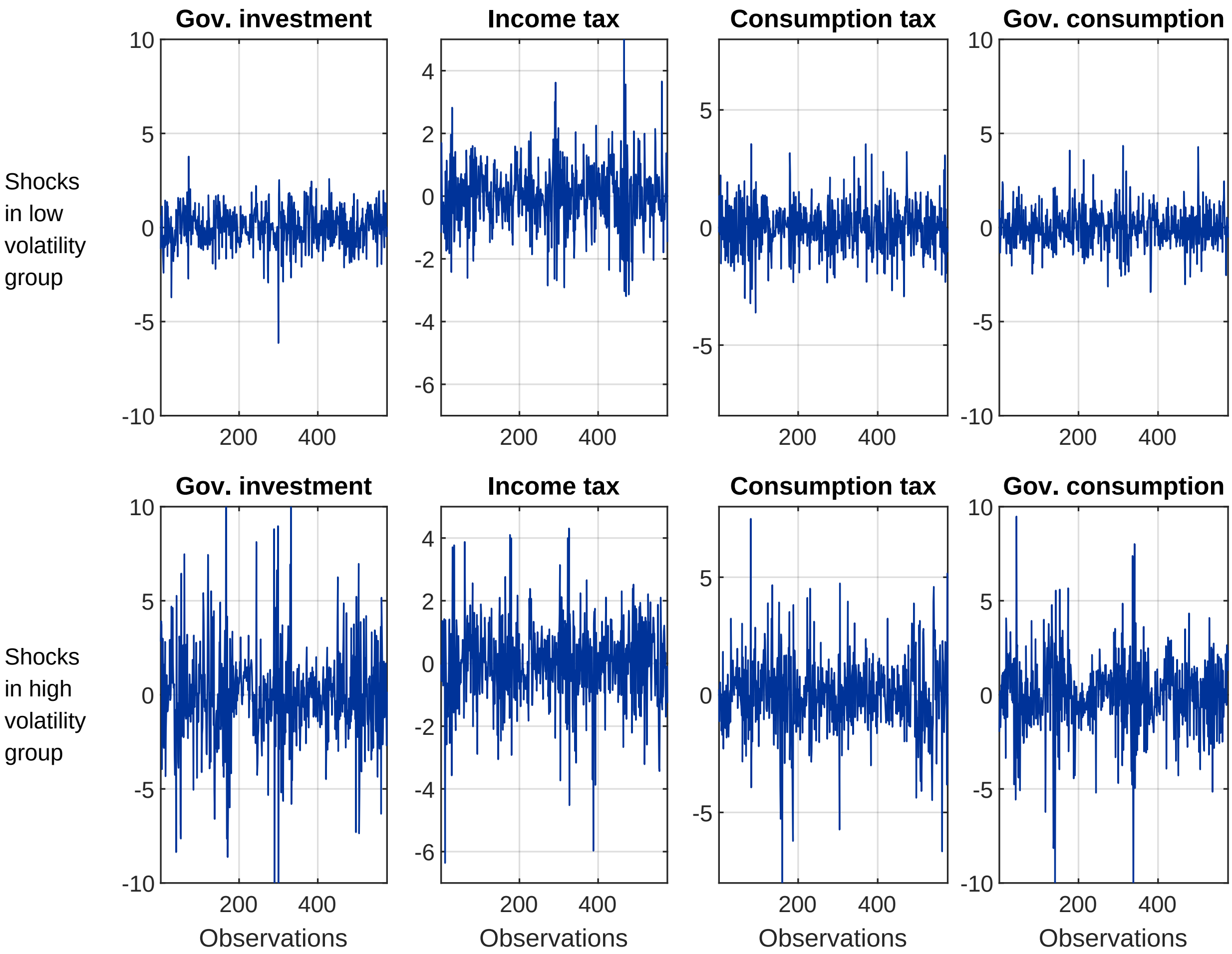

Figure 3: Estimated structural shocks. *Notes*: The figure shows the identified structural fiscal policy shocks in the low-volatility group countries in the top panels and the shocks in the high-volatility group countries in the bottom panels.

3.3.2 Impulse responses and multipliers

Figure 4 shows the estimated responses to the identified fiscal shocks. The shocks are in columns. The top panels report the fiscal instrument associated to each shock. The bottom panels show the corresponding output response. The shaded areas are 68% and 90% confidence bands. We report expansionary shocks of one standard deviation to obtain an impression of the typical size of the shocks. Figure A.2 shows the responses of all variables to all shocks.

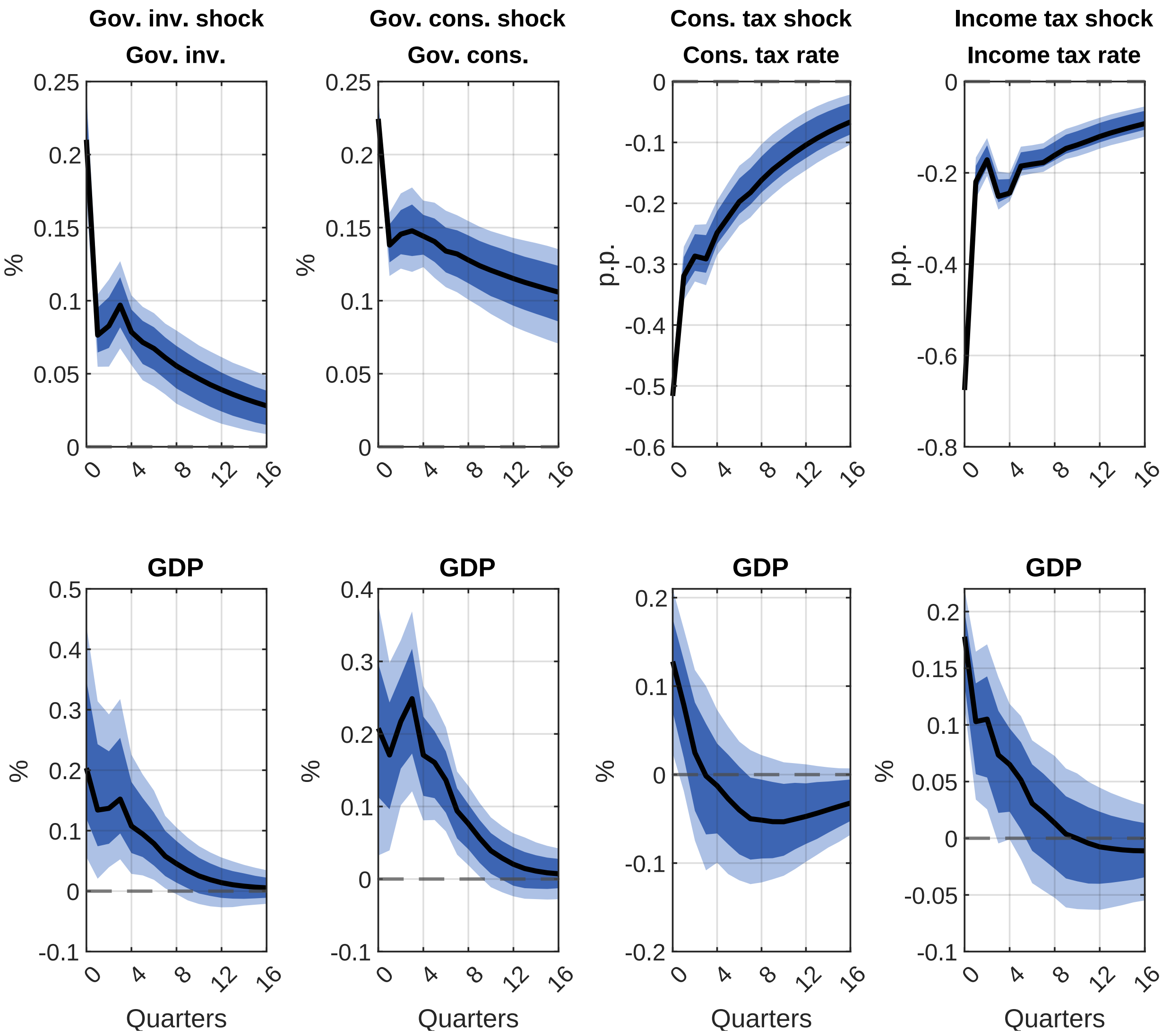

Figure 4: Estimated responses to spending and tax shocks. *Notes:* The figure shows the estimated impulse response functions to a shock to government investment (first column), government consumption (second column), consumption tax rate (third column), and income tax rate (last row) of one standard deviation over 16 quarters. Shaded regions report 68% and 90% bootstrapped standard errors.

We start with the two spending shocks. The government investment shock (first column) leads to a contemporaneous increase in government investment of 0.21%-points of GDP. After the initial spike, public investment falls back quickly to 0.07%-points above trend. But then it needs more than four years to fully return. The shock has an immediate positive and statistically significant effect on GDP of 0.2%. The effect is also persistent. The output gap remains positive for two years. The government consumption shock (second column) is slightly more persistent than the public investment shock. Government consumption increases by 0.22%-points in the first quarter, falls to 0.14%-points in the second quarter, and then stays well above trend for many years. The persistent stimulus leads to an immediate rise in GDP by 0.21%, similar as for the government investment shock. But now GDP rises further during the first year, peaks at 0.25%, and remains above trend for three years.

We proceed with the two tax shocks. The consumption tax shock (third column) corresponds to a cut in the average effective consumption tax rate of 0.5%-points. Thereafter, the tax rate steadily increases to the initial level, which it has not fully reached after four years. Despite the large and persistent tax cut, GDP responds only modestly and temporarily. It increases by 0.11% for one quarter, then drops back within two quarters, and subsequently undershoots for several years. The impact effect is marginally significant. The undershooting is not significant but the dynamic suggests forward shifting of output instead of additional output. The income tax cut (fourth column) has a similar dynamic as the consumption tax cut. The cut is a bit larger and more persistent. The output increase is also larger and more persistent. Output rises by 0.18% upon impact. It remains above trend for two years and significantly so for about a year.

To summarize, all four fiscal tools are effective at stimulating the economy. They raise GDP significantly. However, the magnitude and persistence of the GDP responses differ notably. To compare the efficiency of the tools consistently, we now compute their output multipliers. The multipliers measure by how many euros GDP rises if the government spends one euro more, or foregoes one euro of tax revenues, and thereby account for differences in the size and persistence of the shocks. For the spending components, we only need to compute the ratio of the cumulative response of output to the cumulative response of the spending component to obtain the multiplier since both spending and output are already scaled by trend GDP. To obtain the tax multipliers, we divide the cumulative output response to a tax shock by the cumulative tax rate response and multiply the ratio with the inverse of the respective tax revenue to GDP ratio.

Figure 5 shows the associated cumulative output multipliers. The two spending multipliers have similar size and dynamics. Both are about 1 in the first quarter, keep on rising for two quarters, peak at 1.3, and slowly fall back. The investment multiplier is more persistent than the spending multiplier. It is still 1 after four years, whereas the spending multiplier is 0.7 at that point. Both are statistically significant over most of the horizon. In contrast, the tax multipliers are substantially smaller in absolute value. Both are about –0.3 upon impact. Thereafter, the consumption tax multiplier quickly converges to zero after two years and slightly overshoots. Only the impact effect is statistically significant. The income tax multiplier increases a bit further in absolute value after the impact effect, to –0.4, and is also more persistent. It is still –0.2 after four years and significantly negative for the first two of these.

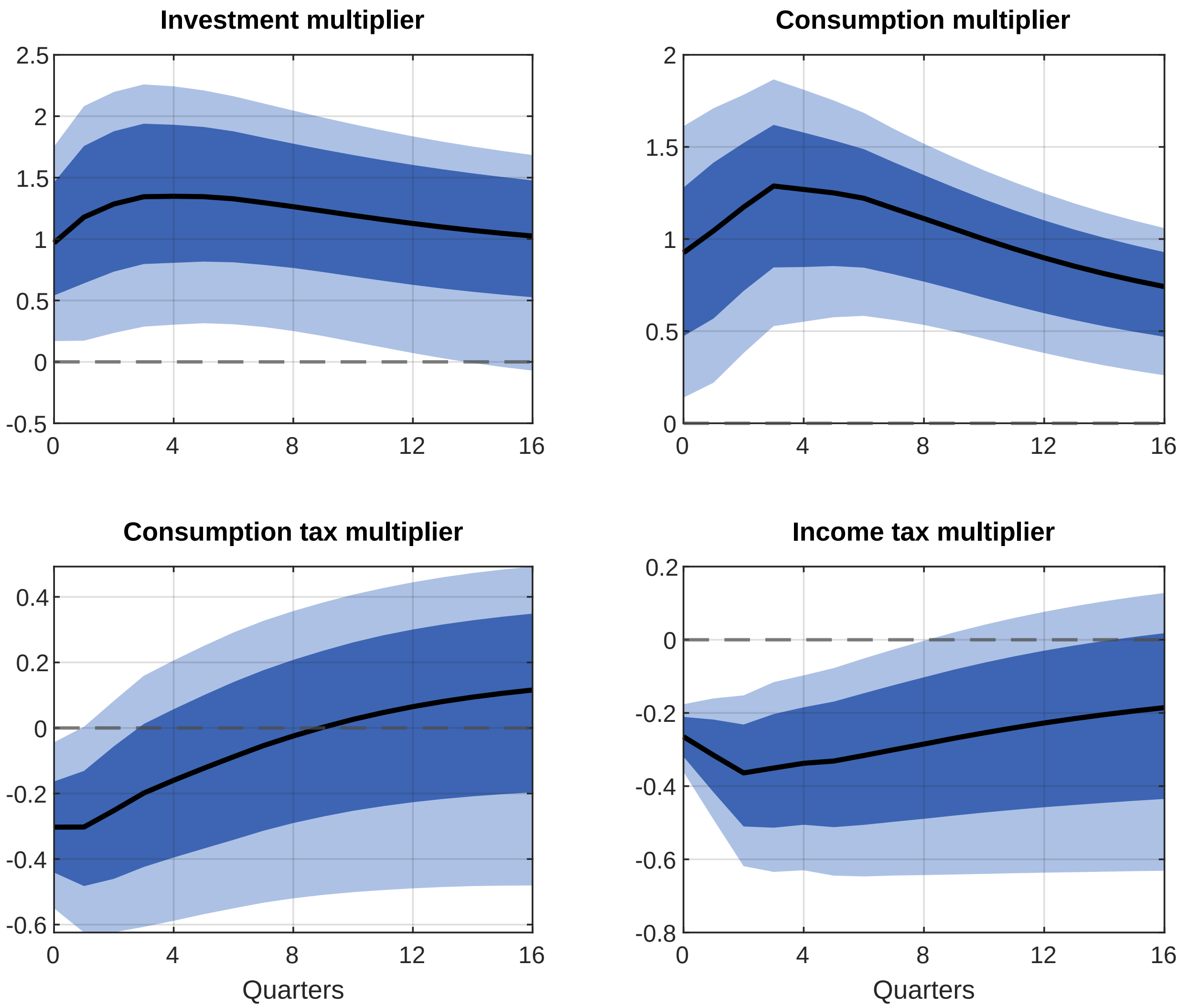

Figure 5: Estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters. Shaded regions report 68% and 90% bootstrapped standard errors.

The estimated multipliers are closely in line with the theoretical predictions in Section 2. The spending multipliers are both in the range 1 to 1.3 in the first three years, whereas the tax multipliers are in the range 0 to 0.4 in absolute value. Furthermore, the investment multiplier is more persistent than the consumption multiplier, and the income tax multiplier is more persistent than the consumption tax multiplier, as predicted by theory.

The estimates shed new light on the relative efficiency of different fiscal tools. Regarding public investment, Auerbach and Gorodnichenko (2012) and Ilzetzki et al. (2013) estimate multipliers in the range 1 to 2, similar to us, whereas Boehm (2020) finds a multiplier of 0. Regarding general spending, the range of multipliers is 0.8 (Canova and Pappa, 2007) to 1.5 (Beetsma and Giuliodori, 2011) for the euro area, and 0.5 to 1 for the US (Ramey, 2016, 2019). Our estimates are compatible with the smaller US multipliers if one accounts for the difference in the monetary response.[12] Ramey and Zubairy (2018) find that the general spending multiplier is 1.5 in the US when monetary policy does not respond.

Only few studies estimate specific tax multipliers. Mertens and Ravn (2013) and Nguyen et al. (2021) find income tax mutlipliers above 2 for the US and UK, respectively. Our theoretical analysis helps square these with our estimate of below 0.5. The DSGE model suggests that tax multipliers are substantially larger when frictions are lower (Figure 2), a comparison that might describe the US and UK relative to most euro area countries. Nguyen et al. (2021) also estimate a consumption tax multiplier for the UK and find a value similar to us. Our theoretical analysis shows that the consumption tax multiplier does not depend much on the degree of frictions in the economy. Finally, Gechert et al. (2021) estimate a social security tax multiplier of 0.4 for Germany, closely in line with our estimates.

3.4 Sensitivity analysis

The estimated multipliers are robust to alternative VAR specifications. In Figure A.3, we augment the model one by one with the ten-year rate, the policy rate, and stock prices to account for potentially omitted financial and monetary conditions. The stock prices also control for fiscal foresight (Forni et al., 2010). Figure A.4 varies the lag length between $p = 5, 6, 7, 8$, and Figure A.5 adds linear and quadratic trends to the baseline VAR model. The multipliers remain close to the baseline estimates in terms of magnitude, persistence, and relative ranking.

[12]In Section 3.5, we show that the identified fiscal shocks do not lead to a monetary policy response. This is consistent with the institutional structure of the European monetary union, where fiscal policy is conducted nationally while monetary policy is set at the union level.

Furthermore, the results are robust to allowing for some cross-country heterogeneity and alternative heteroskedasticity groupings. Figure A.6 estimates country-specific reduced-form VAR models. Figure A.7 replaces the baseline volatility grouping with an unsupervised k-means clustering algorithm. Figure A.8 implements a leave-one-country-out procedure. In all cases, the estimated multipliers are similar to the baseline. The relative ordering of spending and tax multipliers is preserved, and the point estimates are mostly within the confidence intervals of the baseline model.

Finally, the results are robust to alternative definitions of taxes. In Figure A.9, we construct the consumption tax rate using value-added tax revenues only, excluding import duties. In Figure A.10, we replace the effective tax rates with tax revenues. Both robustness checks yield multipliers that are quantitatively and qualitatively similar to the baseline.

3.5 Macroeconomic transmission

To explore the macroeconomic transmission of the four types of fiscal shocks, we project macroeconomic variables on the identified shocks using the following regressions:

$$y_{i,t+h} = \beta_h \, s_{i,t} + \sum_{j=1}^{p} \phi_{h,j} \, y_{i,t-j} + \sum_{j=1}^{p} \boldsymbol{\gamma}_{h,j}^{\top} \mathbf{x}_{i,t-j} + \alpha_{i,h} + \delta_{t,h} + \varepsilon_{i,t+h}, \tag{19}$$

where i indexes countries, t denotes quarters, $p = 4$ is the lag length, and $h = 0, 1, \ldots, H$ represents the forecast horizon. The dependent variable $y_{i,t+h}$ is the outcome of interest h periods ahead, while $s_{i,t}$ denotes the contemporaneous structural shock. The coefficient β_h captures the dynamic response of y at horizon h to a one standard-deviation shock.

The term $\sum_{j=1}^{p} \phi_{h,j} y_{i,t-j}$ includes p lags of the dependent variable, and $\sum_{j=1}^{p} \boldsymbol{\gamma}_{h,j}^{\top} \mathbf{x}_{i,t-j}$ adds p lags of a vector of control variables, $\mathbf{x}_{i,t-j}$, which includes real GDP, government consumption, government investment, the income tax rate, and the consumption tax rate. Country fixed effects $\alpha_{i,h}$ control for time-invariant cross-country heterogeneity, while quarter fixed effects $\delta_{t,h}$ capture common shocks and dynamics. The set of controls ensures that the pojections condition on the same information set as the baseline VAR. The residual $\varepsilon_{i,t+h}$ is assumed to have zero mean, and we use heteroskedasticity- and autocorrelation-consistent (HAC) standard errors. Equation (19) is estimated separately for each horizon h and type of fiscal shock.

Figure 6 shows the responses to a positive government investment shock. Private consumption and investment both increase persistently, by about 0.05-0.1% points. Net exports fall for two years. The significant crowding-in of domestic demand dominates the foreign leakage and rationalizes the output multiplier of larger than 1. The demand pressure feeds mildly into domestic inflation, which increases by about 0.05%-points. The real exchange rate (vis-à-vis the rest of the euro area) appreciates strongly and persistently. Hours worked and the real wage rise for nearly two years. The public deficit spikes, while the policy rate stays flat. Overall, the joint increase of quantities and prices suggests strong demand effects on product and labor markets. The empirical responses resemble the theoretical responses qualitatively except for private investment (Figure A.1).

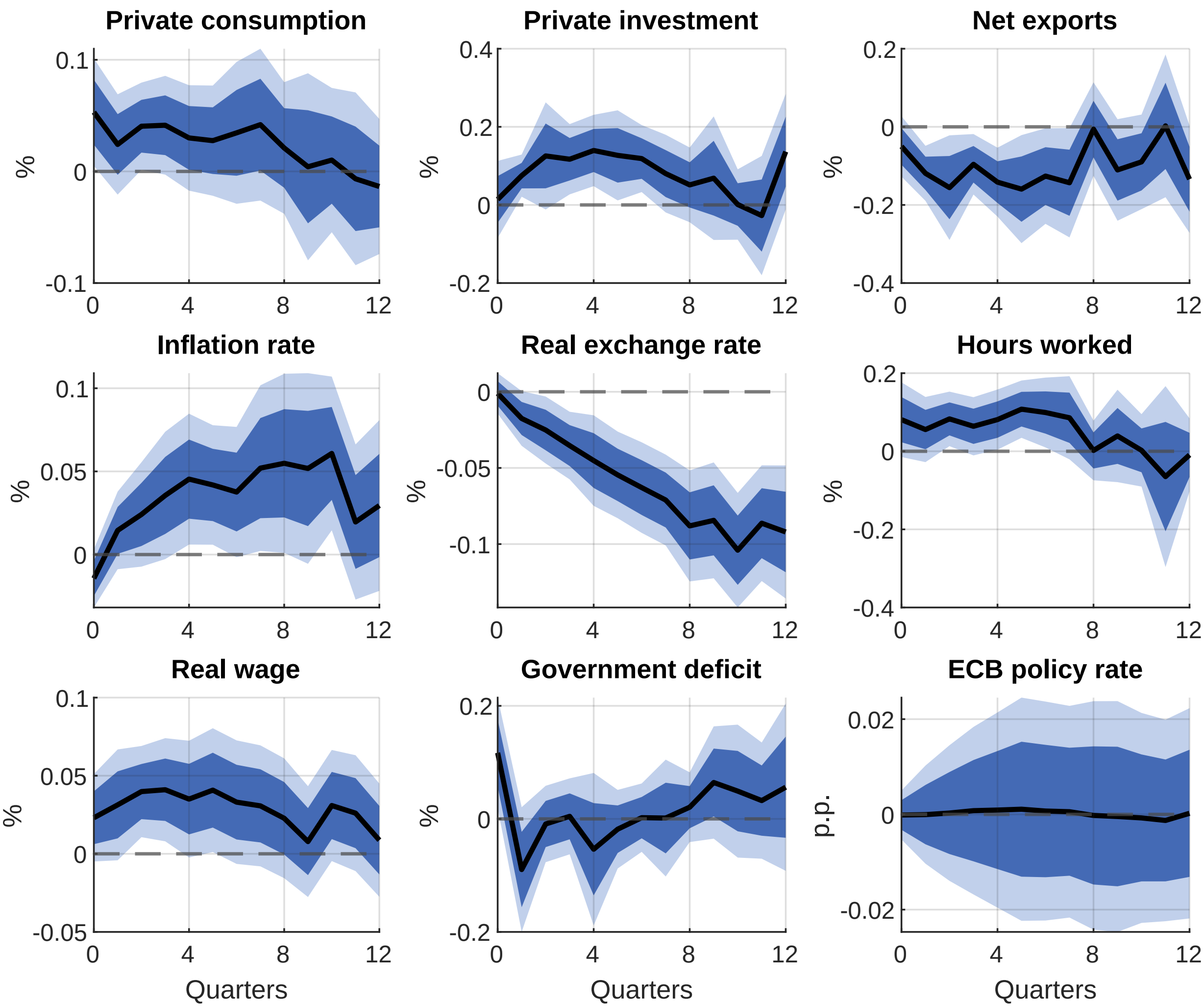

Figure 6: Responses to government investment shock. *Notes*: The figure shows the estimated responses to a positive one standard deviation government investment shock. Shaded regions report 68% and 90% HAC standard errors.

Figure 7 shows the responses to a positive government consumption shock. Private consumption increases strongly, by 0.1%-points upon impact and by 0.2%-points for another two years. Private investment now shows a tendency to fall but the estimates are imprecise. Net exports gradually decline by between 0.1-0.2%-points. The inflation rate rises slowly and peaks at 0.07%-points above trend after 6 quarters. The real exchange rate appreciates strongly and persistently. Hours worked first increase and then undershoot, but the confidence bands mostly cover zero. The real wage rises strongly by more than 0.1%-points for three years. Qualitatively, these responses all align with the theoretical predictions (Figure A.1). Empirically, the government deficit tends to rise over most of the horizon, while the policy rate remains flat. Overall, the empirical patterns resemble those of the government investment shock with notable differences for private consumption and private investment. Public consumption seems to have a strong complementarity with private consumption, while it tends to crowd-out private investment. Public investment, in turn, shows a moderate complementarity with private investment and tends to crowd-in private consumption.

Figure 8 shows the responses to a consumption tax rate cut. The effects are less clear-cut as for the two spending shocks. Private consumption increases marginally before falling below trend. Private investment jumps in the first quarter and then falls below the level where it was before the shock. Net exports fall upon impact and then are back at trend. The inflation rate, the real exchange rate, and hours worked all fall. The response of the real wage is largely insignificant, while the government deficit widens. As before, the monetary response is zero. The effect of consumption taxes on private consumption on the one hand and investment and net exports on the other hand might reflect that consumption taxes are levied on both domestic consumption and imports. If imports are partially investment goods and if these are complements to domestic investment this would explain the mirror image response of domestic private investment and net exports. The cut in VAT taxes together with a sluggish household behavior would then account for the mild increase in private domestic consumption. The falling inflation and exchange rate are consistent with the theoretical idea of a fiscal devaluation but overall the empirical responses are more difficult to square with the theoretical transmission mechanisms of the DSGE model than in case of the fiscal spending shocks.

Finally, Figure 9 shows the responses to an income tax rate cut. Again, these are less clear than for the spending shocks but they do show some of the theoretically expected

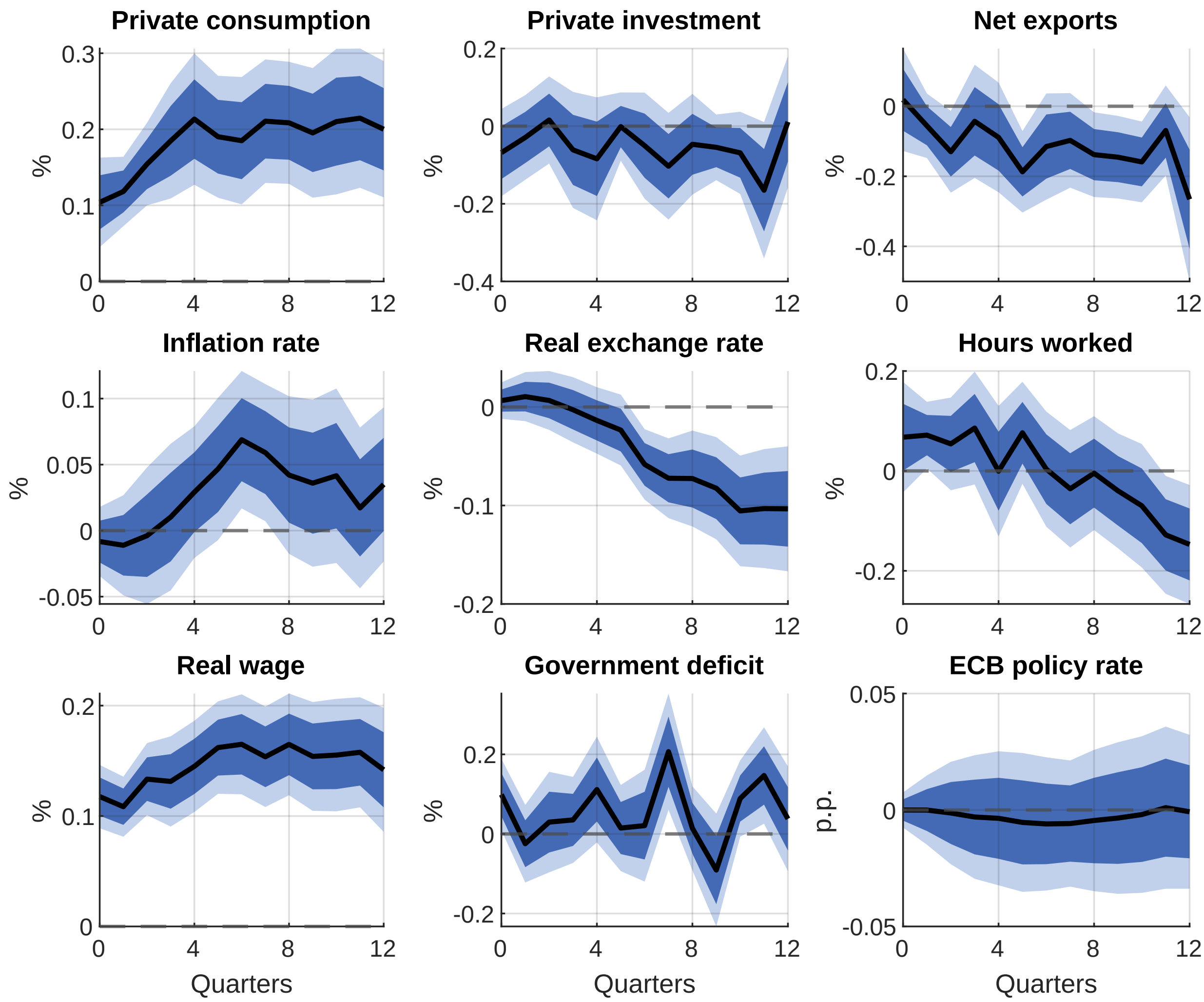

Figure 7: Responses to government consumption shock. *Notes*: The figure shows the estimated responses to a positive one standard deviation government consumption shock. Shaded regions report 68% and 90% HAC standard errors.

patterns. Private consumption does not respond significantly. Instead, private investment increases throughout most of the response horizon. Net exports zigzag around zero and, if anything, show a tendency to increase. The inflation rate falls during the first year but the effect is essentially not differentiable from zero. The real exchange rate depreciates. Hours worked spike shortly, while the real wage falls persistently. The government deficit increases strongly and the policy rate stays fixed again. Together, the responses are in line with the theoretical idea of supply side effects with increasing private investment, net exports, and hours worked versus falling real wage, inflation rate, and exchange rate but most of these effects are small and imprecisely estimated.

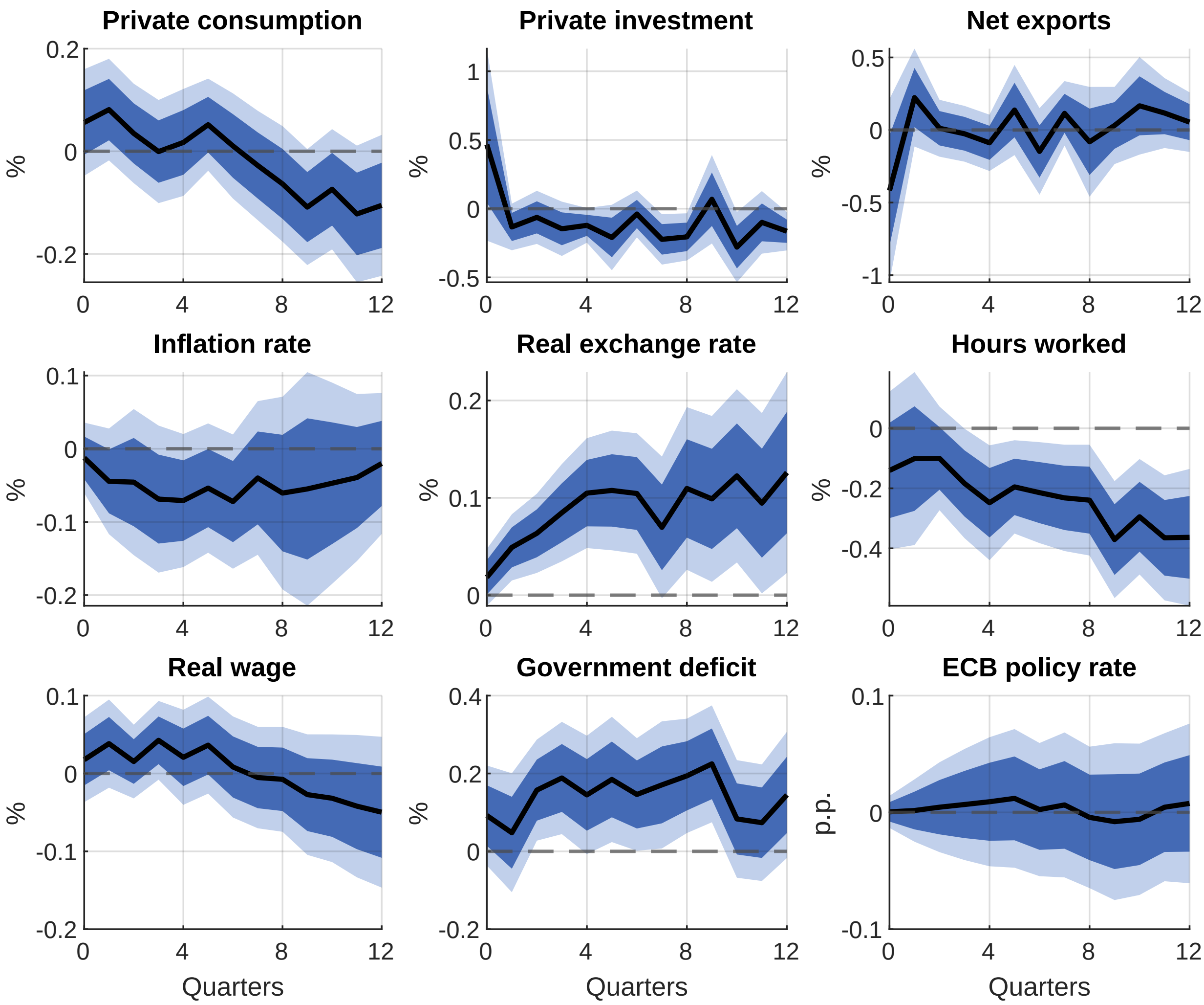

Figure 8: Responses to consumption tax cut. *Notes*: The figure shows the estimated responses to a negative one standard deviation consumption tax rate shock. Shaded regions report 68% and 90% HAC standard errors.

4 Conclusions

We estimate the macroeconomic effects of fiscal shocks for a country in a monetary union. On the public spending side, we differentiate between consumption and investment. On the revenue side, we separate consumption taxes and income taxes. We identify the shocks in a panel structural vector autoregression on quarterly euro area data through time fixed effects and cross-country heteroskedasticity. We find that both spending shocks induce broad-based upswings and have multipliers above 1. Tax cuts have moderate effects on output and other macroeconomic variables but income tax cuts do show patterns of supply-side stimulus. The two tax multipliers are below 0.5 in absolute value.

The empirical findings are consistent with quantitative predictions from a DSGE model

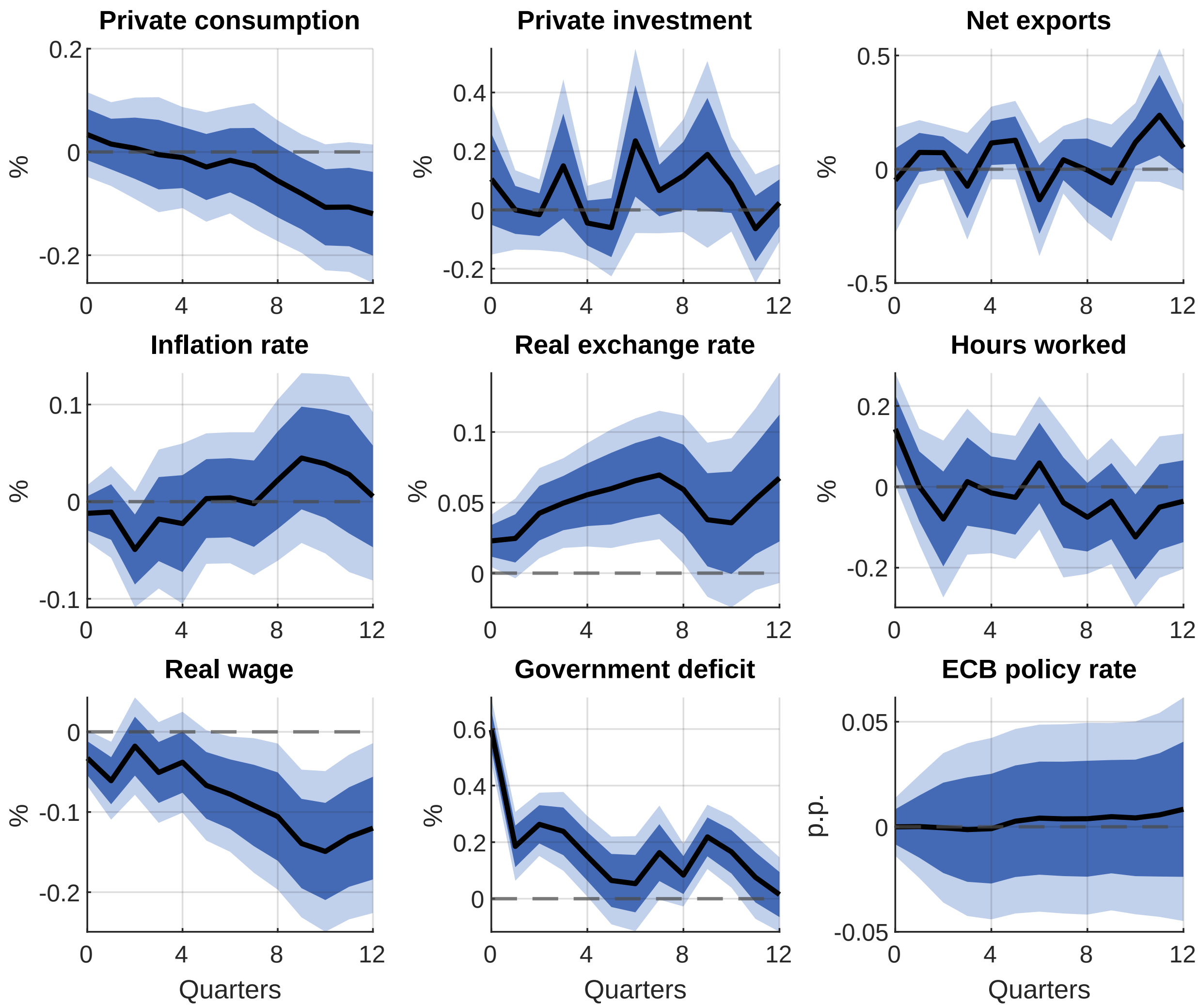

Figure 9: Responses to income tax cut. *Notes*: The figure shows the estimated responses to a negative one standard deviation income tax rate shock. Shaded regions report 68% and 90% HAC standard errors.

of a small open economy belonging to a currency union that is calibrated to the average euro area country. The model predicts that spending multipliers are above 1 and tax mutlipliers below 0.5. One main reason for the differential efficiency of spending and tax policies is that the central bank does not respond to domestic inflation or output. The missing monetary response raises spending multipliers and tends to lower tax multipliers.

Overall, the results suggest that public consumption and public investment are more efficient tools for business cycle stabilization than consumption taxes and income taxes in countries that form a currency union. This short-run advantage of spending policy must be weighted against the risk that secularly growing public sectors and tax burdens in many euro area countries weigh on long-run growth.

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Supplemental Appendix to 'Aggregate Tax and Spending Multipliers in a Monetary Union'

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June 23, 2026

A Data

Table A.1: Detailed description of data used in the analysis

Variable	Description	Notes	Source
real GDP	Real gross domestic product	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP (trend estimated via a 4th-order polynomial).	Eurostat
Income tax rate	Average effective income tax rate: total current tax revenues on the income and wealth of households and firms divided by total household and firm income (tax base)	Quarterly frequency. Seasonally adjusted. Taxes refer to the general government (federal, state, local).	Eurostat
Consumption tax rate	Average effective consumption tax rate: total tax revenues from production (VAT and import duties) divided by final consumption expenditure (tax base)	Quarterly frequency. Seasonally adjusted. Taxes refer to the general government (federal, state, local).	Eurostat
Government consumption	Government consumption expenditures: compensation of employees and intermediate consumption	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP. General government series.	Eurostat

Continued on next page

Variable	Description	Notes	Source
Government investment	Government investment expenditures: gross fixed capital formation	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP. General government series.	Eurostat
Private consumption	Final consumption expenditure of households	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
Private investment	Gross fixed capital formation excluding the general government sector	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
Net exports	Exports less imports	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
Inflation rate	Annual HICP inflation rate	Quarterly frequency. Enters in percent.	Eurostat
Real exchange rate	Real effective exchange rate with respect to the euro area economies.	Quarterly frequency.	Eurostat
Net exports	Exports of goods and services less imports of goods and services	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
Real wage	Wages and salaries	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
Hours worked	Total hours worked in all NACE activities	Quarterly frequency. Seasonally adjusted. Enters as index based on hours worked in 2015=100.	Eurostat
Government deficit	Revenues less expenditures of general government	Quarterly frequency. Seasonally adjusted. Enters in real per-capita terms and scaled by trend GDP.	Eurostat
ECB policy rate	ECB main refinancing operations rate	Quarterly frequency. End-of-period of daily values.	Macrobond Financial AB
10-year yield	10-year nominal government bond yield	Quarterly frequency. End-of-period of monthly values.	Fedaral Reserve Economic Data (FRED)
Stock market index	MSCI country index	Quarterly frequency. End-of-period of daily values.	Macrobond Financial AB

B Supplement DSGE model

B.1 Additional results

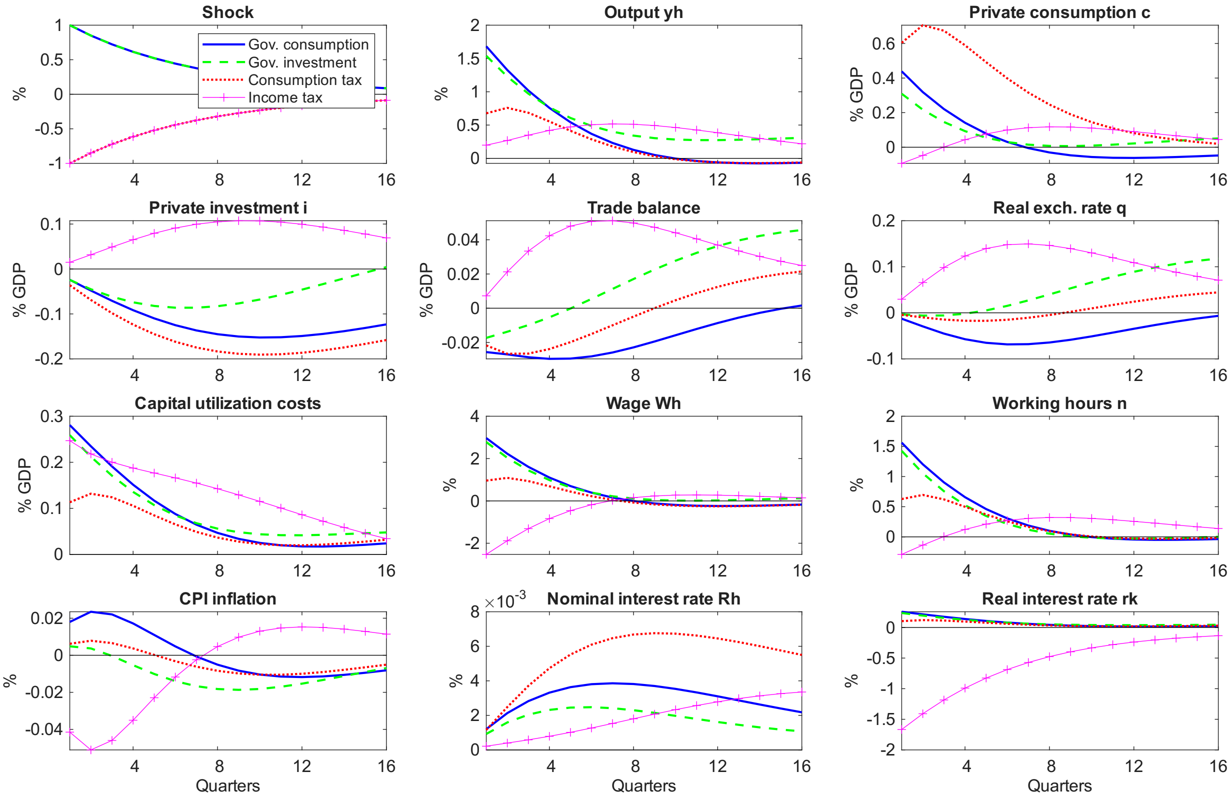

Figure A.1: Theoretical responses to fiscal shocks. *Notes:* The figure shows the responses of selected endogenous variables of the DSGE model of Section 2 to four fiscal shocks over 16 quarters. The shocks are normalized to 1% of GDP upon impact.

B.2 Nonlinear equilibrium

Consumption and labor supply of savers:

$$\begin{aligned}(1+\tau_t^c)\lambda_t &= (c_t^{*S} - hc_{t-1}^{*S})^{-1} \\ c_t^{*S} &= c_t^S + \omega g_t \\ (1-\tau_t^y)\lambda_t w_t^h &= \chi n_t^\eta.\end{aligned}$$

Non-saver budget constraint and total consumption:

$$\begin{aligned}(1+\tau_t^c)c_t^N &= (1-\tau_t^y)\, w_t^h n_t + z_t \\ c_t &= (1-\mu)c_t^S + \mu c_t^N.\end{aligned}$$

Nominal investment decisions for domestic and foreign private short-term bonds and domestic public long-term bonds:

$$\begin{aligned}\lambda_t &= \beta R_t^H E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) \\ \lambda_t q_t &= \beta R_t^F \Upsilon_t E_t\left(\frac{\lambda_{t+1} q_{t+1}}{\pi_{t+1}^*}\right) \\ \lambda_t P_t^B &= \beta E_t\left(\frac{1+\rho P_{t+1}^B}{\pi_{t+1}}\right),\end{aligned}$$

where $q_t = \frac{S_t P_t^*}{P_t}$ is the real exchange rate and π_t^* foreign CPI inflation.

Physical capital and investment:

$$\begin{aligned}\lambda_t &= \lambda_t\lambda_t^k[1 - A(i_t/i_{t-1}) - A'(i_t/i_{t-1})i_t/i_{t-1}] + \beta E_t[\lambda_{t+1}\lambda_{t+1}^k A'(i_{t+1}/i_t)(i_{t+1}/i_t)^2] \\ \tilde{k}_t &= (1-\delta)\,\tilde{k}_{t-1} + i_t\Phi_t \\ \lambda_t\lambda_t^k &= \beta E_t\left[\lambda_{t+1}(1-\tau_{t+1}^y)r_{t+1}^k\nu_{t+1} - \lambda_{t+1}\psi(\nu_t) + \lambda_{t+1}\lambda_{t+1}^k\,(1-\delta)\right] \\ (1-\tau_t^y)r_t^k &= \psi'(\nu_t) \\ k_t &= \nu_t\tilde{k}_{t-1} \\ k_t^G &= \left(1-\delta^G\right)\,k_{t-1}^G + i_t^G,\end{aligned}$$

where $A(\frac{i_t}{i_{t-1}}) = \frac{\kappa}{2}\left(1 - \frac{i_t}{i_{t-1}}\right)^2$.

Production function, capital-labor ratio, and marginal costs:

$$
\begin{aligned}
y_{H,t}pd_t &= k_t^{\alpha} n_t^{1-\alpha} (k_t^G)^{\zeta} - \bar{o} \\
\frac{k_t}{n_t} &= \frac{\alpha}{1-\alpha} \frac{w_t}{r_t^k} \\
mc_t &= (k_t^G)^{-\zeta} w_t^{1-\alpha} (r_t^k)^{\alpha} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^{\alpha},
\end{aligned}
$$

where pd_t stands for price dispersion.

First-order condition for producer prices, PPI index, definition of relative price and CPI inflation:

$$
\begin{aligned}
0 &= E_t \sum_{s=0}^{\infty} (\phi\beta)^s \lambda_{t+s} y_{H,t+s}^i \left[(1-\epsilon) \check{p}_{H,t} Q_{t,s} + \epsilon mc_{t+s} \right] \\
y_{H,t+s}^i &= \left(\frac{\check{P}_{H,t}^i Q_{t,s}}{P_{H,t+s}} \right)^{-\epsilon} y_{H,t+s} \\
1 &= (1-\phi) \check{p}_{H,t}^{1-\epsilon} + \phi \left[(\pi_{H,t-1})^{\iota} \pi^{1-\iota} \pi_{H,t}^{-1} \right]^{1-\epsilon} \\
p_{H,t} &= \left(\frac{1 - \vartheta q_t^{1-\gamma}}{1-\vartheta} \right)^{\frac{1}{1-\gamma}} \\
\pi_t &= \pi_{H,t} \left(\frac{1 - \vartheta q_t^{1-\gamma}}{1 - \vartheta q_{t-1}^{1-\gamma}} \right)^{\frac{1}{\gamma-1}},
\end{aligned}
$$

where $\check{p}_{H,t} \equiv \check{P}_{H,t} / P_{H,t}$.

First-order condition for wage inflation, labor aggregation, and aggregate wage index:

$$
\begin{aligned}
0 &= E_t \sum_{s=0}^{\infty} (\phi_w \beta)^s \frac{P_t}{\lambda_t} \left[\begin{array}{c} \frac{\lambda_{t+s}}{P_{t+s}} \frac{W_{t+s}}{W_t} (1-\epsilon_w) \check{W}_t^{1-\epsilon_w} \left(\frac{Q_{t,s}^w}{W_{t+s}} \right)^{1-\epsilon_w} n_{t+s}^d \\ + \frac{\chi n_{t+s}^{\eta}}{(1-\tau_{t+s}^y) W_t} \epsilon_w \check{W}_t^{-\epsilon_w} \left(\frac{Q_{t,s}^w}{W_{t+s}} \right)^{-\epsilon_w} n_{t+s}^d \end{array} \right] \\
n_t &= n_t^d wd_t \\
1 &= (1-\phi_w) \check{w}_t^{1-\epsilon_w} + \phi_w \left[\frac{(\pi_{t-1})^{\iota_w} \pi^{1-\iota_w}}{\pi_{w,t}} \right]^{1-\epsilon_w},
\end{aligned}
$$

where wd_t is wage dispersion, $\check{w}_t \equiv \check{W}_t / W_t$, and $\pi_{w,t} \equiv W_t / W_{t-1}$.

Government budget constraint and transfer rule:

$$
\begin{aligned}
b_t + \tau_t^y r_t^k k_t + \tau_t^y w_t^h n_t + \tau_t^c c_t &= (1 + P_t^B \rho) \frac{b_{t-1}}{P_{t-1}^B \pi_t} + z_t + p_{H,t}(i_t^G + g_t) \\
\frac{z_t}{z} &= \left(\frac{z_{t-1}}{z} \right)^{\phi_z} \left(\frac{d_{t-1}}{d} \right)^{(1-\phi_z)\phi_d}
\end{aligned}
$$

Market clearing and net foreign assets:

$$
\begin{aligned}
y_t &= c_t + i_t + \psi(\nu_t) \tilde{k}_{t-1} \\
y_{H,t} &= (1 - \vartheta) \left(p_{H,t} \right)^{-\gamma} y_t + \vartheta^* \left(\frac{p_{H,t}}{q_t} \right)^{-\gamma^*} y_t^* + i_t^G + g_t \\
q_t \left(\frac{b_t^F}{R_t^F \Upsilon_t} - \frac{b_{t-1}^F}{\pi_t^*} \right) &= q_t^{\gamma^*} p_{H,t}^{1-\gamma^*} \vartheta^* y_t^* - \vartheta q_t^{1-\gamma} y_t.
\end{aligned}
$$

Exogenous processes:

$$
\begin{aligned}
\hat{f}_t &= \rho_f \hat{f}_{t-1} + \varepsilon_{f,t}, \quad \rho_f \in [0, 1), \quad \varepsilon_{f,t} \sim N(0, \sigma_f^2), \quad f = i^G, g, \tau^c, \tau^y \\
S_t &= S, \quad R_t^F = R^F, \quad \pi_t^* = \pi^* \quad y_t^* = y^* \quad \forall\ t
\end{aligned}
$$

B.3 Steady state

Calibrated values: $g/y_H, i^G/y_H, b/y_H, \tau^c, \tau^y, \pi, \rho, \pi^*, \Upsilon = 1, q = 1, n = 0.3, b^F = 0, \nu = 1$.

$$
\begin{aligned}
R^H &= \pi/\beta \\
R^F &= \pi^*/\beta \\
P^B &= \frac{\beta/\pi}{1-\rho\beta/\pi} \\
\lambda^k &= 1 \\
p_H &= 1 \\
\pi_H &= \pi \\
mc &= \frac{\epsilon-1}{\epsilon} \\
r^k &= \frac{\lambda^k(1/\beta+\delta-1)}{1-\tau^y} \\
\psi'(1) &= (1-\tau^y)r^k \\
k^G &= \frac{i^G}{y_H\delta} \\
w &= \left(\frac{\alpha^\alpha (1-\alpha)^{1-\alpha} mc(k^G)^\zeta}{(r^k)^\alpha}\right)^{\frac{1}{1-\alpha}} \\
k &= \frac{\alpha w n^d}{(1-\alpha)\, r^k} \\
\bar{o} &= k^\alpha n^{1-\alpha}(k^G)^\zeta - wn - r^k k \\
y_H &= k^\alpha n^{1-\alpha}(k^G)^\zeta - \bar{o} \\
i &= k\delta \\
c &= p_H(y_H - i^G - g - i) \\
\vartheta^* y^* &= \vartheta(c+i) \\
w^h &= \frac{w(\epsilon_w - 1)}{\epsilon_w} \\
c^N &= \frac{(1-\tau^y)w^h n - z}{1+\tau^c} \\
c^S &= \frac{c-\mu c^N}{1-\mu} \\
c^{*S} &= c^S + \omega\frac{g}{y_H} y_H \\
z &= \tau^c c + \tau^y(w^h n + r^k k) - i^G - g + b(1-R^H) \\
\vartheta^* y^* &= y_H - c - i - i^G - g \\
\lambda &= \frac{1}{c(1-h)} \\
\chi &= \frac{(1-\tau^y)\lambda w^h}{n^\eta}
\end{aligned}
$$

B.4 Linear equilibrium

For a generic variable x_t, the log-deviation from its steady state x is defined as $\hat{x}_t \equiv log(x_t) - log(x)$. The log-linearized equilibrium conditions are the following:

$$\hat{\lambda}_t + \frac{\tau^c}{1+\tau^c}\,\hat{\tau}^c_t = -\frac{1}{1-h}\,\left(\hat{c}^{*S}_t - h\,\hat{c}^{*S}_{t-1}\right) \tag{A.1}$$

$$\hat{c}^{*S}_t = \frac{c^S}{c^S+\omega\,g}\,\hat{c}^S_t + \frac{\omega\,g}{c^S+\omega\,g}\,\hat{g}_t \tag{A.2}$$

$$\hat{w}^h_t + \hat{\mu}^w_t = \hat{w}_t \tag{A.3}$$

$$\eta\,\hat{n}_t = \hat{\lambda}_t + \hat{w}^h_t - \frac{\tau^y}{1-\tau^y}\,\hat{\tau}^y_t \tag{A.4}$$

$$\tau^c c^N \hat{\tau}^c_t + (1+\tau^c)\;c^N\,\hat{c}^N_t = (1-\tau^y)\;w\,n\,\left(\hat{w}^h_t + \hat{n}_t\right) - n\,\tau^y\,w^h\hat{\tau}^y_t + z\,\hat{z}_t \tag{A.5}$$

$$c\,\hat{c}_t = c^S\;(1-\mu)\,\hat{c}^S_t + c^N\,\mu\hat{c}^N_t \tag{A.6}$$

$$\hat{\lambda}_t + \hat{\lambda}^k_t = E_t\left[\hat{\lambda}_{t+1} + \beta\;(1-\delta)\;\hat{\lambda}^k_{t+1} + (1-\beta\;(1-\delta))\;\hat{r}^k_{t+1} - \frac{\tau^y\,\beta\,r^k}{\lambda^k}\,\hat{\tau}^y_{t+1}\right] \tag{A.7}$$

$$\kappa\,\left(\hat{i}_t - \hat{i}_{t-1}\right) = \hat{\lambda}^k_t + \beta\,\kappa\,E_t\left(\hat{i}_{t+1} - \hat{i}_t\right) \tag{A.8}$$

$$\hat{\bar{k}}_t = (1-\delta)\;\hat{\bar{k}}_{t-1} + \delta\,\hat{i}_t \tag{A.9}$$

$$-\frac{\tau^y}{1-\tau^y}\hat{\tau}^y_t + \hat{r}^k_t = \frac{\tilde{\psi}}{1-\tilde{\psi}}\,\hat{\nu}_t \tag{A.10}$$

$$\hat{k}_t = \hat{\bar{k}}_{t-1} + \hat{\nu}_t \tag{A.11}$$

$$\hat{k}^G_t = (1-\delta)\;\hat{k}^G_{t-1} + \delta\,\hat{i}^G_t \tag{A.12}$$

$$\hat{y}_{H,t} = \frac{y_H + \bar{o}}{y_H}\,\left(\alpha^G\hat{k}^G_{t-1} + \alpha\hat{k}_t + (1-\alpha)\,\hat{n}_t\right) \tag{A.13}$$

$$\hat{k}_t - \hat{n}_t = \hat{w}_t - \hat{r}^k_t \tag{A.14}$$

$$\hat{mc}_t = (1-\alpha)\,\hat{w}_t + \alpha\hat{r}^k_t - \alpha^G\hat{k}^G_{t-1} \tag{A.15}$$

$$\hat{\pi}_{H,t} = \frac{\frac{(1-\phi)\,(1-\beta\,\phi)}{1+\beta\,\iota}}{\phi}\,\left(\hat{mc}_t + \frac{\vartheta}{1-\vartheta}\,\hat{q}_t\right) + \frac{\iota}{1+\beta\,\iota}\,\hat{\pi}_{H,t-1} + \frac{\beta}{1+\beta\,\iota}\,E_t\hat{\pi}_{H,t+1} \tag{A.16}$$

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\vartheta}{1-\vartheta}\,(\hat{q}_t - \hat{q}_{t-1}) \tag{A.17}$$

$$\hat{\pi}_t + \hat{w}_t - \hat{w}_{t-1} - \iota_w\,\hat{\pi}_{t-1} = \beta\,E_t\,(\hat{w}_{t+1} + \hat{\pi}_{t+1} - \hat{w}_t - \iota_w\hat{\pi}_t) - \frac{(1-\beta\,\phi)\,(1-\phi)}{\phi}\hat{\mu}_t^w \tag{A.18}$$

$$\hat{\lambda}_t - E_t\hat{\lambda}_{t+1} = \hat{R}_t^H - E_t\hat{\pi}_{t+1} \tag{A.19}$$

$$\hat{R}_t^H + \hat{P}_t^B = \frac{\rho}{R^H}\,E_t\hat{P}_{t+1}^B \tag{A.20}$$

$$\hat{\lambda}_t - E_t\hat{\lambda}_{t+1} = \hat{R}_t^F - \frac{\varphi}{y_H}\hat{b}_t^F - E_t\hat{\pi}_{t+1}^* + E_t\hat{q}_{t+1} - \hat{q}_t \tag{A.21}$$

$$\begin{aligned} &b\,\hat{b}_t + \tau^c\,c\,(\hat{\tau}_t^c + \hat{c}_t) + n\,\tau^y\,w^h\,(\hat{n}_t + \hat{w}_t^h + \hat{\tau}_t^y) + \tau^y\,r^k\,k\,\left(\hat{k}_t + \hat{\tau}_t^y + \hat{r}_t^k\right) \\ &= z\,\hat{z}_t + g\,p_H\,\left(\hat{g}_t - \frac{\vartheta}{1-\vartheta}\,\hat{q}_t\right) + p_H\,i^G\,\left(\hat{i}_t^G - \frac{\vartheta}{1-\vartheta}\,\hat{q}_t\right) + \frac{R^H\,b}{\pi}\,\left(\hat{b}_{t-1} - \hat{\pi}_t - \hat{P}_{t-1}^B\right) + \rho\,b\hat{P}_t^B \end{aligned} \tag{A.22}$$

$$\hat{z}_t = \phi_z\,\hat{z}_{t-1} + (1-\phi_z)\,\phi_b\,\left(\hat{b}_{t-1} - \hat{y}_{H,t}\right) \tag{A.23}$$

$$0 = \hat{\pi}_t - \hat{\pi}_t^* + \hat{q}_t - \hat{q}_{t-1} \tag{A.24}$$

$$\begin{aligned} y_H\hat{y}_{H,t} = &\left(\vartheta\,\gamma\,(c+i) + \frac{\gamma^*\,\vartheta^*y^*}{1-\vartheta}\right)\hat{q}_t \\ &+ (1-\vartheta)\,\left(c\,\hat{c}_t + i\hat{i}_t + k\,(1-\tau^y)\,r^k\hat{\nu}_t\right) + i^G\hat{i}_t^G + g\,\hat{g}_t + \vartheta^*y^*\hat{y}_t^* \end{aligned} \tag{A.25}$$

$$\begin{aligned} \frac{-\hat{b}_t^F}{R^H} + \frac{\hat{b}_{t-1}^F}{\pi^*} = &\,\vartheta\,\left(c\,\hat{c}_t + i\hat{i}_t + k\,(1-\tau^y)\,r^k\hat{\nu}_t\right) + (c+i)\,\vartheta\,(1-\gamma)\,\hat{q}_t \\ &- \vartheta^*y^*\left[\left(1 + \frac{\vartheta\,(1-\gamma^*)}{\vartheta-1}\right)\hat{q}_t + \hat{y}_t^*\right] \end{aligned} \tag{A.26}$$

$$\hat{g}_t = \rho_g\,\hat{g}_{t-1} + \epsilon_{g\,t} \tag{A.27}$$

$$\hat{i}_t^G = \rho_{i^G}\,\hat{i}_{t-1}^G + \epsilon_{i^G\,t} \tag{A.28}$$

$$\hat{\tau}_t^c = \rho_{\tau^c}\,\hat{\tau}_{t-1}^c + \epsilon_{\tau^c\,t} \tag{A.29}$$

$$\hat{\tau}_t^y = \rho_{\tau^y}\,\hat{\tau}_{t-1}^y + \epsilon_{\tau^y\,t} \tag{A.30}$$

and $\hat{R}_t^F = \hat{\pi}_t^* = \hat{y}_t^* = 0$.

C Supplement SVAR analysis

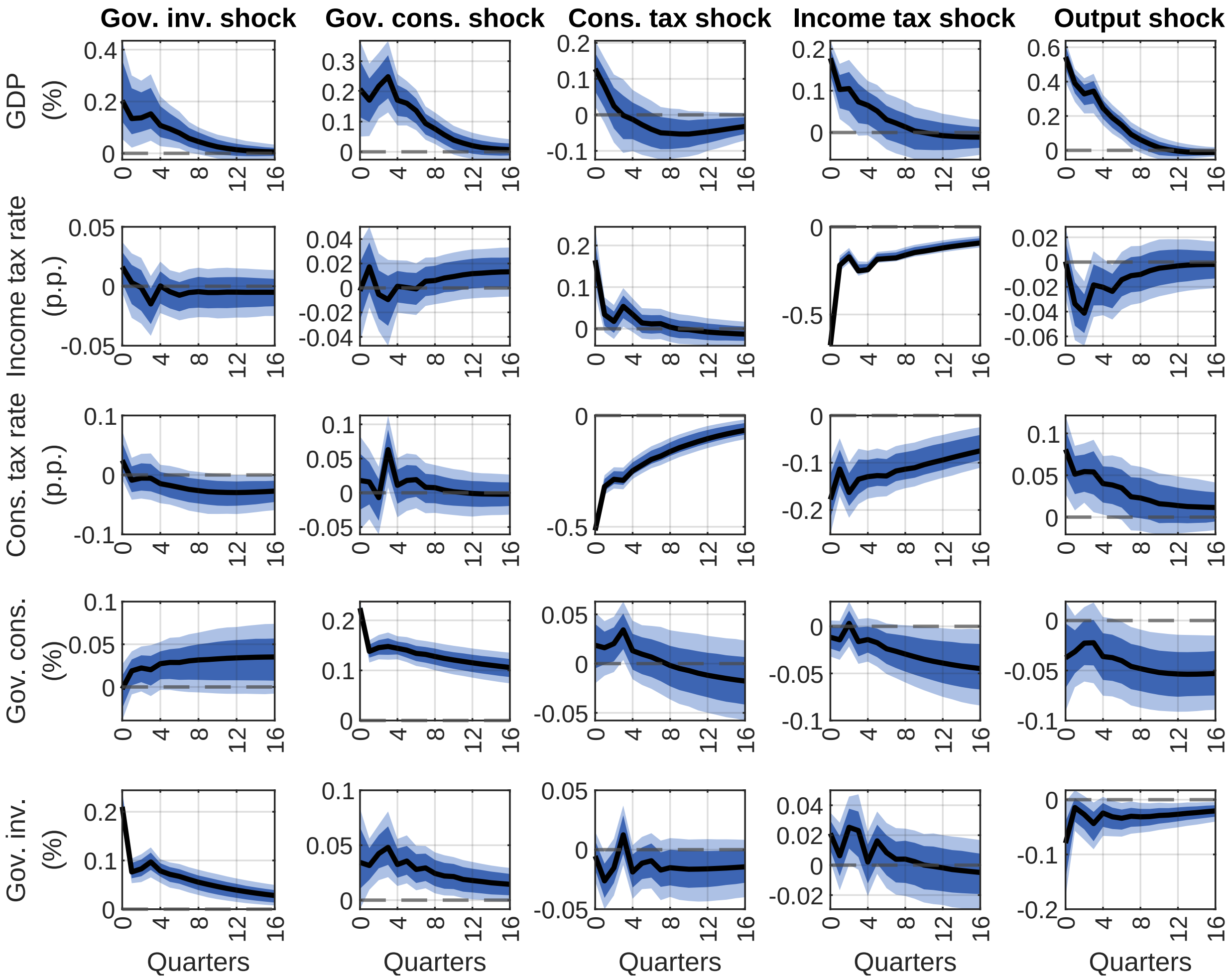

Figure A.2: All responses of baseline model. *Notes*: The figure shows the estimated responses of the endogenous variables (in rows) to the structural shocks (in columns) of the baseline model. The shaded areas are 68% and 90% bootstrapped standard errors

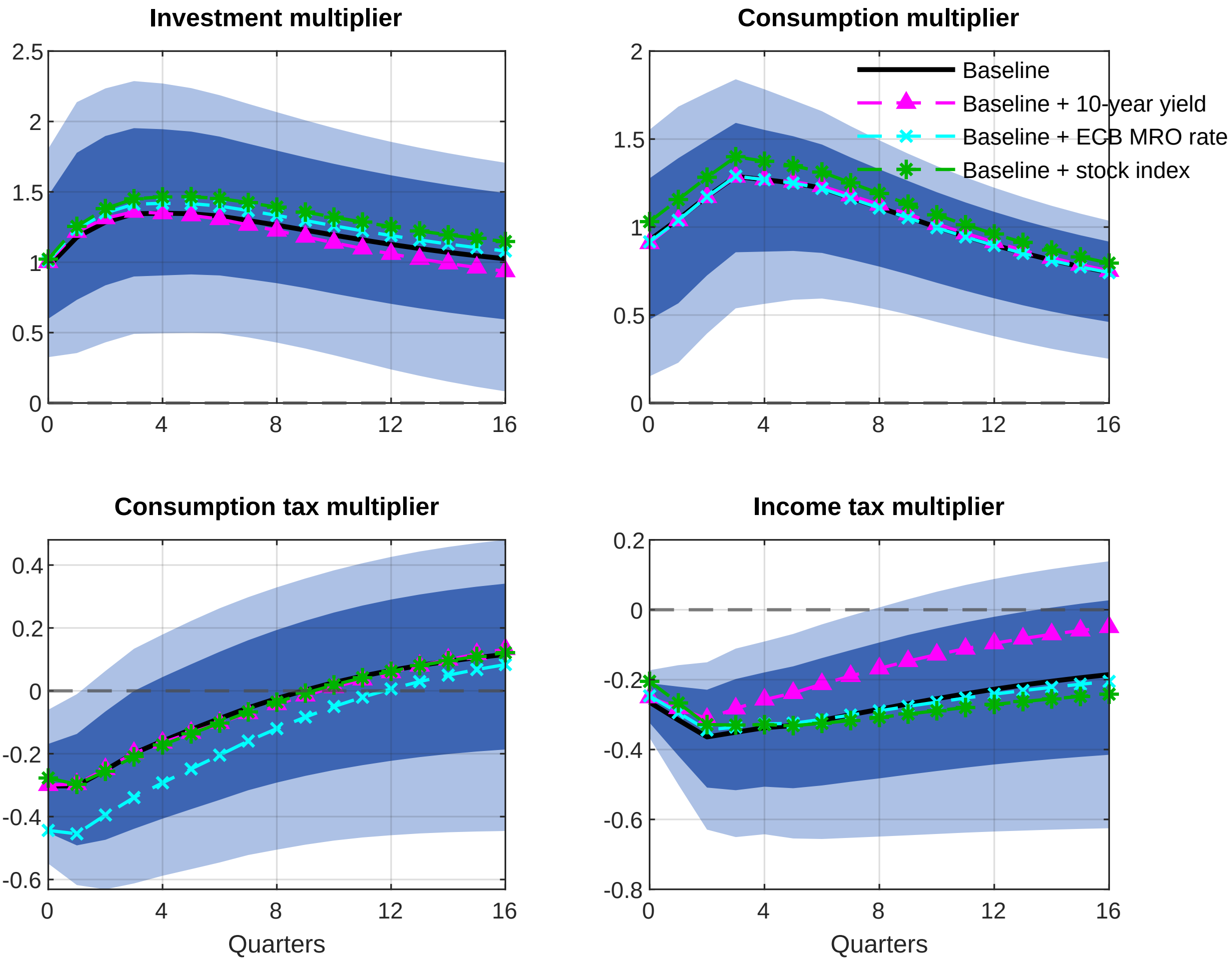

Figure A.3: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to specifications that augment the baseline VAR model with an additional variable: the 10-year government bond yield, the ECB policy rate, and a stock market index. The multipliers are computed as the cumulative sum of the GDP response divided by the cumulative sum of the response of the fiscal variable to the shock. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

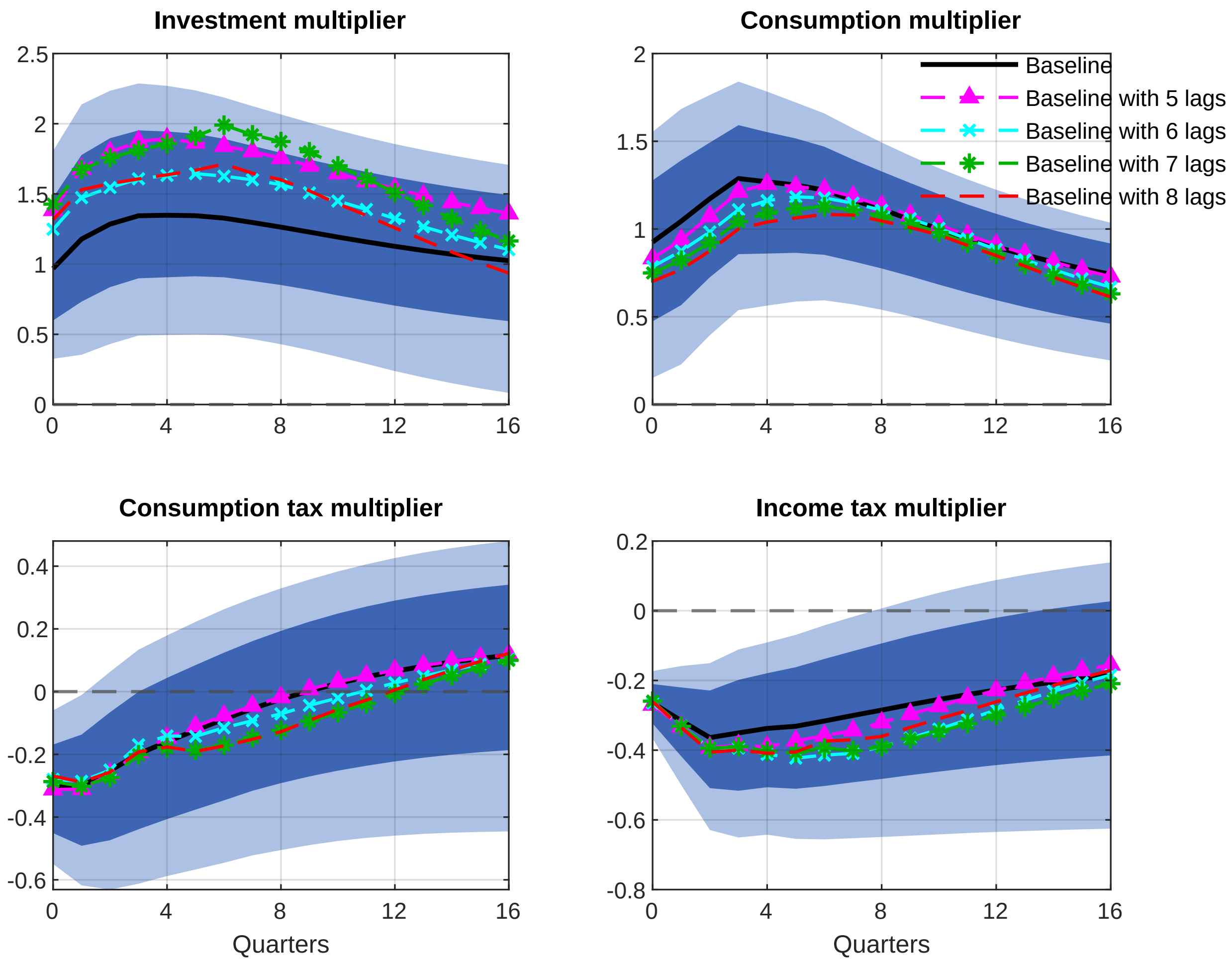

Figure A.4: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to specifications with different lag numbers of endogenous variables in the VAR. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

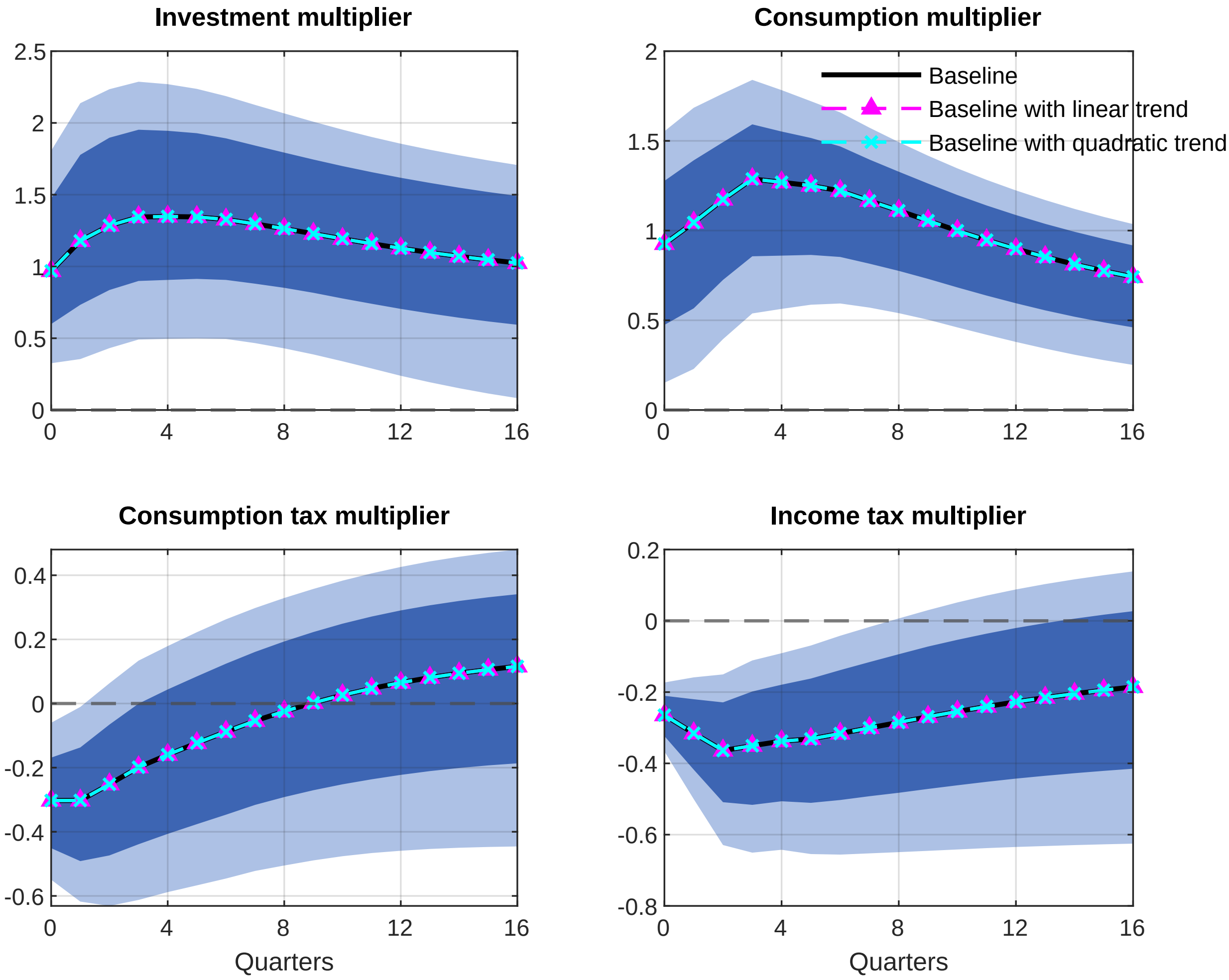

Figure A.5: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to specifications with a linear or quadratic trend included in the VAR. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

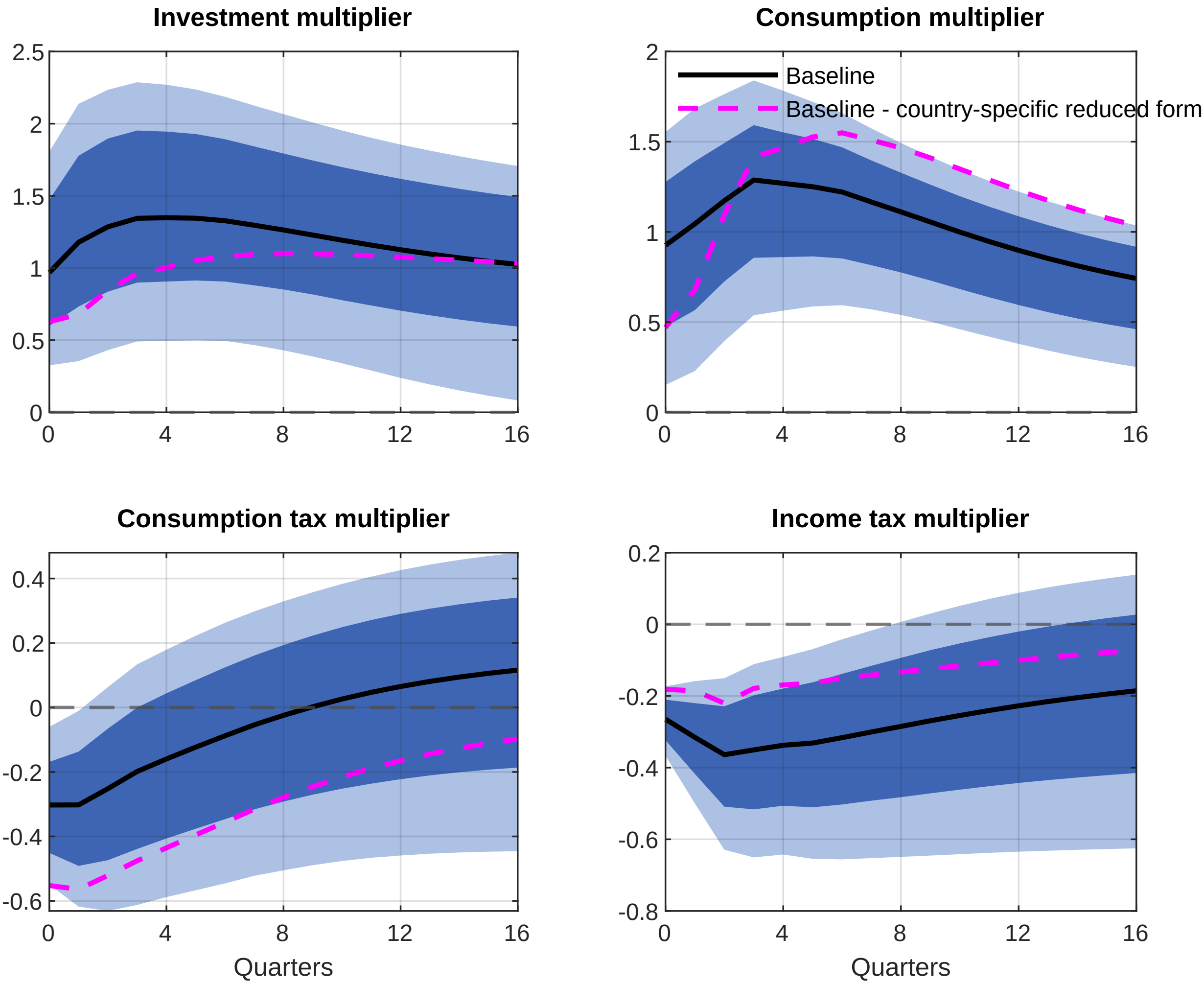

Figure A.6: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to a specification where the reduced-form is estimated for each country seperately. This specification checks sensitivity of the homogenous coefficients asumption of the reduced-form estimation. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

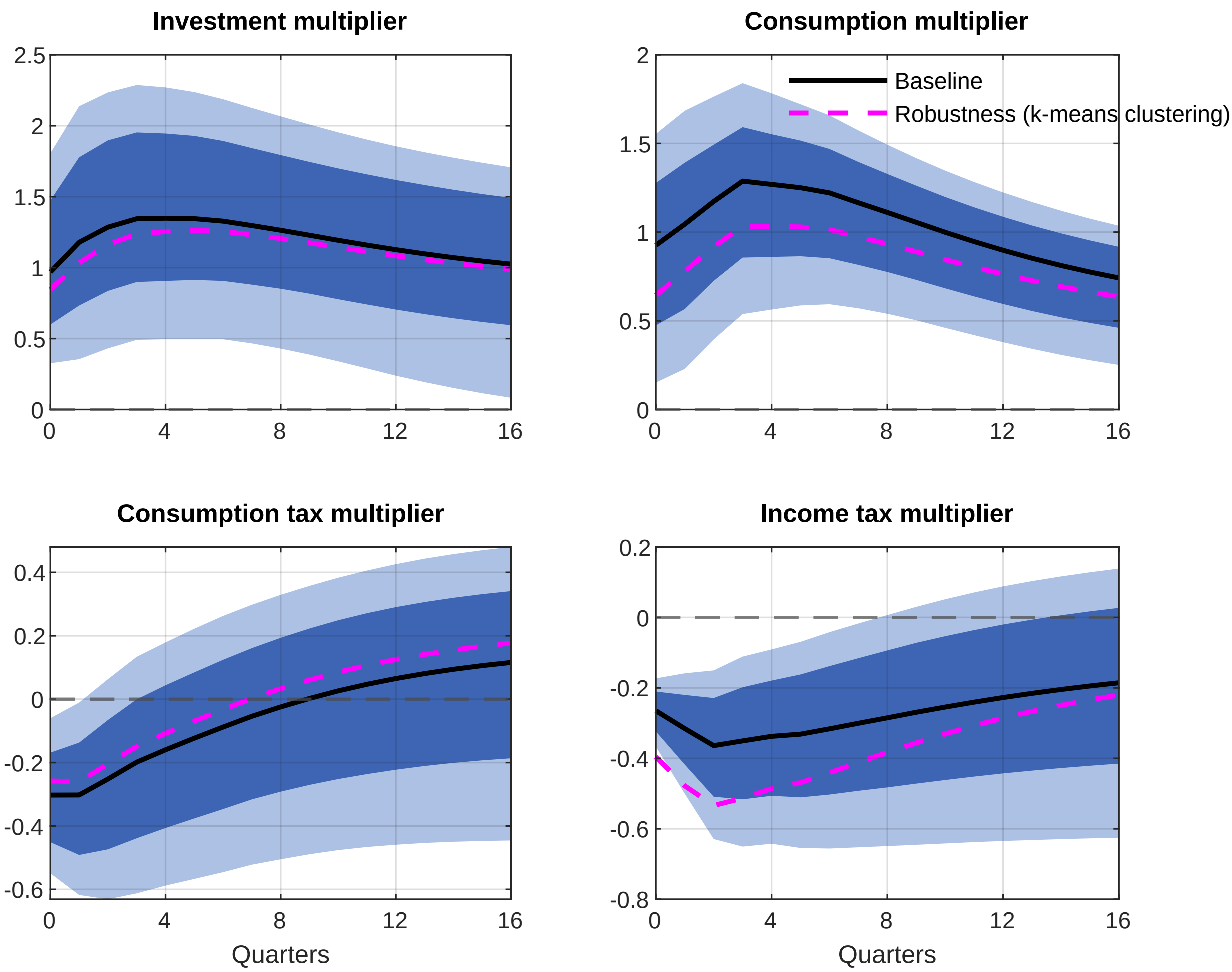

Figure A.7: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to a specification where the volatility grouping is determined by an unsupervised machine learning algorithm, specifically the k-means clestering algorithm. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

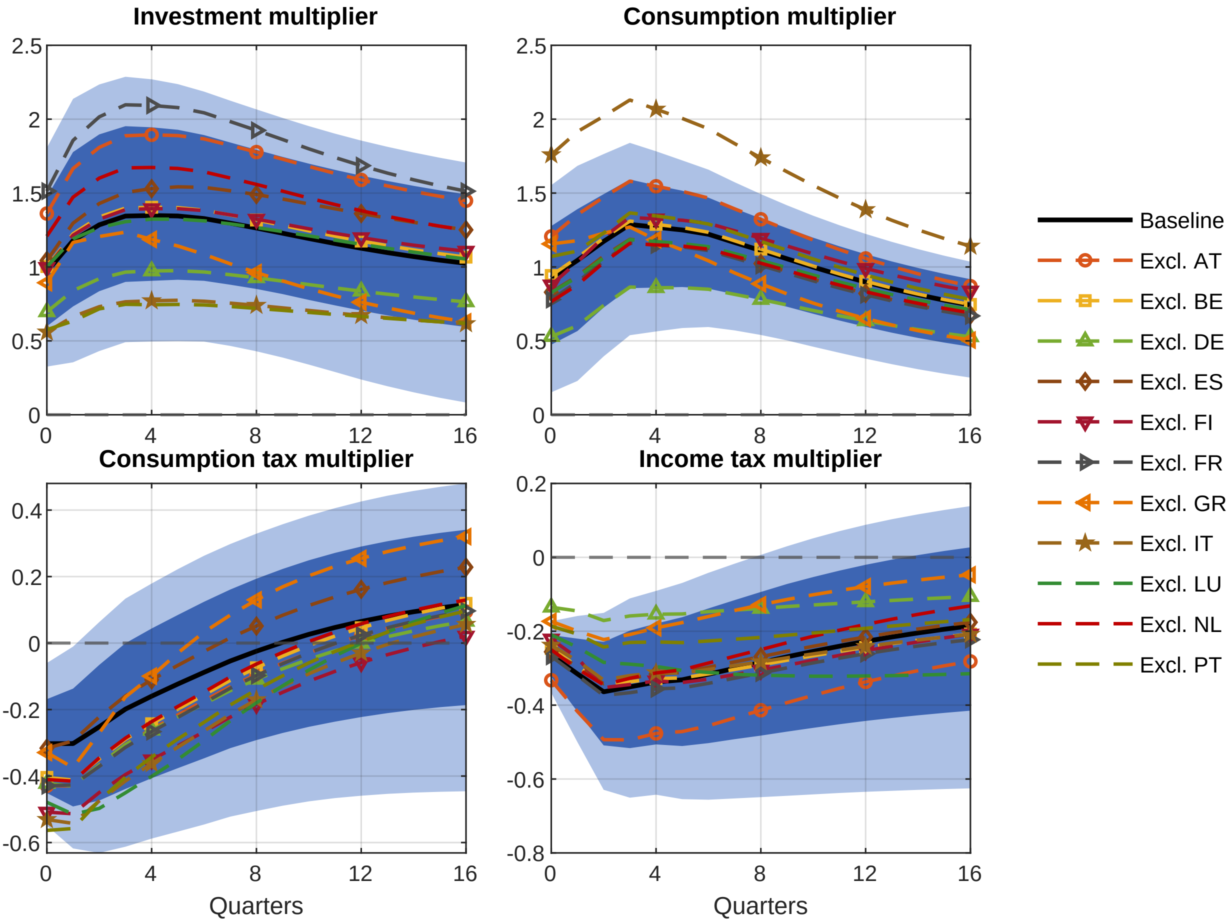

Figure A.8: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to specifications that sequentially exclude one country at a time from the country sample. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

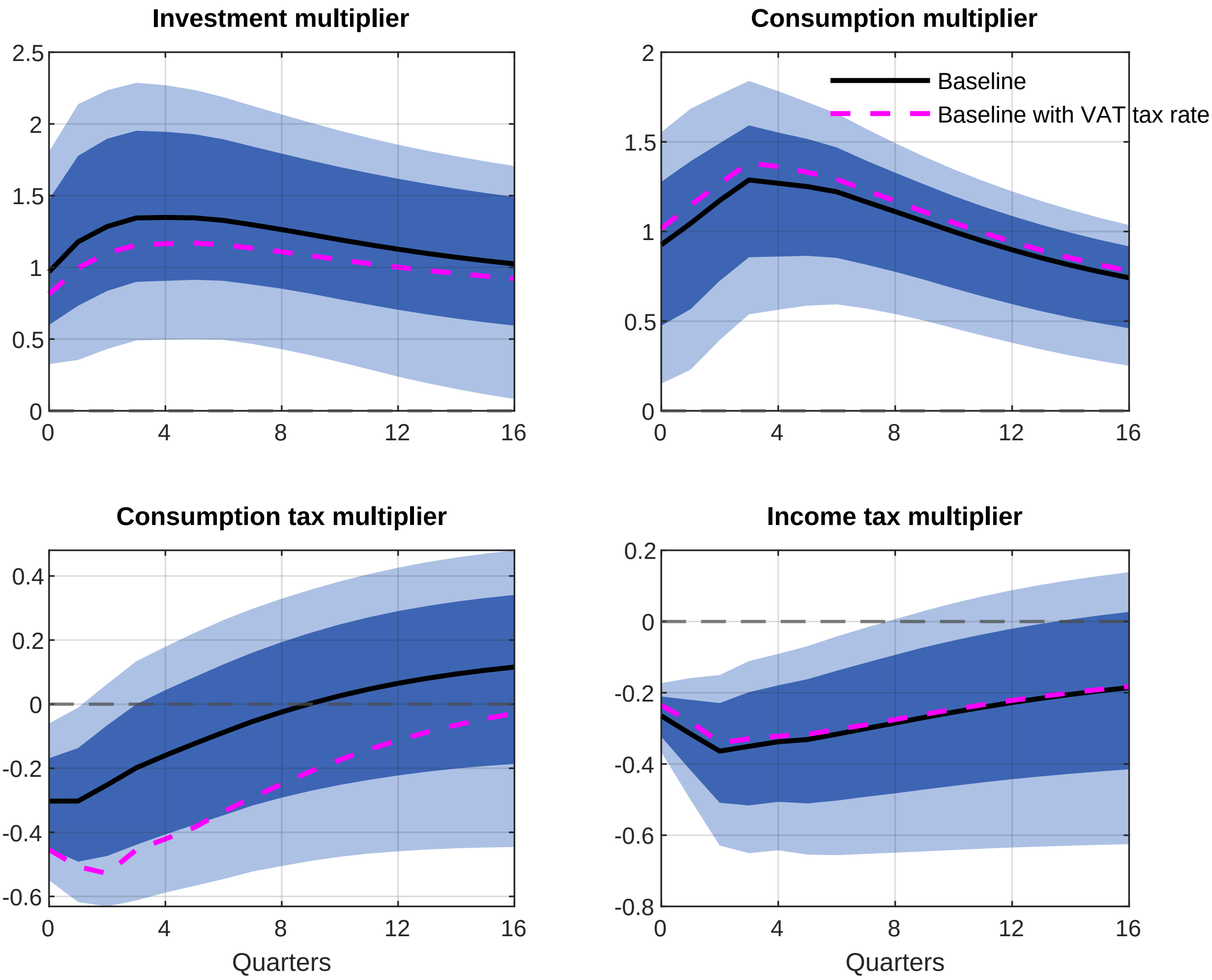

Figure A.9: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to a specification in which the consumption tax rate is constructed using value-added tax (VAT) revenues only, thereby excluding import duties. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.

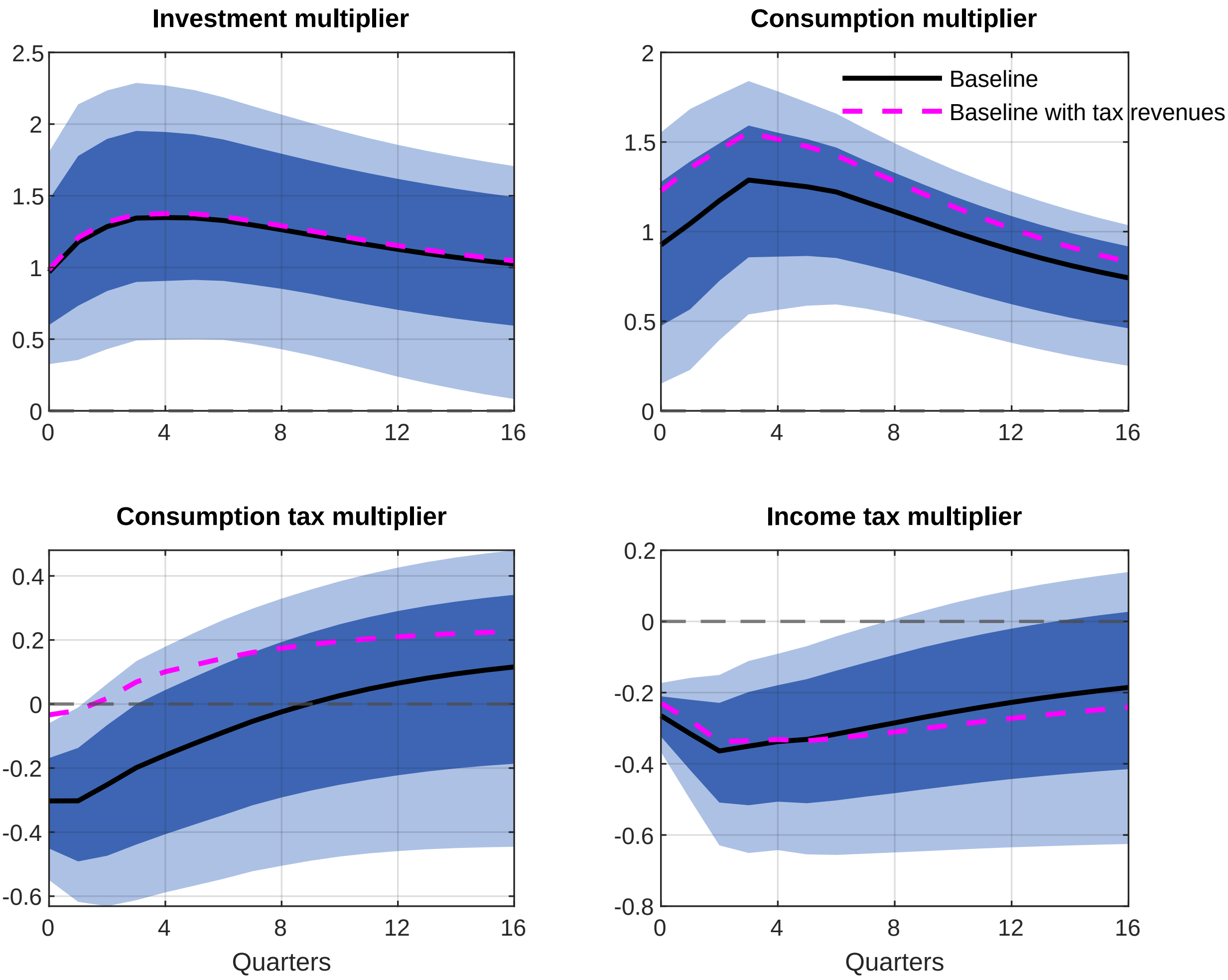

Figure A.10: Robustness of estimated output multipliers. *Notes*: The figure shows the cumulative output multipliers for government investment shocks, government consumption shocks, consumption tax shocks, and income tax shocks over 16 quarters under alternative model specifications. The baseline results are compared to a specification that uses tax revenues instead of effective tax rates. Shaded regions report 68% and 90% bootstrapped standard errors of the baseline estimates.