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On fiscal multipliers in New Keynesian small open economy models

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Abstract

This paper uses a medium-sized New Keynesian general equilibrium model of a small open economy in a monetary union to systematically quantify the sensitivity of various fiscal multiplier measures to the model's key assumptions and parameters for an array of fiscal instruments. Using a unified framework circumvents the typical problems of diverging parameterizations, model extensions, shock definitions, fiscal reaction functions or multiplier measurements that come with inference from cross-study comparison and make results hard to compare. Linearity of multipliers in most parameters allows us to quickly compute rough multiplier estimates for alternative parameterizations by simply using our reported local sensitivities and a pocket calculator. Reflecting the synthesis character of the New Keynesian paradigm, the key parameters that quantitatively determine the size of multipliers differ considerably between the short and the long run. We show that ex-post multipliers should be preferred over ex-ante multipliers when ranking fiscal instruments. Rankings are sensitive to the considered time horizon, shock persistence and anticipation assumptions.

Keywords: fiscal multipliers, small open economy, monetary union, New Keynesian, general equilibrium, Austria

JEL Classification: E62, F41, F45, H30

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1 Introduction and motivation

The aftermath of the Great Recession has brought renewed attention to the question of the size of fiscal multipliers during the last decade. The majority of recent quantitative estimates is done using one of the following three approaches: 1) structural vector autoregression (SVAR), 2) event studies ('narrative approach') and 3) New Keynesian dynamic general equilibrium models (D(S)GE)[1]. The present paper focuses on the latter. Soon after the emergence of the New Keynesian paradigm, essentially the introduction of nominal rigidities in a neoclassical macro model that breaks the neutrality of monetary policy in the short run, economists realized that this framework can also change the transmission channels and implications of fiscal policy. Recent years have seen a number of studies employing New Keynesian (NK) models to derive individual estimates of output effects for selected fiscal policy interventions, emphasizing the role of certain assumptions or model extensions. To keep track of the variety of results, there has also been a rise in the number of survey and meta studies collecting and contrasting different estimates and underlying assumptions such as the studies by Spilimbergo et al. (2009), Ramey (2011a), Mineshima et al. (2014), Gechert (2015) or Ramey (2019). However, the respective results are often hard to compare and difficult to put into context due to, amongst other things, deviating parameterizations, model extensions, shock definitions, multiplier measurements, and considered budget rules.

The aim of this paper is to systematically analyze the transmission channels for a large set of fiscal instruments to output in the New Keynesian setting and quantify the sensitivity of the key assumptions and parameters in a single consistent framework.[2] To do so, we use a vanilla New Keynesian model (e.g. as presented in Galí, 2015) enriched by typical medium-scale model extensions and a comprehensive fiscal policy block that allows for an array of fiscal instruments ranging from public consumption and investment to factor taxes, taxes on consumption and income as well as transfers to households and subsidies to firms. We then systematically quantify the sensitivity of several multiplier definitions along various dimensions by running thousands of different simulations. To keep the scope of the paper manageable we restrict our analysis to small open economies as opposed to more US-focused closed economy models that are prevalent in the literature. Our analysis is further narrowed down by focusing on an economy in a monetary union (e.g. European Economic and Monetary Union), which simplifies the analysis as the countries' monetary authorities do not actively control the nominal interest rate. In comparison to a closed

[1]For a fundamental discussion on the usefulness of DSGE models, see Stiglitz (2018), Christiano et al. (2018) and Galí (2018).

[2]The principal aim is therefore related to the approach adopted by Caldara and Kamps (2017) in their paper on SVARs.

economy, one would typically expect multipliers to be smaller in an open economy because of outward leakages through imports. At the same time however, multipliers should be larger as monetary policy in a monetary union does not react to domestic shocks and does not 'lean against the wind' provided that the country under review is also small with respect to the monetary union it is part of, which we assume (see e.g. Nakamura and Steinsson, 2014). Therefore, discussions on whether or not a fiscal policy shock occurs at the zero lower bound (see e.g. Christiano et al., 2011a) can be put aside.[3]

This paper is mainly related to three strands of the literature. The first strand includes a series of instructive papers that – while also providing numerical results – mainly focus on analytically exploring the key mechanisms of fiscal policy and deriving closed form solutions for multipliers or output effects. Representative papers for the neoclassical case are Baxter and King (1993) (representative agent) and Heijdra and Ligthart (2000) (overlapping generations). For the New Keynesian model representative papers include Hall (2009), Woodford (2011) or Christiano et al. (2011a). However, all of these papers assume a closed economy and focus on a limited set of fiscal instruments (often exclusively on public consumption). At the opposite end of the spectrum is the second strand of the literature that uses large-scale New Keynesian DSGE models to simulate output effects of various fiscal policy shocks. A key contribution in this respect is Coenen et al. (2012) who benchmark the structural policy models applied by several institutions (i.e. Bank of Canada, Board of Governors of the Federal Reserve System, European Central Bank, European Commission, International Monetary Fund and Organisation for Economic Cooperation and Development) using a large set of standardized fiscal shocks. They find that there is considerable agreement across the models that temporary fiscal stimulus via public consumption or targeted transfers to constrained households is most effective in raising output on impact. However, if stimuli shocks are too persistent multipliers are severely reduced at the outset. While the authors succeed in neatly summarizing the differences between the models and in highlighting diverging results it is difficult to identify which of the model distinctions are responsible for that, whether – and if so how – the results are transferable to other cases and how to disentangle the effect of the discretionary fiscal shock from assumed fiscal policy reaction functions.

Given the spectrum outlined above, our paper may be located in-between the two strands of the literature. On the one hand, it includes a sufficient amount of complexity to capture the most important transmission channels, looking at the effects of a variety of fiscal

[3]This does not mean that the consequences of hitting the zero lower bound are unimportant for fiscal policy making. However, for the economy under review expansionary fiscal policy always works as if it was constantly facing the zero lower bound constraint.

instruments. On the other hand, it still aims to comprehensively describe the connection between key assumptions as well as parameter choice and resulting findings. An additional focus of the paper, which relates it to the third strand of the literature (e.g. Turnovsky, 2004; Gemmell et al., 2016), is the analysis of the long-run effects of fiscal policy, emphasizing its structural role in the long run in addition to macro stabilization in the short-run. Although the term 'multiplier' is less commonly used in this context, the measurement concept as such can be easily applied to the long run as well. Analyzing both short-run and long-run effects in using a single framework allows us to examine how the relative importance of certain assumptions and effectiveness rankings of instruments change over the horizon. To be able to take permanent fiscal policy shocks into account, we have to restrict our analysis to the deterministic version of the New Keynesian model which does not require log-linear approximation around a steady state. The drawback of not capturing the existence of uncertainty is comparatively small for the purpose of our study (for a similar argumentation, see Hall, 2009).[4]

Our contribution goes beyond computing multiplier sensitivities for all key parameters. First, we show when and how it is possible to generalize our multiplier benchmark results with regard to different parameterizations by means of linear approximation. Second, picking up the question of whether the impact multipliers of a temporary shock (e.g. Hall, 2009 and Coenen et al., 2012) or those of a permanent shock (e.g. Baxter and King, 1993 and Barro and Redlick, 2011) are higher, our results suggest that this critically depends on the type of fiscal instrument used. Third, we clearly distinguish between the concept of ex-ante multipliers measured using the exogenous fiscal shock size and ex-post multipliers that are related to the actual change in the fiscal balance. Fourth, we show that ex-post multipliers reveal economic equivalence for some of the fiscal instruments which only hold in a real business cycle (RBC) setting but break down in our New Keynesian model. Fifth, we discuss the consequences of assuming different budget rules and relate balanced budget multipliers that assume distortive financing instruments to the multipliers of the two corresponding instruments and their self-financing ratios. Sixth, we show how prior announcement has differential effects on output responses depending on the fiscal instrument in question. The paper is organized as follows. Section 2 presents the New Keynesian small open economy model used in the analysis, while section 3 discusses the benchmark calibration and multiplier measurement. Section 4 presents the benchmark results and quantifications of multiplier sensitivity to individual parameters for each of the selected fiscal instruments. Afterwards, the section goes on the describe the effects on private consumption and the connection of GDP and value added multipliers, before

[4] In fact, impulse responses of a geometrically decaying shock using the deterministic versus a higher order approximation of the stochastic version of our model give virtually identical results.

thoroughly discussing the roles of shock persistence, the chosen budget rule and shock anticipation. Finally, section 5 concludes.

2 A New Keynesian small open economy model

This section presents a medium-sized New Keynesian small open economy model based on Gali and Monacelli (2005)[5] with the following notable differences:[6] The model includes capital accumulation, which is carried out in the firm sector, finance-constrained households, and a large block of fiscal instruments. We abstract from aggregate uncertainty and assume membership in a monetary union. The economy is not only small with respect to the rest of the world but also with respect to the monetary union it is part of.[7] This implies that after abstracting from foreign shocks, all foreign variables expressed in domestic currency can be treated as exogenous constants. Model stationarity is guaranteed by finitely-lived households (e.g. Smets and Wouters, 2002, Ghironi, 2008, Castelnuovo and Nistico, 2010) as well as a foreign debt risk premium in an incomplete asset markets setting (Schmitt-Grohé and Uribe, 2003). Technology and price levels are assumed to be stationary.[8]

Households

The population size is normalized to $N_t = 1, \forall t$. Households differ along three dimensions (z, l, v). First, households are either finance-constrained $(z = C)$ or unconstrained $(z = U)$ following Mankiw (2000). This distinction is governed by a constant share parameter π, such that $N_t^U = \pi$ and $N_t^C = 1 - \pi$. Second, following Erceg et al. (2000), households provide differentiated labor varieties $l \in [0, 1]$. Third, households differ by time of birth $v \leq t$, but face the same constant age-independent mortality rate $1 - \gamma$ in a given period following Blanchard (1985). Hence, cohort population evolves according to $N_{t+1}^v = \gamma N_t^v,\ \forall v \leq t$ and $N_{t+1}^{t+1} = (1 - \gamma) N_t$ with $\sum_{v=-\infty}^{t} N_t^v = N_t = 1$. If $\gamma = 1$ households are infinitely-lived. All of the three characteristics are distributed independently.

[5] Christiano et al. (2011b) additionally introduce search unemployment and entrepreneurial financial frictions into the New Keynsian small open economy model. We neglect these extensions for the sake of simplicity.

[6] A detailed model description in form of a separate technical appendix is available available upon request.

[7] An analysis of fiscal multipliers in a New Keynesian open economy model with different exchange rate regimes is for example provided by Corsetti et al. (2013).

[8] Because of this assumption, we are not restricted to parameterizations required for balanced growth. As multipliers turn out to be rather insensitive to the choice of the calibrated real interest rate, we do not think that this assumption is harmful for our analysis.

The remaining lifetime utility of a household is given by

$$\sum_{s=0}^{\infty}(\beta\gamma)^s\left[\frac{(\tilde{C}_{t+s}^{z,v})^{1-1/\sigma}-1}{1-1/\sigma}-\eta\frac{(\tilde{L}_{t+s}^{l})^{1+1/\sigma^F}}{1+1/\sigma^F}\right],\quad z\in\{C,U\}, \tag{2.1}$$

where β denotes the discount factor, σ the intertemporal elasticity of substitution and σ^F the Frisch labor supply elasticity. We model external habits in consumption and leisure based on Muellbauer (1988) by assuming $\tilde{C}_t^{z,v}=C_t^{z,v}-\kappa\bar{C}_{t-1}^{z,v}$ and $\tilde{L}_t^l=L_t^l-\kappa^L\bar{L}_{t-1}$, where κ and κ^L measure the strength of habit persistence and bars refer to average consumption and labor supply. Optimization with respect to labor supply is done collectively via a union that redistributes average wage incomes back to the households. This explains why labor supply does not differ by v or z and, consequently, why consumption is independent of l.

Unconstrained households (U) have full access to a single financial market and share the risk of lifetime uncertainty by means of a reverse life insurance. They maximize (2.1) w.r.t. $C_t^{U,v}$ subject to the following intertemporal budget constraint, where $A_t^{U,v}$ denotes all financial assets,

$$\gamma A_{t+1}^{U,v}=(1+i_{t+1}^W)\left[A_t^{U,v}+W_t^W\hat{L}_t-P_t^C C_t^{U,v}-P_t\tau_t^L\right]. \tag{2.2}$$

Nominal after-tax prices are $i_{t+1}^W=i_{t+1}(1-\tau_t^R)$, $W_t^W=(1-\tau_t^W)W_t$ and $P_t^C=(1+\tau_t^C)\bar{P}_t^C$, where $\bar{P}_t^C$ is the before-tax price level of the consumption basket and τ_t^L are lump-sum taxes indexed to the production price index P_t. As the union equalizes wage income over all labor varieties l, individual ex-ante labor income $(1-\tau_t^W)W_{l,t}L_{l,t}$ was replaced in (2.2) with average labor income $(1-\tau_t^W)W_t\hat{L}_t$. Optimal consumption behavior can be expressed by an aggregated consumption function that describes current per capita consumption as a function of lifetime wealth and last period's per capita consumption (A.1).

Constrained households (C) consume their disposable income every period, which is justified by the existence of financial frictions and/or myopia. Consumption per constrained household therefore is

$$C_t^C=\left[W_t^W\hat{L}_t-P_t\tau_t^L-P_t\tau_t^{L,C}\right]/P_t^C, \tag{2.3}$$

where $\tau_t^{L,C}$ is a lump-sum tax (transfer if $\tau_t^{L,C}<0$) specific to constrained households.

Labor packers are assumed to competitively combine individual labor varieties to a homogeneous labor input for production using the aggregator $\hat{L}_t=\left[\int_0^1(L_t^l)^{\frac{\epsilon^w-1}{\epsilon^w}}dl\right]^{\frac{\epsilon^w}{\epsilon^w-1}}$, with $\epsilon^w > 1$. Cost minimization gives demand for labor variety l where W_t denotes the wage index,

$$L_t^l = \left(\frac{W_t}{W_t^l}\right)^{\epsilon^w} \hat{L}_t, \quad \text{with} \quad W_t = \left[\int_0^1 (W_t^l)^{1-\epsilon^w} dl\right]^{1/(1-\epsilon^w)}. \tag{2.4}$$

The union carries out collective wage setting for all households and for each labor variety l. Wage setting is hampered by a nominal rigidity of Calvo (1983)-form, such that wages can only be reset for a random share $1-\theta^w$ of households in a given period. The union optimizes the following objective function w.r.t. the wage rate W_t^l

$$\sum_{s=0}^{\infty} (\theta^w \beta)^s \left[W_t^l L_{t+s}^l \tilde{\lambda}_{t+s} - \eta \frac{(\tilde{L}_{t+s}^l)^{1+1/\sigma^F}}{1+1/\sigma^F}\right], \quad \forall l \in [0,1], \tag{2.5}$$

subject to (2.4), where wage income is weighted by the marginal utility of average per capita consumption $\tilde{\lambda}_t = (1-\tau_t^W)(\pi \tilde{C}_t^U + (1-\pi)\tilde{C}_t^C)^{-1/\sigma}/P_t^C$. The markup μ^w, which is set by the union over the marginal rate of substitution (for an average household), is, in general, non-constant if $\theta^w > 0$. In steady state or in the absence of wage rigidity ($\theta^w = 0$), the markup is given by $\mu^w = 1/(\epsilon^w - 1)$, which approaches 0 if varieties become perfectly substitutable ($\epsilon^w \to \infty$). The optimal resetting wage W_t^* is the same for all varieties l and enters the usual aggregate wage dynamics equation as follows

$$W_t^{1-\epsilon^w} = (1-\theta^w)(W_t^*)^{1-\epsilon^w} + \theta^w (W_{t-1})^{1-\epsilon^w}. \tag{2.6}$$

Firms

Final goods producers competitively combine differentiated value added varieties to a homogeneous final good using the aggregator $Y_t = \left[\int_0^1 (Y_t^i)^{\frac{\epsilon-1}{\epsilon}} dl\right]^{\frac{\epsilon}{\epsilon-1}}$, with $\epsilon > 1$. Cost minimization gives demand for value added variety i where P_t denotes the final good price index,

$$Y_t^i = \left(\frac{P_t}{P_t^i}\right)^{\epsilon} Y_t, \quad \text{with} \quad P_t = \left[\int_0^1 (P_t^i)^{1-\epsilon} di\right]^{1/(1-\epsilon)}. \tag{2.7}$$

Value added goods producers create differentiated varieties and are assumed to be equally distributed across the unit interval.[9] Producer $i \in [0,1]$ uses the following technology

$$Y_t^i = \Phi_t \left[\alpha^{1-\rho}(\hat{K}_t^i)^{\rho} + (1-\alpha)^{1-\rho}(\hat{L}_t^i)^{\rho}\right]^{1/\rho}, \tag{2.8}$$

[9]We assume that market imperfections are fundamental by presuming that the mass of firms is fixed over time and that value added producers earn economic rents even in the long run.

where Φ_t is the total factor productivity which depends on the public capital stock[10], i.e. $\Phi_t = A^0 \cdot (K_t^G)^{\sigma^G}$, and $\sigma^P = 1/(1-\rho)$ is the elasticity of substitution between capital and labor. Homogeneous labor $\hat{L}_t$ and effective capital $\hat{K}_t$ are rented at the competitive after-tax nominal rates, namely $W_t^F = (1+\tau_t^F)W_t$ and $P_t^F = (1+\tau_t^K)P_t^K$. Firms face fixed costs FC_t in terms of the final good, which are assumed to be small enough to guarantee non-negative profits, which are taxed at rate τ_t^{prof}. Minimized marginal costs for one additional unit of Y_t^i are $MC_t = \left[\alpha(P_t^F)^{1-\sigma^P} + (1-\alpha)(W_t^F)^{1-\sigma^P}\right]^{1/(1-\sigma^P)}/\Phi_t$ and do not depend on i. In a second optimization step, firms set prices P_t^i subject to a Calvo constraint that allows price resetting only for a random fraction $1-\theta$ of firms in a given period. The corresponding objective function

$$V_t^i = \sum_{s=0}^{\infty} (\theta)^s \varrho_{t,t+s}(1-\tau_{t+s}^{prof}) \left[\left(P_t^i - MC_{t+s}\right) Y_{t+s}^i - P_{t+s}FC_{t+s}\right], \quad \forall i \in [0,1], \tag{2.9}$$

is maximized subject to (2.7), where $\varrho_{t,t+s} = \prod_{k=0}^{s}(1+i_{t+s})^{-1}$ is the cumulative discount factor.[11] The optimal resetting price P_t^* is independent of i and enters the aggregate law of motion for the final good price level as follows

$$P_t^{1-\epsilon} = (1-\theta)(P_t^*)^{1-\epsilon} + \theta(P_{t-1})^{1-\epsilon}. \tag{2.10}$$

A capital goods producer uses final goods to build up the economy-wide capital stock which is competitively rented to value added goods producers at price P_t^K. The capital goods firm maximizes the discounted firm value w.r.t. investment $\tilde{I}_t$ and capacity utilization o_t, i.e.

$$V_t^C = \sum_{s=0}^{\infty} \varrho_{t,t+s} \left[P_{t+s}^K \hat{K}_{t+s} - P_{t+s}^I I_{t+s} - T_{t+s}^F\right], \tag{2.11}$$

subject to (2.12), where $\hat{K}_t = o_t K_t$ is the effective capital and $T_t^F = \tau_t^{prof}\left[P_t^K \hat{K}_t - P_t^I \delta_0 K_t\right] - sub_t^L P_t - sub_t^I P_t^I \tilde{I}_t$ profit taxes net of a lump-sum transfer and an investment subsidy. Gross investment I_t includes capital adjustment costs, i.e. $I_t = \tilde{I}_t + J_t$. The constraints are capital's law of motion, the depreciation rate δ_t, which depends on capacity utilization, and the functional form of capital adjustment costs J_t, i.e.

$$K_{t+1} = (1-\delta_t)K_t + \tilde{I}_t, \quad \delta_t = \delta^0 + \delta^1(o_t - 1) + \frac{\delta^2}{2}(o_t-1)^2, \quad J_t = \frac{\psi K_t}{2}\left[\frac{\tilde{I}_t}{K_t} - \delta_0\right]^2. \tag{2.12}$$

[10]The public capital stock is built up by public investment and evolves according to $K_{t+1}^G = (1-\delta^G)K_t^G + I_t^G$.

[11]Firms are managed by the domestic share holders. In our trivial portfolio setting, discounting before-tax cash flows with the before-tax interest rate is equivalent to discounting after-tax cash flows and capital gains with the typical stochastic discount factor expressed in marginal utility of the Ricardian households.

Optimal investment is given by the typical Tobin's q-investment function (Hayashi, 1982), which decreases in user costs of capital and increases in future profits (A.13).

Fiscal policy

The government faces an intertemporal budget constraint of the following form

$$D_{t+1}^{G} = (1+i_{t+1})\left[D_t^G - PB_t - P_t\tau_t^L\right], \quad PB_t = Rev_t - Exp_t \tag{2.13}$$

where D_t^G is stock of public debt in nominal terms and $D_t^{G,r} = D_t^G P_0/P_t$ in real terms. Note that in the law of motion for debt, lump-sum taxes enter separately in addition to the primary balance PB which contains all of the other fiscal instruments to emphasize their fundamental difference.[12] Expenditure Exp_t consists of public consumption and investment plus transferred subsidies

$$Exp_t = P_t^{C^G} C_t^G + P_t^{I^G} I_t^G + sub_t^L P_t + sub_t^I P_t^I \tilde{I}_t. \tag{2.14}$$

Revenue Rev_t comes from profit taxes, consumption taxes, targeted lump-sum taxes (transfers if negative), wage and payroll taxes, capital taxes and capital income taxes

$$\begin{aligned} Rev_t = {} & \tau_t^{prof}\left[P_t\hat{Y}_t - P_t^I\delta_0 K_t - \tau_t^K P_t^K \hat{K}_t - (1+\tau_t^F)W_t\hat{L}_t\right] + \tau_t^C \bar{P}_t^C C_t \\ & + P_t(1-\pi)\tau_t^{L,C} + (\tau_t^W + \tau_t^F)W_t\hat{L}_t + \tau_t^K P_t^K \hat{K}_t + \tau_t^R \frac{i_{t+1}}{1+i_{t+1}} S_t, \end{aligned} \tag{2.15}$$

where per-period savings are $S_t = A_t + W_t^W \hat{L}_t - P_t^C C_t - T_t^L$, with $T_t^L = P_t\left[\tau_t^L + (1-\pi)\tau_t^{L,C}\right]$. Instead of actual investment, only depreciation is deductible from the capital goods firm's tax base which implies that the profit tax distorts investment. In addition, profit taxes also fall on pure economic rents earned by value added variety producers. The government may follow different budget rules. In this paper, we particularly considers four options:[13]

(a) *instantaneous budget rule*: τ_t^L such that $D_{t+1}^{G,r} - D_0^{G,r} = 0, \quad \forall t > 0,$

(b) *smooth budget rule*: $\tau_t^L = \psi_1^B \tau_\infty^L + (1-\psi_1^B)\tau_{t-1}^L + \psi_2^B(D_t^{G,r} - D_0^{G,r})/\hat{Y}_0,$

(c) *debt-financing rule*: $\tau_t^L = \tau_0^L, \quad \forall t \leq \bar{t}$ and τ_t^L such that $D_{t+1}^{G,r} - D_t^{G,r} = 0, \quad \forall t > \bar{t},$

[12] Even if Ricardian equivalence does not fully hold the resemblance of financing with lump-sum taxes with deficit-financing is still so strong that it is more adequate to interpret it as form of deficit-financing as opposed to a balanced budget setting with distortionary financing instruments.

[13] Corsetti et al. (2012) find that temporary expansionary fiscal shocks are often consolidated by means of spending reversals, i.e. a cut in government spendings below trend at a later point. This is not considered in the present paper.

(d) *balanced budget rule*: any distortionary instrument such that $D^{G,r}_{t+1} - D^{G,r}_0 = 0, \ \forall t > 0$.

Depending on the parameter choices for ψ^B_1 and ψ^B_2, the smooth budget rule generates hump-shaped evolutions of real public debt of different forms before returning to its initial value $D^{G,r}_0$. As regards the debt-financing rule, the government does not react at all to fiscal shocks and lets debt float freely until $\bar{t}$, which is set to 120 quarters throughout the analysis, before stabilizing debt. Note that only if Ricardian equivalence does not fully hold (e.g. in case of finance-constrained or finitely-lived households) the first three rules are not equivalent. Conversely, the balanced budget rule, which is defined as using a distortionary instrument to close the budget every period, will in general always deliver deviating results compared to debt-financing.

Final demands and equilibrium

Final demands and foreign trade. Demand for final goods stems from consumption C_t, investment (including capital adjustment costs) I_t, public consumption C^G_t, public investment I^G_t and from abroad in form of exports E_t. However, only a share of final demand falls on domestic final goods (priced at P_t) which are imperfect substitutes for foreign final goods (priced at P^m_t in domestic currency). We assume sub-utility/sub-production functions of CES-form equivalent to (2.8) with (import) share parameters ξ^x and elasticities of substitution λ^x. This results in the following demand functions for imported vs. domestic final goods

$$x^h_t = (1-\xi^x)\left[\frac{\bar{P}^x_t}{P_t}\right]^{\lambda^x} x_t, \quad x^m_t = \xi^x \left[\frac{\bar{P}^x_t}{P^m_t}\right]^{\lambda^x} x_t, \quad \text{for } x \in \left\{C, I, C^G, I^G\right\}, \tag{2.16}$$

where the price index is $\bar{P}^x_t = \left[\xi^x (P^m_t)^{1-\lambda^x} + (1-\xi^x)(P_t)^{1-\lambda^x}\right]^{1/(1-\lambda^x)}$.[14] Export demand is given in reduced form by $E_t = \lambda^E \ln(E^0/P_t)$, where $\lambda^E > 0$ is a price semi-elasticity.[15] If $\lambda^E \to \infty$, export demand becomes infinitely elastic, which implies that the domestic price level is fixed $P_t = P_0$. The nominal current account CA_t and the evolution of nominal net foreign assets D^F_t is given by

$$D^F_{t+1} = (1+i_{t+1})\left[D^F_t + CA_t\right], \quad CA_t = P_t E_t - P^m_t \left[C^m_t + I^m_t + C^{G,m}_t + I^{G,m}_t\right]. \tag{2.17}$$

[14] It is assumed that only private consumption is subject to product taxes. Therefore before-tax prices $\bar{P}^x_t$ and after-tax prices P^x_t coincide for the other types of demand.

[15] A 1% increase in P_t reduces exports by $(\lambda^E \cdot 100)\%$ of initial GDP when it was normalized to 1.

The nominal interest rate i deviates from the foreign rate i^* by a (symmetric) risk premium which increases in net foreign debt and is normalized to zero in the initial steady state

$$i_{t+1} = i^* \cdot e^{-\psi^{DF}\left[D_t^F/(P_t\hat{Y}_t)-D_0^F/(P_0\hat{Y}_0)\right]}, \quad \psi^{DF} \geq 0. \tag{2.18}$$

Equilibrium is characterized by optimal choices of households and firms as described above and in the appendix in aggregated form, a budget rule and the following set of excess demands being equal to zero:

$$\zeta_t^Y = C_t^h + I_t^h + C_t^{G,h} + I_t^{G,h} + E_t - \hat{Y}_t, \tag{2.19}$$

$$\zeta_t^A = V_t + V_t^C + D_t^G + D_t^F - A_t, \tag{2.20}$$

$$\zeta_t^L = \hat{L}_t^D - \hat{L}_t^S, \quad \zeta_t^L = \hat{K}_t^D - \hat{K}_t^S, \tag{2.21}$$

where $\hat{Y}_t = Y_t - FC_t$ and superscripts D and S make demand for and supply of labor and capital explicit. value added is $P_t\hat{Y}_t$; GDP additionally includes product taxes, i.e. $GDP_t = P_t\hat{Y}_t + \tau_t^C\bar{P}_t^C C_t$.[16] The real equivalents are $P_0\hat{Y}_t$ and $GDP_t^r = P_0\hat{Y}_t + \tau_0^C\bar{P}_0^C C_t$.

3 Data and measurement of fiscal multipliers

Data and calibration

A period is one quarter. Let $t = 0$ be the initial steady state, $t \to \infty$ the final steady state[17] and $t = 1$ the period in which an unanticipated fiscal shock occurs. Although the aim of the paper is not to advocate a single multiplier estimate, we nevertheless require a benchmark calibration from which individual deep parameters are altered one at a time, as the alternative approach of evaluating the model over the full parameter space is simply not feasible.[18] The benchmark calibration is done for Austria, a small open economy in the euro area, based on national accounts data (ESA 2010) and, to a large extent, on parameter estimates for both Austria (Breuss and Rabitsch, 2009 and Fenz et al., 2012) and Europe ('New Area Wide Model' of the European Central Bank by Christoffel et al., 2008 and 'Quest III' of the European Commission by Ratto et al., 2009). As labor supply effects and the distinction between substitution and income effect will be of fundamental quantitative importance, the related calibration strategy is discussed in more detail, while

[16] Alternatively, nominal GDP is given as $GDP_t = P_t^C C_t + P_t^I I_t + P_t^{C^G} C_t^G + P_t^{I^G} I_t^G + CA_t$ and $GDP_t = W_t^F \hat{L}_t + P_t^F \hat{K}_t + \Pi_t$, where Π_t are aggregated per-period profits of the value added producers before tax.

[17] In the numerical implementation the model is run for 500 quarters.

[18] With 26 deep parameters one would already require more than 67 million simulations (2^{26}) just to evaluate the model at the boundary of the parameter space for a single shock type and a single fiscal instrument.

table 3.1 comprehensively summarizes the remaining benchmark calibration. Based on the estimates by Chetty (2012) and Müllbacher and Nagl (2017) we target a Marshallian elasticity of labor supply of 0.2 and a Hicksian elasticity of 0.5. However, since these elasticities are not deep parameters of the model, they have to be replicated by setting the Frisch labor supply elasticity (σ^F)[19] and the intertemporal elasticity of substitution (σ) accordingly. Table C.1 reveals $\sigma = 0.7$ and $\sigma^F = 1$ as the appropriate choices.

In addition to the benchmark calibration, table 3.1 contains the considered ranges for each parameter that is used later on in the multiplier sensitivity tests. The choice of the ranges was guided, on the one hand, by the variety of estimates or calibration choices found in the literature and, on the other hand, the limits of computing numerical solutions for reasonably sized shocks. Ranges are considered only for those parameters that are not directly dictated by national accounts data. Hence, the focus lies on the multipliers' sensitivity to the choice of deep (behavioral) parameters that cannot be directly measured (in contrast to e.g. the private consumption-to-GDP ratio).

To illustrate certain mechanisms, it will be instructive to occasionally contrast the results of the New Keynesian model with those of a plain RBC model (e.g. Baxter and King, 1993 or Burnside et al., 2004), which is nested and attained using $\gamma = \pi = 1$, $\epsilon = \epsilon^w = \delta^2 \to \infty$ and $\theta = \theta^w = \kappa = \kappa^L = 0$.[20] In addition, the RBC model requires a recalibration of $\sigma = 0.9$ and $\sigma^F = 0.7$ to again match our targeted Marshallian and Hicksian labor supply elasticities (see table C.1).

Measurement of fiscal multipliers

Bearing in mind the finding of Ramey (2019), namely that a considerable amount of cross-study variation in multipliers is due to diverging measurements, we clearly lay out the different concepts of computing multipliers after introducing some additional notation. An unanticipated fiscal policy intervention is captured by the expansionary effect $\epsilon_1^r > 0$ (i.e. a rise in expenditure or a cut in taxes) at $t = 1$. Throughout the paper, we set ϵ_1^r to 0.1% of initial GDP. Starting from the initial shock ϵ_1^r, the instantaneous change in the value of the shocked fiscal instrument versus the baseline at time t at constant prices evolves according to

$$\epsilon_t^r = \rho^\epsilon \epsilon_{t-1}^r, \quad \forall t > 1 \text{ with } \epsilon_1^r \text{ given.} \tag{3.1}$$

[19] In the model, the labor supply elasticities are measured as the long-run increases in labor supply (i.e. $L_\infty/L_0 - 1$) for a 1% increase in the wage rate (i.e. $W_\infty = W_0 \cdot 1.01$) assuming that other prices remain unchanged and holding wealth (Marshallian), utility (Hicksian) or marginal utility of consumption (Frisch) constant.

[20] Note that finite lifespans are typically not a defining assumption of the New Keynesian framework unlike monopolistic competition and sticky prices; see e.g. Galí (2015).

Table 3.1: Calibration summary for the New Keynesian model

Parameter	Symbol	Value	Range	Target/Source[3)]
survival rate (yearly)	γ	0.975	[0.952,1]	40 active years on average
interest rate (yearly)	i_0	0.03	[0.02,0.05]	historical average
discount factor (yearly)[1)]	β	0.987	-	$P_0^C C_0/GDP_0$: 0.567
depreciation rate K (yearly)[1)]	δ_0	0.082	-	$P_0^I I_0/GDP_0$: 0.186
depreciation rate K^G (yearly)	δ_0^G	0.05	[0.03,0.15]	Ratto et al. (2009)
capacity utilization costs	δ^2	0.05	[0.02,∞)	Sims and Wolff (2018a)
intertemporal elasticity of substitution[2)]	σ	0.7	[0.2,1]	see table C.1[4)]
Frisch labor supply elasticity[2)]	σ^F	1	[0.25,4]	see table C.1[4)]
habit persistence consumption	κ	0.5	[0,0.75]	Christoffel et al. (2008), Ratto et al. (2009)
habit persistence labor supply	κ^L	0.25	[0,0.75]	half of consumption persistence
capital share production function[1)]	α	0.327	-	corrected[5)] labor income/GDP: 0.551
elast. of subst. capital vs. labor	λ^P	1	[0.8,1.2]	Cobb-Douglas specification
capital adjustment speed	ψ	10	-	halfway K recovery after 32 quarters[6)]
scaling disutility of labor	η	11.6	-	aggregate wage sum
productivity of public capital	σ^G	0.08	[0,0.15]	Bom and Ligthart (2014)[7)]
share of constrained households	$1-\pi$	0.3	[0,0.7]	Coenen et al. (2005), Ratto et al. (2009)
price elast. of demand: value added	ϵ	11	[7,∞)	steady state markup: 10%
price elast. of demand: labor varieties	ϵ^w	11	[7,∞)	steady state markup: 10%
Calvo parameter prices	θ	0.7	[0,0.8]	average price duration: 3.3 quarters[8)]
Calvo parameter wages	θ^w	0.5	[0,0.8]	average wage duration: 2 quarters[8)]
fixed costs parameter[1)]	$\overline{FC}$	0.1	[0,1]	fixed costs share: 10%[9)]
sensitivity of risk premium	ψ^{DF}	0.15	[0,0.1]	Fenz et al. (2012)
import share consumption	ξ^C	0.277	[0.05,0.7]	input-output tables 2015
import share investment	ξ^I	0.371	[0.05,0.7]	input-output tables 2015
import share public consumption	ξ^{C^G}	0.116	[0.05,0.7]	input-output tables 2015
import share public investment	ξ^{I^G}	0.116	[0.05,0.7]	same as public consumption[10)]
elast. of subst. dom. vs. imp. for C	λ^C	1.2	[0.5,1.5]	Breuss et al. (2009), Ratto et al. (2009)
elast. of subst. dom. vs. imp. for I	λ^I	1.2	[0.5,1.5]	Breuss et al. (2009), Ratto et al. (2009)
elast. of subst. dom. vs. imp. for C^G	λ^{C^G}	0.8	[0.5,1.5]	lower than for private consumption
elast. of subst. dom. vs. imp. for I^G	λ^{I^G}	0.8	[0.5,1.5]	lower than for private investment
price semi-elasticity of export demand	λ^E	1.2	[0.5,5]	Ratto et al. (2009): price elast. of 2.5
consumption tax rate	τ_0^C	0.235	-	revenue of product taxes
payroll tax rate	τ_0^F	0.22	-	revenue of labor taxes of employers
wage tax rate	τ_0^W	0.34	-	revenue of labor taxes of employees
capital tax rate	τ_0^K	0.015	-	revenue of capital usage taxes
profit tax rate	τ_0^{prof}	0.15	-	revenue of profit taxes
interest tax rate	τ_0^R	0.1	-	revenue of interest taxes
lump-sum tax rate (constrained only)	$\tau_0^{L,C}$	0	-	no direct empirical counterpart
lump-sum tax rate	τ_0^L	-0.156	-	close budget
investment subsidy	sub_0^I	0.01	-	expenditure on subsidies
lump-sum subsidy	sub_0^L	0.01	-	expenditure on subsidies
public consumption	C_0^G	0.197	-	$P_0^{C^G} C_0^G/GDP_0$: 0.197
public investment	I_0^G	0.03	-	$P_0^{I^G} I_0^G/GDP_0$: 0.03
public debt	D_0^G	0.7	-	historical average
gross domestic product	GDP_0	1	-	normalization (by setting A^0)[1)]
capacity utilization	o_0	1	-	normalization
domestic final goods price	P_0	1	-	normalization
imported final goods price	P_0^m	1	-	normalization
wage rate	W_0	1	-	normalization

Notes: 1) Parameters are recalibrated automatically in every simulation. 2) Parameters are recalibrated for RBC model. 3) The benchmark calibration values chosen do not necessarily match those of the sources cited, but are reasonably close. 4) Targeted Marshallian and Hicksian elasticities of 0.2 and 0.5, respectively, based on Chetty (2012) and Müllbacher and Nagl (2017). 5) Includes income from self-employment. 6) See Cummins et al. (1996) and Radulescu and Stimmelmayr (2007). 7) In combination with the assumption for δ_0^G, this results in approximately the same productivity of public and private capital, i.e. $dY_0/dK_0^G \approx dY_0/dK_0$. 8) The fixed cost share parameter translates into fixed costs as $FC_t = Y_0/\epsilon \cdot \overline{FC}$, which are assumed to be constant $\forall t$. 9) The estimates of the Calvo parameters for Austria by Breuss and Rabitsch (2009) and Fenz et al. (2012) are in the range of 0.8 to 0.9 for prices and 0.3 to 0.7 for wages; however, since these estimates include indexation rules in case of non-adjustment, lower values were targeted. 10) There is no data on the public part of investment in the input-output tables. It seems plausible that the import share of public investment lies between the import shares for public consumption and overall investment. Mainly for expositional purposes we target the import share of public consumption.

For the special case of $\rho^{\epsilon} = 1$, the fiscal shock is permanent. Examples such as a public consumption shock ($\epsilon_t^r = \left[C_t^G - C_0^G\right] P_0^{CG}$) or a wage tax shock ($\epsilon_t^r = \left[\tau_0^W - \tau_t^W\right] W_0 \hat{L}_0$) reveal why it makes sense to label ϵ_t^r as the 'ex-ante' fiscal shock. After all, it does not capture effects on prices, agents' behavior and indirect effects on other fiscal instruments.[21] We can define an 'ex-post' fiscal shock in nominal ($\bar{\epsilon}_t$) and real terms ($\bar{\epsilon}_t^r$)

$$\bar{\epsilon}_t = PB_0 - PB_t, \qquad \bar{\epsilon}_t^r = PB_0 - PB_t \frac{P_0}{P_t}, \tag{3.2}$$

which measures the actual change in the primary balance (excluding changes in τ^L) triggered by ϵ_t^r. As a rule, one can expect that $\epsilon_t^r > \bar{\epsilon}_t^r$ as the latter is reduced by self-financing effects, resulting from changes in all tax bases following the triggered economic expansion. The self-financing ratio is given by $sf_t = 1 - \bar{\epsilon}_t/\epsilon_t^r$.[22] Since fiscal multipliers can be measured in different ways, the importance of the exact definition cannot be overemphasized for cross-study comparisons. First, the duration of measurement has to be specified and second, the exact definition of how output is measured matters. Both the *instantaneous multiplier* of gross value added measured ex-ante, as m_t^Y (vs. ex-post: $\bar{m}_t^Y$) and the *present-value multiplier* for the time span 1 to t (following Mountford and Uhlig, 2009) measured ex-ante as $m_{1,t}^Y$ (vs. ex-post: $\bar{m}_{1,t}^Y$) are defined as follows:[23]

$$m_t^Y = \frac{P_0\left[\hat{Y}_t - \hat{Y}_0\right]}{\epsilon_t^r}, \qquad \bar{m}_t^Y = \frac{P_0\left[\hat{Y}_t - \hat{Y}_0\right]}{\bar{\epsilon}_t^r}, \tag{3.3}$$

$$m_{1,t}^Y = \frac{\sum_{s=1}^t \varrho_{1,1+s}^r P_0\left[\hat{Y}_s - \hat{Y}_0\right]}{\sum_{s=1}^t \varrho_{1,1+s}^r \epsilon_s^r}, \qquad \bar{m}_{1,t}^Y = \frac{\sum_{s=1}^t \varrho_{1,1+s}^r P_0\left[\hat{Y}_s - \hat{Y}_0\right]}{\sum_{s=1}^t \varrho_{1,1+s}^r \bar{\epsilon}_s^r}, \tag{3.4}$$

where $\varrho_{t,t+s}^r = \varrho_{t,t+s}(P_{t+s}/P_t)$ is the real cumulative discount factor. m_1^Y is also known as the *impact multiplier* and $m_{1,t}^Y$ without discounting (i.e. $\varrho_t^r = 1, \ \forall t$) as the *cumulative multiplier*.[24] Furthermore, instead of measuring the effect on value added, empirical studies typically use $m_t^{GDP} = (GDP_t^r - GDP_0^r)/\epsilon_t^r$, which captures the effect on real GDP and can deviate substantially depending on the fiscal instrument used and the response of private consumption. In our model, in which product taxes only depend on private consumption, we can establish the following relationship: $m_{1,t}^{GDP} = m_{1,t}^Y + m_{1,t}^C \tau_0^C/(1+\tau_0^C)$.

[21]This static cost plan of a fiscal measure is often found in administrative budget documents.

[22]As outlined below, one can define a self-financing ratio over a given period in present-value terms: $sf_{1,t} = 1 - (\sum_{s=1}^t \varrho_{1,1+s}^r \bar{\epsilon}_s)/(\sum_{s=1}^t \varrho_{1,1+s}^r \epsilon_s^r)$.

[23]Note that for a fully self-financing measure (in real terms), the ex-post multiplier tends to infinity. Large values of $\bar{m}_t^Y$ are therefore not uncommon.

[24]Particularly in the SVAR literature (e.g. Blanchard and Perotti, 2002), the concept of the *peak multiplier* $m_{max(1,t)}^Y = \frac{\max_s\left\{P_0\left[\hat{Y}_s - \hat{Y}_0\right]\right\}_{s=1}^t}{\epsilon_1^r}$ or $m_{max(1,t)}^Y = \frac{\max_s\left\{P_0\left[\hat{Y}_s - \hat{Y}_0\right]\right\}_{s=1}^t}{\max_s\{\epsilon_s^r\}_{s=1}^t}$ is often used. For a detailed discussion on the importance of measurement, see Ramey (2019).

To facilitate comparison with the empirical literature focusing on tax base effects following tax rate changes, we report the own tax base semi-elasticity $\varepsilon_t^T = -\frac{\partial \ln(T_t)}{\partial \tau_t} \cdot 100$, where T_t is the nominal tax base of some tax τ_t, and which states that a 1 percentage point cut in the tax rate τ_t increases the tax base T_t by $\varepsilon_t^T\%$.

4 Results

In this section, we first focus on the multipliers of different fiscal instruments based on the ex-ante present-value multiplier of value added in the short run ('SR', measured after 4 quarters), the medium run ('MR', measured after 4 years) and the long run ('LR', measured after 30 years) for a permanent shock, unanticipated on impact, using the instantaneous budget rule. Afterwards, this section discusses the effects on private consumption and GDP, the role of shock persistence and budget rules, and whether or not shocks are anticipated.

Multipliers by fiscal instruments

The analysis of multipliers by fiscal instrument presented is mainly based on three complementary components: 1) on the results using the benchmark calibration for the New Keynesian model and the RBC model (tables 4.1 and 4.2); 2) on the visualization of the multiplier range that is spanned by the considered parameter intervals listed in table 3.1 (figures 4.1 and C.1); and 3) on local multiplier sensitivity that translates comprehensive parameter changes into changes in the multipliers (table C.3).

Public consumption and investment. In a New Keynesian model, the procurement of final goods by the government affects total output via four distinct channels. First, even though Ricardian equivalence is diluted by the inclusion of finance-constrained and finitely-lived households, output is affected by the neoclassical wealth effect, albeit to a slightly lower extent than in the RBC model. Government procurement extracts resources from the private sector, irrespective of the chosen budget rule, leading forward-looking households to realize their loss in wealth and, consequently, consume less and work harder. This channel is expected to be stronger, the larger the income effect of labor supply, which is approximately given by the difference between the Marshallian and the Hicksian labor supply elasticity. Hence, the multiplier will strongly depend on the chosen Frisch elasticity (positively) and the intertemporal elasticity of substitution (negatively).[25] An increase in the Frisch elasticity σ^F by 1 boosts the short-run multiplier by 0.17 and the long-run

[25] In fact, the intertemporal elasticity of substitution affects the government spending multiplier almost exclusively via its relevance for the size of the income effect of labor supply.

multiplier by 0.31, while an increase in the intertemporal elasticity of substitution σ by 0.1 reduces the multiplier by 0.02 in the short run and 0.04 in the long run.

Table 4.1: Benchmark results for the New Keynesian model (permanent shock)

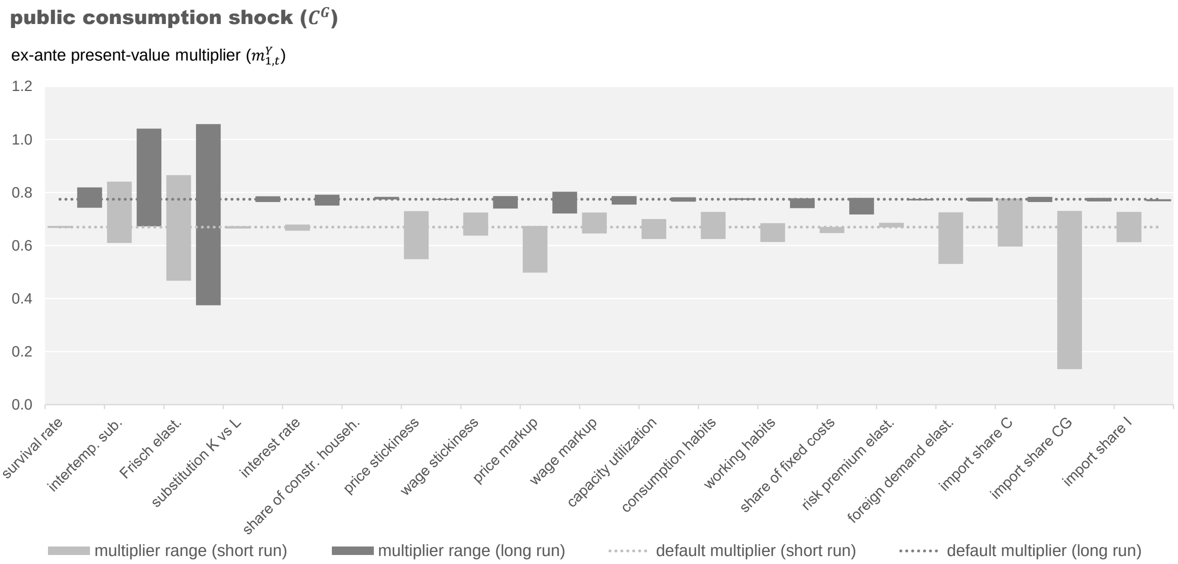
	impact	short run (4 quarters)				medium run (4 years)				long run (30 years)			
	m_1^Y	$m_{1,4}^Y$	$\bar{m}_{1,4}^Y$	$\varepsilon_{1,4}^T$	$sf_{1,4}$	$m_{1,16}^Y$	$\bar{m}_{1,16}^Y$	$\varepsilon_{1,16}^T$	$sf_{1,16}$	$m_{1,120}^Y$	$\bar{m}_{1,120}^Y$	$\varepsilon_{1,120}^T$	$sf_{1,120}$
C^G	0.817	0.670	0.821	-	0.199	0.645	0.743	-	0.142	0.775	0.929	-	0.159
I^G	0.956	0.786	1.177	-	0.362	0.749	1.019	-	0.294	1.626	4.230	-	0.580
sub^I	1.683	1.532	2.886	-	0.481	1.580	2.737	-	0.411	2.284	6.901	-	0.569
sub^L	-0.072	-0.033	-0.038	-	0.125	-0.144	-0.157	-	0.100	-0.231	-0.237	-	0.039
τ^C	0.161	0.227	0.262	0.242	0.136	0.312	0.377	0.298	0.170	0.413	0.525	0.300	0.199
τ^W	0.335	0.444	0.591	0.239	0.247	0.652	0.984	0.289	0.323	0.882	1.563	0.347	0.403
τ^F	0.657	1.012	4.652	0.944	0.728	0.881	5.758	1.091	0.807	0.579	2.218	1.039	0.717
τ^{prof}	0.684	0.973	1.498	0.491	0.314	0.970	1.702	0.349	0.398	0.867	1.418	0.277	0.354
τ^K	1.023	0.962	1.882	1.301	0.495	0.968	1.793	1.269	0.454	1.356	3.294	1.288	0.530
τ^R	-0.087	0.033	0.030	0.303	-0.134	0.326	0.337	0.293	-0.009	0.487	0.574	0.249	0.122
Exp	0.804	0.661	0.829	-	0.219	0.632	0.743	-	0.162	0.852	1.094	-	0.211
Rev	0.381	0.549	0.840	-	0.331	0.628	1.077	-	0.397	0.672	1.202	-	0.416
PB	0.539	0.591	0.836	-	0.289	0.630	0.921	-	0.309	0.739	1.153	-	0.339

Table 4.2: Benchmark results for the RBC model (permanent shock)

	impact	short run (4 quarters)				medium run (4 years)				long run (30 years)			
	m_1^Y	$m_{1,4}^Y$	$\bar{m}_{1,4}^Y$	$\varepsilon_{1,4}^T$	$sf_{1,4}$	$m_{1,16}^Y$	$\bar{m}_{1,16}^Y$	$\varepsilon_{1,16}^T$	$sf_{1,16}$	$m_{1,120}^Y$	$\bar{m}_{1,120}^Y$	$\varepsilon_{1,120}^T$	$sf_{1,120}$
C^G	0.470	0.479	0.485	-	0.028	0.510	0.523	-	0.035	0.604	0.646	-	0.063
I^G	0.180	0.232	0.237	-	0.080	0.425	0.470	-	0.140	1.431	2.959	-	0.488
sub^I	0.689	0.789	0.735	-	0.002	1.122	1.200	-	0.089	2.167	4.780	-	0.447
sub^L	0.000	0.000	0.000	-	0.099	0.000	0.000	-	0.099	0.000	0.000	-	0.099
τ^C	0.346	0.352	0.428	0.248	0.172	0.372	0.457	0.246	0.177	0.434	0.550	0.259	0.196
τ^W	0.656	0.668	1.006	0.311	0.327	0.706	1.089	0.313	0.336	0.823	1.378	0.327	0.371
τ^F	0.356	0.362	1.007	0.990	0.635	0.383	1.090	0.991	0.640	0.446	1.380	0.999	0.660
τ^{prof}	0.402	0.460	0.463	0.205	0.051	0.655	0.717	0.132	0.102	1.264	1.997	-0.113	0.309
τ^K	0.338	0.387	0.464	1.215	0.203	0.551	0.719	1.223	0.246	1.064	2.000	1.285	0.419
τ^R	0.713	0.731	0.744	0.077	-0.066	0.799	0.854	0.079	-0.016	1.149	1.660	0.086	0.243
Exp	0.415	0.430	0.437	-	0.037	0.483	0.501	-	0.051	0.695	0.797	-	0.121
Rev	0.482	0.494	0.746	-	0.332	0.534	0.829	-	0.343	0.663	1.134	-	0.389
PB	0.457	0.470	0.601	-	0.222	0.515	0.674	-	0.234	0.675	0.975	-	0.289

In contrast, the second channel, which is only present in case of rigid prices (and therefore absent in the RBC specification), is more reminiscent of the Keynesian cross demand-driven mechanism. When demand for final goods rises, value added producers increase labor demand. However, because of their inability to raise output prices immediately, which temporarily leads to reduced markup ratios, labor supply is not deterred by higher consumer prices. This would happen in the flexible price case as the increase in labor demand is immediately canceled by a decrease in labor supply. Over time, as more and more value added producers can set their prices as desired the effect of the channel vanishes, which means it is present only in the short run. We can therefore expect the short-run multiplier to be rather sensitive to the degree of price stickiness (positively), the import share of public consumption (negatively) and the foreign demand price elasticity[26], while these parameters have virtually no impact on the long-run multiplier, as is confirmed by figure 4.1 and table C.3. This also explains why the multiplier for public consumption C^G decreases again in the New Keynesian model during the first quarters (from 0.82 on impact to 0.67 after one year and 0.65 after 4 years in the benchmark calibration, see table 4.1) in the New Keynesian model, while it slightly increases in the RBC model over time (from 0.47 on impact to 0.51 after 4 years, see table 4.2).

Figure 4.1: Multiplier range for considered parameter space for public consumption



The third channel is only present in small open economy settings, though of limited quantitative importance, and is rooted in the differential effect on the production price index (P, value added deflator) and the consumer price index (P^C, CPI). As the CPI contains import prices which are insensitive to domestic fiscal shocks, P^C is less sensitive than P. Labor demand depends on real wages expressed in terms of P, while labor supply is affected by P^C. Therefore, the net labor effect increases in the import share of private consumption.

The fourth channel comes into play whenever publicly purchased output entails externalities which alter private sector productivity, which distinguishes public investment I^G from public consumption C^G in our framework. As expected this additional channel leads to higher multipliers for I^G compared to C^G in the short and medium run, and particularly

[26]In fact, if foreign demand was infinitely elastic, i.e. domestic and foreign goods were perfect substitutes, the domestic price level wold be completely determined by the (exogenous) foreign prices, which would close this channel altogether and eliminate the distinction between the New Keynesian and the RBC model in this respect.

in the long run, when public capital stock is close to its new stationary level and the multiplier of 1.63 clearly exceeds unity in the benchmark calibration. Note the stark contrast to the RBC model for which the short-run multiplier is smaller than for C^G, which at first sight seems unintuitive as the productivity channel just works on top of the channels present for C^G. The reason is that, because of stronger self-financing characteristics, a shock in I^G leads to lower perceived losses in lifetime wealth of unconstrained households. Consequently, the drop in consumption is lower and so are the increases in labor supply and the short-run multiplier. Figure C.1 and table C.3 reveal that the efficiency assumptions of the public capital stock K^G and its depreciation rate δ^G are the key parameters that positively influence the long-run multiplier for I^G in particular.

In a small brief digression, we temporarily abandon the assumption that the economy consists of a single industry, and look at a multi-industry extension of the model outlined in appendix B instead. This allows us to examine the effects resulting from varying import shares and production function parameters without the need to calibrate the single-industry model in complete odds with the macro data. Table C.2 displays the short- and long-run multipliers for industry-specific public consumption shocks for 19 different industries. Short-run multipliers vary from -0.6 (manufacturing) to 0.8 (education and real estate), while long-run multipliers range from 0.6 (education) to 0.9 (real estate). The industry-specific variation in short-run multipliers can mainly be explained by the variation in import shares ranging from 7% to 93% (correlation of -0.99). In contrast, differences in long-run multipliers can mostly be attributed to varying capital shares ranging from 4% to 76% (correlation of 0.93). Our digression also highlights the importance of taking policy-specific peculiarities into account when trying to evaluate output effects of fiscal measures instead of applying one-size-fits-all multipliers.

Taxation of consumption and labor works quite similarly in the New Keynesian compared to the RBC framework, producing comparable multipliers in the medium and long run, which are positively influenced by the Frisch elasticity and the intertemporal elasticity of substitution. In the short run, however, results differ significantly with multipliers being lower for consumption (τ^C) and wage (τ^W) taxes and considerably higher for payroll taxes (τ^F) in the New Keynesian setting. Let us first look at the RBC results. The multipliers for τ^C and τ^F are comparable in size, reflecting the fact that the corresponding tax bases used in our calibration are approximately equally large. In contrast, the multiplier for τ^W is about twice as large, which is explained by the existing positive tax rates $\tau_0^W, \tau_0^F > 0$ that drive a wedge between the ex-ante multiplier for τ^W and τ^F.[27]

[27] To illustrate the relationship between τ^C, τ^W and τ^F, think of the simplest neoclassical model with $Y = C$, $Y = L^{1-\alpha}$ and log-specifications in the utility function. Abstracting from income effects that are

However, note that the self-financing ratio for the τ^W-shock is only about half that of τ^F. The intuitive economic equivalence of both measures is revealed by comparing the ex-post multipliers in table 4.2 with each other. An ex-ante fixed cut in payroll tax revenue has a smaller impact on output but also turns out to be less expensive ex-post. This economic equivalence is not captured in the ex-ante multiplier, which makes a case for looking at ex-post multipliers when ranking fiscal instruments. Let us now turn to the short-run multipliers in the New Keynesian model. Habit persistence in consumption and labor provision leads to a more gradual increase in economic activity following a tax cut in τ^C or τ^W. In addition to that, the gross wage rate declines at a slower pace due to wage stickiness, preventing labor demand from picking up more quickly. In stark contrast, wage stickiness dampens the wage inflating effects resulting from a payroll tax cut, and thereby, considerably boosts the short-run multiplier. At the same time, price stickiness influences the short-run multiplier in the opposite direction as it prevents a stronger decline in price levels and a more pronounced increase in labor supply.

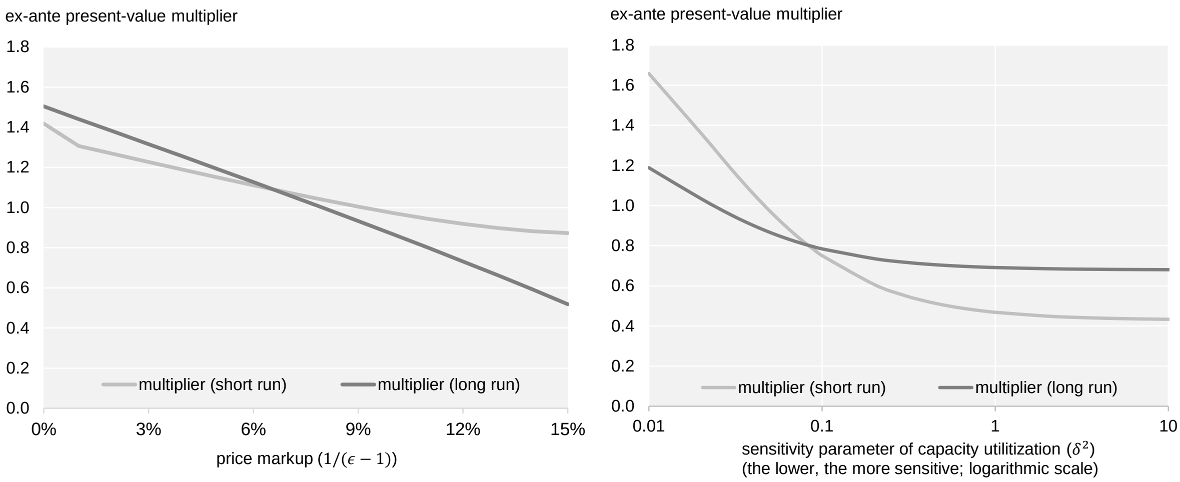
Taxation of profits, capital and capital income.[28] There are two aspects of profit taxation that need to be distinguished in our New Keynesian framework. First, profit taxes are not neutral to investment decisions, as it is only possible to deduct depreciation of past investments as opposed to current investment costs from the tax base. Second, as firms compete in imperfect markets, they earn economic rents, which are also taxed with τ^{prof}. While the first aspect of profit taxation is highly distortive the second is not. It is therefore not surprising that the profit tax multiplier is decreasing in the calibrated price markup (see left panel of figure 4.2), as this implies that the less distortive aspect of taxing economic rents has a higher weight. By the same token, the multiplier increases in the share of fixed costs which reduce rents. This also explains why the long-run multiplier is larger in the RBC case where rents are zero and only aspect of investment distortions with regard to profit taxation prevails. Due to slow capital adjustment, the expansionary effect of a profit tax cut builds up gradually. By contrast, in the New Keynesian setting, the short-run multiplier can easily exceed the long-run multiplier (and does so in the benchmark calibration), first, because sticky wages prevent immediate spikes in

of second order importance in this respect, one can easily show that steady state wage and hours worked are given by $W = (1+\tau^C)^{\frac{\alpha}{1+\alpha}}(1-\tau^W)^{-\frac{\alpha}{1+\alpha}}(1+\tau^F)^{\frac{1}{1+\alpha}} \cdot \Omega_W$ and $L = (1+\tau^C)^{-\frac{1}{1+\alpha}}(1-\tau^W)^{\frac{1}{1+\alpha}}(1+\tau^F)^{-\frac{1}{1+\alpha}} \cdot \Omega_L$, with the last terms being invariant constants. This reveals that the wage response is strongest for shocks to τ^F. Furthermore, while $\partial Y/\partial \tau^F = \partial Y/\partial \tau^C$, the multiplier for τ^F exceeds the multiplier for τ^C whenever the corresponding tax base is smaller, i.e. when $WL < C$, and vice versa, as multipliers are compared in terms of the same shock size and not in terms of the same tax rate changes. Lastly, note that $\partial Y/\partial \tau^W = \partial Y/\partial \tau^F \cdot \frac{1+\tau^F}{1-\tau^W}$, i.e. these two taxes share the same tax base. Therefore, the ex-ante multiplier for τ^W will exceed the one for τ^F whenever $\tau^F > 0$ and/or $\tau^W > 0$.

[28]Keep in mind that these models typically do not incorporate strategic international profit shifting motives and possibilities, which, if included, tend to amplify the multipliers of these taxes.

the wage rate, and second, if capacity utilization is sufficiently elastic, i.e. if δ^2 is small. The lower the losses in form of reduced depreciation, the higher the incentive to temporarily overutilize existing capacity to expand the capital stock as quickly as possible, thereby partially circumventing the capital adjustment rigidity. The right panel of figure 4.2 shows the shift in dominance from the short- to the long-run multiplier depending on the chosen sensitivity of capacity utilization. It also reveals the strong non-linear impact of this parameter on the multipliers, which is confirmed by table C.4.

Figure 4.2: Sensitivity of profit tax multiplier to calibrated price markup and capacity utilization assumptions



As was the case for the taxation of labor, there exists an equivalence result between the taxation of profits (τ^{prof}) and the taxation of (physical) capital (τ^K) in the RBC setting. Ex-post multipliers are identical and ex-ante multipliers differ by the wedge $(1+\tau^K)/(1-\tau^{prof})$. This equivalence result breaks down in the New Keynesian model, mainly because of the aforementioned additional aspect of taxing monopolistic rents that are not captured by a capital tax. This explains why the (short-run) multiplier for τ^K is less sensitive to both the price markup and the share of fixed costs, and more heavily influenced by the import share of investment goods. Turning to the channels driving the multiplier for capital income taxes (τ^R), let us once again look at the RBC mechanisms that are deeply rooted in intertemporal optimization of the households, before moving on to explain the New Keynesian effects working on top. First, a cut in capital income taxes increases the after-tax return rate for households (i^W), leading to an immediate drop in consumption to build up higher financial wealth. With domestic demand for assets remaining constant, additional savings are invested abroad, which lowers the before-tax interest rate as the risk premium declines. Lower domestic rates cause firms to increase investment, thereby slowly raising the capital stock and production. In the RBC case, the impact multiplier is already considerably high. This finding is rooted in an additional immediate labor supply increase due to the drop in consumption (income effect). By comparison, the corresponding multipliers are distinctively lower in the New Keynesian model, not only during the first quarters but also in the long run. The latter can mainly be explained by the existence of economic rents, which dampens the business sector's response to a change in the interest rate.[29] The considerably slower increase in the multiplier during the first periods (in fact, in our benchmark calibration the short-run multiplier for τ^R is the lowest of all considered taxes) is attributable to, and therefore dependent on, the choices made with regard to wage and price stickiness as well as habit persistence in labor supply. In addition, a positive mortality rate and a lower elasticity of intertemporal substitution weaken the backloading of consumption, and thus reduce the long-run multiplier.

Subsidies to firms. In our analysis we focus on two rather distinct types of subsidies. The first type directly leverages investment (sub^I); the second type s granted unconditionally and simply increases cash flow (sub^L). In principle, the mechanism of a investment subsidy mirrors that of the capital tax and both are sensitive to the same parameters (see figure C.1). There is, however, one important difference. While a cut in τ^K also matters for already installed capital, sub^I only affects newly installed capital. This not only explains why multipliers are in general higher for sub^I in our benchmark calibration, but also serves as an explanation when examining different shock durations and prior announcements. In contrast, a lump-sum subsidy is characterized by a multiplier of zero in the RBC model as investment and labor decisions are not affected and household wealth (i.e. financial wealth plus discounted future labor income) remains constant when an increase in sub^L is financed by τ^L which leaves prices and output unchanged.[30] The equivalence of lump-sum taxes and subsidies breaks down in the New Keynesian model, yet with a close to zero multiplier. This is mainly due to finite lifespans which make households treat financial wealth and discounted future labor income slightly differently in their consumption decision, ultimately leading to an increase in consumption and a drop in labor supply due to the income effect.

Linearity in parameter sensitivity and multiplier approximation for different parameterizations. Note that local sensitivity results as presented in table C.3 may only be

[29]It has to be borne in mind that this link is tightly related to our calibration strategy of targeting the observed labor share, which when assuming higher economic rents implies a lower recalibrated capital stock.

[30]The fact that the self-financing ratio reported in table 4.2 is non-zero is attributable to the measurement and does not provide meaningful information. This is because in the instantaneous budget rule, only the change in lump-sum taxes is interpreted as deficit-financing which ignores the effect of changes in lump-sum taxation on revenue from interest taxes. More formally, (using a unit-normalization of the output price) the instantaneous budget rule implies $\Delta sub^L = \Delta\tau^L + \left[\Delta sub^L - \Delta\tau^L i/(1+i)\right]\tau^R$, revealing that $\Delta sub^L > \Delta\tau^L$.

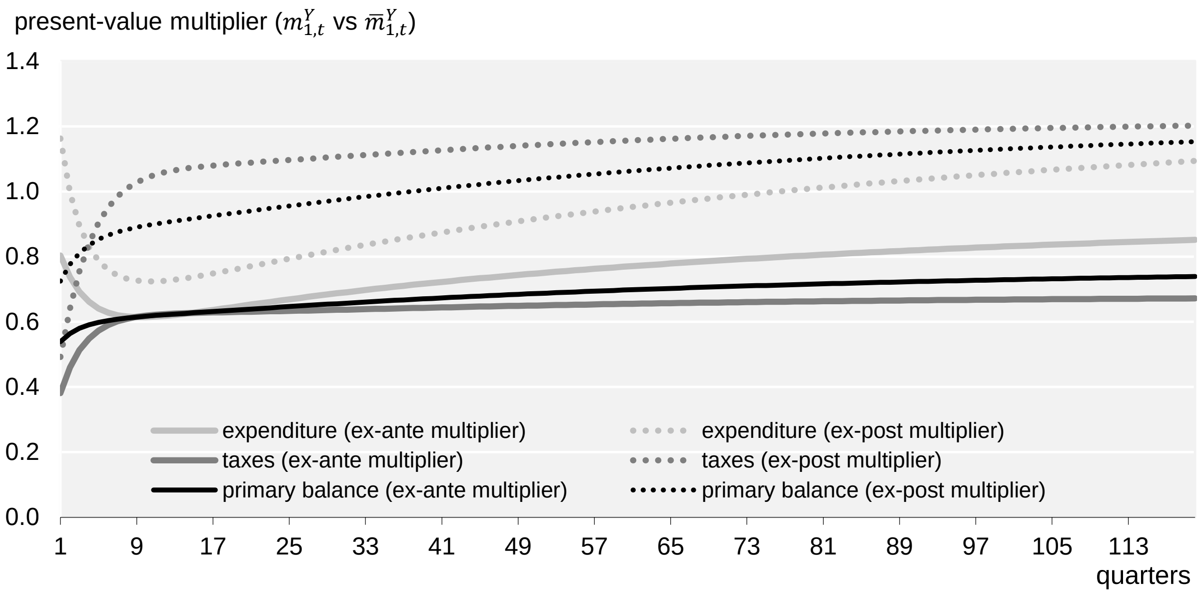
generalized for the entire parameter interval if the sensitivities are sufficiently linear. We therefore carried out non-linearity checks which are documented in table C.4. As has already been shown, the sensitivity of the profit tax multiplier to changes in the capacity utilization parameter δ^2 is highly non-linear (see figure 4.2). Similar effects can be observed for the Calvo parameters (θ and θ^w) and the variety taste parameters (ϵ and ϵ^w), albeit to a lesser extent. To get a better understanding of how well suited local sensitivities are to approximate multipliers for different calibrations and to what extent this is hampered by non-linearities for some parameters, we present two illustrative examples. In the first example, we aim to approximate the public consumption multiplier by only using our benchmark results and information from table C.4 for the following specification: log-felicity for consumption ($\sigma = 1$), halving the Frisch elasticity ($\sigma^F = 0.5$), and zero import shares for private and public consumption ($\xi^C = \xi^{C^G} = 0$). Since, all of these parameters are reported in table C.4 to have a largely linear impact on the multiplier, we expect to obtain suitable approximation results. Indeed the approximated short-run multiplier, which amount to 0.538, comes close to the simulated one of 0.530. The difference is slightly larger for the long-run multiplier but still reasonably small (approximated: 0.498 vs. simulated: 0.462).[31] In the second example, we change the parameters that are reported to be characterized by substantial non-linearity. We simulate a profit tax cut assuming that average price duration is increased to 4 quarters ($\theta = 0.75$), price and wage markups are halved to 5% ($\epsilon = \epsilon^w = 21$) and the capacity utilization parameter δ^2 is doubled. As expected the approximated short-run multiplier, which amounts to 0.762, considerably deviates from the simulated multiplier, which comes to 1.010. By contrast, the long-run multiplier approximation works quite well (approximated: 1.073 vs. simulated: 1.103).[32] However, this is mainly due to the fact that the long-run multiplier is not very sensitive to the aforementioned parameters. Thus, while generalizations from linear approximation can be a powerful tool to quickly get a rough multiplier estimate for alternative parametric specifications, there are also some limitations to this approach.

Aggregate multipliers. To allow for easier comparison with other studies and methods, we aggregate over the fiscal instruments presented above, keeping their relative shares constant. Figure 4.3 plots the multipliers for a uniform shock to all taxes (Rev), all expenditure items (Exp) and all budget items (PB) over time. In the benchmark calibration, the aggregate tax multiplier increases from close to 0.4 on impact to close to 0.7

[31] The short-run multiplier is approximated as $0.670 - 0.024 \cdot 3 + 0.172 \cdot (-0.5) + 0.029 \cdot (-2.77) - 0.092 \cdot (-1.16) = 0.538$. The long-run multiplier is approximated as $0.775 - 0.04 \cdot 3 + 0.308 \cdot (-0.5) + 0.004 \cdot (-2.77) - 0.007 \cdot (-1.16) = 0.498$.

[32] The short-run multiplier is approximated as $0.973 - 0.102 \cdot (2/3) + 0.131 \cdot (2/3) - 0.030 \cdot (-5) - 0.076 \cdot 5 = 0.762$. The long-run multiplier is approximated as: $0.867 - 0.002 \cdot (2/3) + 0.034 \cdot (2/3) - 0.067 \cdot (-5) - 0.030 \cdot 5 = 1.073$.

Figure 4.3: Aggregate multipliers



in the long run. The aggregate expenditure multiplier, in contrast, is characterized by a J-shape, decreasing from 0.8 on impact to a minimum of around 0.6 after 3 years before steadily rising to between 0.8 and 0.9 in the long run. The finding that the aggregate expenditure multiplier exceeds the aggregate tax multiplier at virtually every point in time deviates from the results of the RBC model where both multipliers are approximately of equal size, amounting to 0.4 to 0.5 in the short run and to around 0.7 in the long run. Does this imply that expenditure measures should always be preferred over tax measures? Not necessarily. First, with regard to both expenditure and tax measures, fiscal multipliers vary substantially depending on the specific instrument used, which does not allow for a generalization of this kind. Second, as argued before, the ex-post multiplier, which includes self-financing effects, is the relevant metric when it comes to ranking instruments. However, the relative ranking of instruments based on the ex-post multiplier can differ greatly as the ratio between the ex-post and the ex-ante multiplier is not constant. This is the case because the composition of the expansionary effect and corresponding changes to the tax bases matter. Figure 4.3 reveals that, when self-financing effects are taken into account, the aggregate tax multiplier exceeds the aggregate expenditure multiplier for all horizons except for the first couple of quarters, when expenditure measures on average are considerably more effective in raising output. Apart from an instrument's wage inflating effect, the other key aspect explaining the difference between ex-ante and ex-post multipliers is the reaction of private consumption.

Effects on consumption and the role of multiplier measurement

So far, we have focused on the effects on gross value added. Typically, empirical analyses tend to estimate GDP multipliers, while theory-driven analyses often do not differentiate at all. GDP and value added multipliers are related as follows: $m_{1,t}^{GDP} = m_{1,t}^{Y} + m_{1,t}^{C}\tau_0^C/(1+\tau_0^C)$, i.e. they vary depending on the private consumption multiplier $m_{1,t}^{C}$ and the consumption tax rate in the base year. The response of private consumption to a fiscal shock is important for understanding not only the difference between GDP and value added multipliers or ex-ante and ex-post multipliers, as outlined in the previous section, but it is at the heart of the economic debate on whether private consumption is crowded in or out by public consumption. At the theory level, a neoclassical model predicts a decline in private consumption following a positive public consumption shock while the traditional Keynesian narrative argues for the opposite. Empirical evidence is also divided. On the one hand, SVAR models typically find a rise in private consumption, which motivated the introduction of rule-of-thumb consumers to numerous New Keynesian general equilibrium models to at least dampen the negative private consumption response (see e.g. Galí et al., 2007). On the other hand, the narrative approach based on the military spending time series by Ramey and Shapiro (1998) points to the opposite conclusion. Ramey (2011b) argues that the key difference is that anticipation crucially matters for the correct shock identification, which is typically neglected in the SVAR specifications.

Table 4.3: Consumption and GDP multipliers in the New Keynesian model

	impact			short run (4 quarters)			medium run (4 years)			long run (30 years)		
	m_1^Y	m_1^C	m_1^{GDP}	$m_{1,4}^Y$	$m_{1,4}^C$	$m_{1,4}^{GDP}$	$m_{1,4}^Y$	$m_{1,4}^C$	$m_{1,4}^{GDP}$	$m_{1,120}^Y$	$m_{1,120}^C$	$m_{1,120}^{GDP}$
C^G	0.817	-0.251	0.769	0.670	-0.393	0.595	0.645	-0.475	0.555	0.775	-0.472	0.685
I^G	0.956	0.040	0.963	0.786	0.007	0.788	0.749	-0.013	0.747	1.626	0.373	1.697
sub^I	1.683	0.017	1.686	1.532	-0.076	1.517	1.580	-0.089	1.563	2.284	0.333	2.347
sub^L	-0.072	-0.004	-0.073	-0.033	0.161	-0.003	-0.144	0.190	-0.108	-0.231	0.017	-0.227
τ^C	0.161	0.180	0.195	0.227	0.297	0.283	0.312	0.378	0.384	0.413	0.408	0.491
τ^W	0.335	0.343	0.401	0.444	0.496	0.539	0.652	0.637	0.774	0.882	0.768	1.028
τ^F	0.657	0.182	0.692	1.012	0.470	1.101	0.881	0.567	0.989	0.579	0.496	0.674
τ^{prof}	0.684	0.011	0.686	0.973	0.281	1.026	0.970	0.393	1.045	0.867	0.294	0.923
τ^K	1.023	0.012	1.025	0.962	0.007	0.963	0.968	0.012	0.971	1.356	0.220	1.398
τ^R	-0.087	-0.518	-0.185	0.033	-0.551	-0.072	0.326	-0.433	0.244	0.487	-0.036	0.480
Exp	0.804	-0.202	0.765	0.661	-0.316	0.601	0.632	-0.386	0.559	0.852	-0.338	0.787
Rev	0.381	0.210	0.421	0.549	0.386	0.622	0.628	0.496	0.723	0.672	0.546	0.776
PB	0.539	0.056	0.550	0.591	0.123	0.614	0.630	0.167	0.661	0.739	0.215	0.780

Tables 4.3 and 4.4 show the results of the decomposition of the GDP multiplier in the New Keynesian and the RBC model. In the latter, all expenditure measures as well as cuts in taxes on profits, capital and capital income cause private consumption to decrease strongly both on impact and in the short run, while cuts in taxes on labor

Table 4.4: Consumption and GDP multipliers in the RBC model

	impact			short run (4 quarters)			medium run (4 years)			long run (30 years)		
	m_1^Y	m_1^C	m_1^{GDP}	$m_{1,4}^Y$	$m_{1,4}^C$	$m_{1,4}^{GDP}$	$m_{1,4}^Y$	$m_{1,4}^C$	$m_{1,4}^{GDP}$	$m_{1,120}^Y$	$m_{1,120}^C$	$m_{1,120}^{GDP}$
C^G	0.470	-0.771	0.323	0.479	-0.769	0.333	0.510	-0.760	0.365	0.604	-0.706	0.470
I^G	0.180	-0.244	0.134	0.232	-0.234	0.188	0.425	-0.193	0.388	1.431	0.202	1.470
sub^I	0.689	-1.071	0.485	0.789	-1.036	0.591	1.122	-0.902	0.950	2.167	-0.137	2.141
sub^L	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
τ^C	0.346	0.318	0.406	0.352	0.319	0.413	0.372	0.325	0.434	0.434	0.362	0.503
τ^W	0.656	0.603	0.771	0.668	0.606	0.783	0.706	0.618	0.824	0.823	0.688	0.954
τ^F	0.356	0.327	0.418	0.362	0.328	0.425	0.383	0.335	0.447	0.446	0.373	0.517
τ^{prof}	0.402	-0.625	0.283	0.460	-0.604	0.345	0.655	-0.526	0.555	1.264	-0.078	1.249
τ^K	0.338	-0.526	0.238	0.387	-0.508	0.290	0.551	-0.443	0.466	1.064	-0.066	1.051
τ^R	0.713	-1.270	0.471	0.731	-1.227	0.497	0.799	-1.066	0.596	1.149	-0.224	1.106
Exp	0.415	-0.674	0.287	0.430	-0.671	0.302	0.483	-0.657	0.357	0.695	-0.557	0.589
Rev	0.482	0.317	0.542	0.494	0.321	0.555	0.534	0.339	0.599	0.663	0.442	0.747
PB	0.457	-0.054	0.447	0.470	-0.049	0.461	0.515	-0.033	0.509	0.675	0.069	0.688

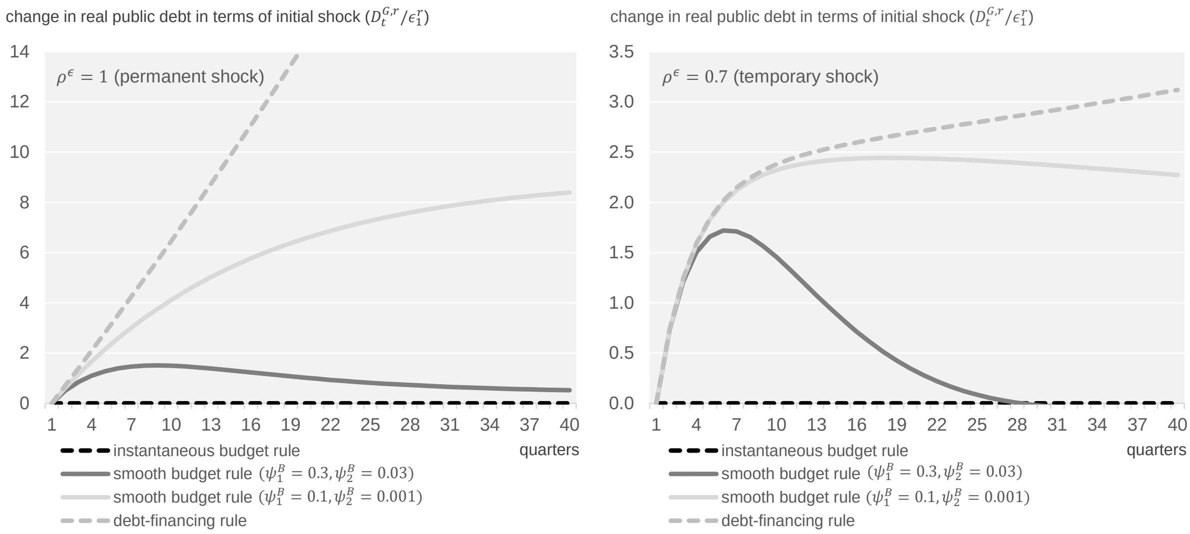
and consumption have the opposite effect. As a result, GDP multipliers fall short of or exceed value added multipliers accordingly. Consumption multipliers, and consequently the deviation of value added multipliers from GDP multipliers, are considerably muted in the New Keynesian model in the short run. The impact consumption multiplier for a public consumption shock is -0.25 instead of -0.77. The corresponding consumption multipliers for taxes on profits, capital and capital income decrease by a similar extent. As the effect on consumption is quite sensitive to the shock duration and the assumed financing rule, we will continue to address these issues in the next part.

The role of shock persistence and budget rules

Until now, we have restricted our analysis to permanent fiscal shocks set off immediately by changes in lump-sum taxes (*instantaneous budget rule*). However, lump-sum taxes are commonly deemed to be unrealistic in practice and when thinking of fiscal policy as a tool for stabilizing output a focus on temporary fiscal measures seems to be much more appropriate. We therefore relax these assumptions in this section to examine how this affects our benchmark results. We start by introducing alternative budget rules as laid out in section 2. In addition to the instantaneous budget rule, we introduce a debt-financing rule and a smooth budget rule with two specifications, one specification that smooths less ($\psi_1^B = 0.3$, $\psi_2^B = 0.03$) and one that smooths more ($\psi_1^B = 0.1$, $\psi_2^B = 0.001$). Figure 4.4 visualizes the impact on real debt under these rules. Furthermore, we introduce a temporary shock by setting $\rho^\epsilon = 0.7$ in (3.1). This implies that about 75% of the cumulated shock occur within the first year and close to 95% within the first two years.

Table 4.5 shows a comparison of the impact multipliers and short-run multipliers based

Figure 4.4: Implied changes in real public debt under different budget rules for both permanent and temporary primary balance shocks



Note: Both panels of this figure are based on an average fiscal shock (PB).

on the altered assumptions of the New Keynesian model. Recall that all of the four considered budget rules would yield the same results in the RBC model. First, we can observe that the three alternative budget rules lead to an increase in consumption and value added multipliers for all instruments, particularly on impact. In case of a permanent shock, the increase in the impact multiplier for value added is highest using the less smoothing budget rule ($\psi_1^B = 0.3$, $\psi_2^B = 0.03$) and varies depending on the instrument used, between 0.03 and 0.12, while the increase in consumption is strongest using the more smoothing budget rule ($\psi_1^B = 0.1$, $\psi_2^B = 0.001$), with increases ranging from 0.11 to 0.33. However, when comparing short-run multipliers, the choice of which budget rule is used seems to have little bearing on the size of the multipliers and the relative ranking of fiscal instruments, as long as the financing instrument is lump-sum taxes.

In contrast, changes in shock persistence alter the multiplier pattern considerably and, depending on the fiscal instrument, to varying degrees. For some instruments, the impact multiplier is slightly lower. This is the case for public consumption, lump-sum subsidies as well as consumption and capital income taxes. For other instruments, namely taxes on labor, capital and profits as well as public investment the impact multiplier is considerably lower. In the most extreme case, i.e. if capital taxes are cut, the impact multiplier declines from 1.0 to 0.1. Furthermore, some instruments are considerably more effective in raising output if the shock is only temporary instead of permanent. In stark contrast to capital taxation, the impact multiplier for investment subsidies – despite working through similar channels – is boosted from 1.7 to 2.8. The reason is quite intuitive. As capital taxes are paid on the entire existing capital stock, a temporary cut is a rather weak incentive to go through a time- and resource-consuming adjustment process. For investment subsidies, however, there is a very strong incentive to front-load investment expenditure to the point in time when investment is cheap. Lastly, if both assumptions, i.e. a temporary shock and a non-instantaneous budget rule, are combined, we replicate the results of Galí et al. (2007), as the private consumption multiplier switches sign, i.e. turns out positive, in case of a public consumption shock, which does not happen in the RBC model (in which case $m_1^C = -0.165$).

Table 4.5: Multipliers under different budget rules for both permanent and temporary shocks

permanent shock ($\rho^\epsilon = 1$)	instantaneous budget rule				smooth ($\psi_1^B = 0.3, \psi_2^B = 0.03$)				smooth ($\psi_1^B = 0.1, \psi_2^B = 0.001$)				debt-financing rule			
	impact		short run		impact		short run		impact		short run		impact		short run	
	m_1^Y	m_1^C	$m_{1,4}^Y$	$m_{1,4}^C$	m_1^Y	m_1^C	$m_{1,4}^Y$	$m_{1,4}^C$	m_1^Y	m_1^C	$m_{1,4}^Y$	$m_{1,4}^C$	m_1^Y	m_1^C	$m_{1,4}^Y$	$m_{1,4}^C$
C^G	0.817	-0.251	0.670	-0.393	0.875	-0.105	0.683	-0.291	0.871	-0.065	0.675	-0.217	0.836	-0.108	0.653	-0.258
I^G	0.956	0.040	0.786	0.007	1.001	0.232	0.789	0.228	0.966	0.179	0.765	0.163	0.971	0.168	0.771	0.141
sub^I	1.683	0.017	1.532	-0.076	1.715	0.129	1.537	0.045	1.701	0.125	1.525	0.049	1.692	0.109	1.520	0.030
sub^L	-0.072	-0.004	-0.033	0.161	0.021	0.201	-0.014	0.253	0.020	0.254	-0.021	0.347	-0.021	0.203	-0.047	0.300
τ^C	0.161	0.180	0.227	0.297	0.253	0.396	0.247	0.420	0.248	0.434	0.238	0.492	0.216	0.394	0.218	0.454
τ^W	0.335	0.343	0.444	0.496	0.421	0.550	0.463	0.624	0.414	0.574	0.454	0.674	0.391	0.545	0.440	0.646
τ^F	0.657	0.182	1.012	0.470	0.734	0.327	1.024	0.486	0.735	0.343	1.024	0.517	0.724	0.330	1.017	0.506
τ^{prof}	0.684	0.011	0.973	0.281	0.790	0.237	0.993	0.366	0.788	0.270	0.988	0.428	0.763	0.238	0.972	0.399
τ^K	1.023	0.012	0.962	0.007	1.065	0.129	0.969	0.099	1.057	0.139	0.961	0.123	1.042	0.118	0.952	0.102
τ^R	-0.087	-0.518	0.033	-0.551	0.033	-0.225	0.061	-0.364	0.025	-0.188	0.048	-0.288	-0.010	-0.232	0.027	-0.330
$\tau^{L,C}$	0.193	0.460	0.025	0.224	0.260	0.623	0.042	0.328	0.258	0.675	0.033	0.421	0.215	0.623	0.006	0.372
Exp	0.804	-0.202	0.661	-0.316	0.861	-0.048	0.674	-0.200	0.853	-0.020	0.663	-0.143	0.824	-0.058	0.645	-0.182
Rev	0.381	0.210	0.549	0.386	0.468	0.407	0.566	0.484	0.464	0.434	0.560	0.537	0.441	0.405	0.546	0.510
PB	0.539	0.056	0.591	0.123	0.615	0.237	0.606	0.228	0.610	0.264	0.599	0.282	0.584	0.232	0.583	0.251
temporary shock ($\rho^\epsilon = 0.7$)																
C^G	0.739	-0.136	0.615	-0.198	0.836	0.096	0.651	0.026	0.829	0.092	0.642	0.036	0.828	0.089	0.641	0.031
I^G	0.776	-0.107	0.711	-0.132	0.872	0.120	0.748	0.082	0.866	0.118	0.740	0.095	0.865	0.116	0.739	0.092
sub^I	2.782	0.386	2.323	0.178	2.750	0.337	2.323	0.227	2.749	0.337	2.319	0.225	2.748	0.336	2.319	0.225
sub^L	-0.151	-0.357	-0.045	-0.309	0.010	0.012	0.011	-0.001	0.001	0.008	-0.001	0.016	-0.001	0.005	-0.002	0.012
τ^C	0.134	0.246	0.220	0.435	0.262	0.537	0.261	0.670	0.254	0.533	0.252	0.683	0.253	0.531	0.251	0.679
τ^W	0.118	0.030	0.340	0.111	0.260	0.349	0.390	0.366	0.253	0.347	0.382	0.383	0.252	0.345	0.381	0.381
τ^F	0.323	-0.097	0.709	0.117	0.432	0.130	0.734	0.227	0.428	0.128	0.731	0.237	0.427	0.127	0.730	0.235
τ^{prof}	0.136	-0.423	0.566	-0.219	0.321	-0.019	0.620	0.051	0.313	-0.022	0.612	0.071	0.311	-0.025	0.611	0.067
τ^K	0.085	-0.310	0.308	-0.204	0.226	0.004	0.353	0.029	0.218	0.001	0.345	0.044	0.217	-0.001	0.344	0.041
τ^R	-0.163	-0.392	-0.050	-0.359	0.001	-0.018	0.006	-0.047	-0.009	-0.022	-0.005	-0.028	-0.010	-0.025	-0.006	-0.033
$\tau^{L,C}$	0.353	0.836	0.106	0.723	0.438	1.043	0.137	0.940	0.430	1.039	0.127	0.947	0.428	1.037	0.126	0.942
Exp	0.722	-0.138	0.613	-0.192	0.821	0.097	0.650	0.033	0.814	0.093	0.640	0.044	0.813	0.091	0.639	0.040
Rev	0.165	0.015	0.399	0.163	0.298	0.310	0.441	0.379	0.291	0.307	0.434	0.394	0.290	0.305	0.433	0.391
PB	0.373	-0.042	0.479	0.031	0.493	0.230	0.519	0.250	0.487	0.227	0.511	0.263	0.486	0.225	0.510	0.260

Transfers to finance-constrained households ($\tau^{L,C}$) is another instrument that is more effective in case of a temporary shock, especially in combination with lagged counter-financing, and it is only in this setting that it can be interpreted in a meaningful way.[33] The impact multiplier for value added is slightly above 0.4; however, after four quarters it declines rapidly to around 0.1. While the expansionary effect on output is rather modest, transfers to finance-constrained households are the instrument of choice to stimulate private consumption. The consumption multiplier exceeds unity on impact and is above 0.9 after the first year. Strong consumption responses in combination with modest changes

[33] In the tables base on the instantaneous budget rule, we therefore did not report any results for $\tau^{L,C}$.

in domestic production and investment imply that a large share of goods is imported (as indicated by the impact current account multiplier, which is -0.34 for the less smoothing budget rule). The strong increase in consumption also implies a considerable discrepancy between the value added multiplier (0.44 on impact, less smoothing budget rule) and the GDP multiplier (0.64). Not surprisingly, the effects are increasing in the share of constrained households. Assuming $1-\pi = 0.7$, causes impact multipliers for value added and GDP to increase to 0.508 and 0.735, respectively. Note that this is not a mechanical effect, as the shock size remains unchanged and the same amount of transfers is thus distributed to more heads, which should not matter in the aggregate. The effect stems from the fact that there are fewer unconstrained households who restrict their consumption as soon as they learn about their additional future tax obligations.

Table 4.6: Balanced budget (ex-ante) multipliers in case of permanent fiscal shocks

policy	financing instrument											
	short-run present-value multiplier						long-run present-value multiplier					
	C^G	τ^C	τ^W	τ^{prof}	τ^K	τ^R	C^G	τ^C	τ^W	τ^{prof}	τ^K	τ^R
C^G	0.000	0.459	0.132	-0.774	-1.061	0.624	0.000	0.337	-0.521	-0.424	-2.250	0.284
I^G	0.262	0.624	0.345	-0.306	-0.375	0.760	1.361	1.457	0.833	0.988	0.733	1.447
sub^I	1.115	1.403	1.190	0.669	0.616	1.511	2.017	2.125	1.692	1.801	1.333	2.118
sub^L	-0.768	-0.270	-0.615	-1.587	-1.954	-0.082	-1.148	-0.747	-1.725	-1.636	-3.859	-0.808
τ^C	-0.481	0.000	-0.312	-1.170	-1.413	0.191	-0.318	0.000	-0.805	-0.713	-2.436	-0.049
τ^W	-0.161	0.251	0.000	-0.673	-0.802	0.422	0.366	0.589	0.000	0.079	-1.097	0.558
τ^F	0.817	0.940	0.886	0.722	0.598	1.006	0.325	0.438	0.195	0.204	-0.428	0.418
τ^{prof}	0.432	0.793	0.580	0.000	-0.215	0.950	0.292	0.543	-0.067	0.000	-1.369	0.506
τ^K	0.550	0.832	0.631	0.116	0.000	0.939	0.994	1.148	0.677	0.760	0.000	1.129
τ^R	-0.864	-0.253	-0.625	-1.618	-1.818	0.000	-0.292	0.045	-0.841	-0.715	-2.510	0.000

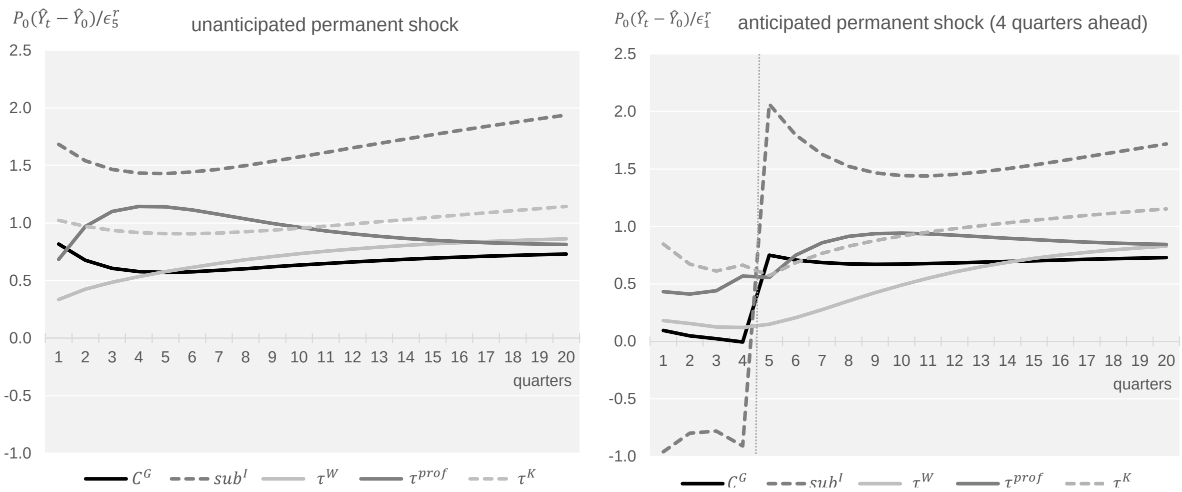
Note: Policy interventions (rows) are always expansionary, i.e. a rise in spending or a cut in taxes, while the opposite is true for the financing instruments (columns).

Balanced budget multipliers are ex-ante multipliers that are based on an instantaneous budget rule but using a distortionary fiscal instrument instead of lump-sum taxes (*balanced budget rule*). Defining balanced budget multipliers therefore always requires a pair of instruments, i.e. a policy instrument and a financing instrument. Table 4.6 shows the corresponding results in case of a permanent shock. Whenever the balanced budget multiplier is positive (negative), the policy instrument is more (less) distortionary than the financing instrument. In turn, the more (less) distortionary the policy instrument, the higher (lower) the multiplier in absolute value. This pairwise comparison allows us to create a ranking of instruments, which proves to be same as ranking instruments by ex-post multipliers (see table 5.1). We can make two interesting observations. First, the balanced budget multiplier is not perfectly symmetric. Second, the intuitive idea that the balanced budget multiplier can be approximated by the difference between the corresponding ex-post multipliers is not true. Both observations are related to the fact that the balanced budget multiplier is still measured in terms of the ex-ante shock ϵ_t^r, while the output effect results from a policy mix, with the instruments having variable weight depending on the self-financing ratios.[34]

Unanticipated versus anticipated shocks

The final aspect of our analysis deals with the role of shock anticipation. So far, each shock occurred in the first period and was therefore unforeseen by households and firms. However, if we introduced a permanent shock as late as in the fifth period, the agents learn about the corresponding policy four quarters in advance. Figure 4.5 contrasts the output responses for five selected instruments in case of both an unanticipated and anticipated shock. Depending on the instrument's nature, anticipation can alter the short-run output responses in qualitatively different ways. As regards profit and capital taxation we already observe quite strong and positive output responses in the first year after the policies had been announced but before they were actually put in place. The reaction after the first four quarters, however, is somewhat less pronounced. This is because changes to the capital stock are best started earlier such that firms can smooth the adjustment process over a longer period of time. In contrast, a previously announced rise in investment subsidies causes firms to postpone investments resulting in a strong decline in output during the first four quarters before skyrocketing up once the investments are eligible for extended subsidies.

Figure 4.5: Multipliers of unanticipated vs. anticipated shocks



Note: Instantaneous multipliers here are computed with respect to the first positive shock (i.e. ϵ_1^r for the unanticipated and ϵ_5^r for the anticipated case.)

[34] A naive approximation – neglecting more involved interaction effects – of the instantaneous balanced budget multiplier $m_t^Y(\tau^x, \tau^y)$ for policy instrument τ^x and financing instrument τ^y would be $m_t^Y(\tau^x, \tau^y) \approx m_t^Y(\tau^x) - m_t^Y(\tau^y) \cdot \frac{1-sf_t(\tau^x)}{1-sf_t(\tau^y)}$ which is clearly not the same as $m_t^Y(\tau^y, \tau^x)$.

Lastly, policies such as rise in public consumption or a cut in wage taxes are only mildly affected by prior announcement, meaning that output effects are low in the anticipation phase and similar to the output effects observed for unanticipated shocks in the period following implementation. The last finding is specific to the New Keynesian model. In an RBC setting, anticipated and unanticipated public consumption shocks show very similar output effects during the first four quarters. This is because the main transmission mechanism is the neoclassical income effect channel, which is driven by the discounted value of future tax liabilities irrespective of when an increase in public consumption occurs. Furthermore, anticipated wage tax shocks lead to negative output responses in the period before the tax cut implementation – in contrast to the mild positive effect in the New Keynesian setting – before skyrocketing once the tax cut becomes effective. This results from the negative income effect of labor supply that already comes into play in the period preceding the tax cut implementation. After implementation the income effect is overcompensated by the substitution effect and the resulting jump is not smoothed by any rigidity.

5 Conclusions

This paper contributes to the literature on fiscal multipliers by providing a systematic comparison of output effects for an array of fiscal instruments using different specifications in a unified New Keynesian general equilibrium framework for a small open economy in a monetary union. We quantify local multiplier sensitivities with respect to changes in the model's deep parameters for every fiscal instrument. The key parameters that drive the multipliers vary considerably depending on the instrument as well as on the considered time horizon. As a rule of thumb, preference and technology parameters such as the intertemporal elasticity of substitution, the Frisch elasticity of labor supply or the labor share in production are key determinants of the size of long-run multipliers, while import shares, the degree of price stickiness and the elasticity of export demand are fundamental for the magnitude of the short-run multipliers. This reflects the nature of the New Keynesian paradigm that introduces nominal rigidities, which heavily influence short-run dynamics, into a neoclassical setting. The neoclassical setting, in turn, drives the long-run characteristics of the model. The sensitivities of our benchmark multipliers to parameter changes are often quite linear over the entire considered parameter space, which allows us to quickly compute rough multiplier estimates for alternative parameterizations using our local sensitivity results. However, caution is warranted for some parameters such as the degrees of price and wage stickiness, the markup parameters, and the parameter gauging the sensitivity of capacity utilization, as their relation to multipliers is highly non-linear.

Table 5.1: Ranking of fiscal instruments in the benchmark calibration by multiplier (from highest to lowest)

model	NK	NK	NK	NK	RBC	RBC	NK	NK	NK
persistence	perm.	perm.	perm.	perm.	perm.	perm.	temp.	perm.	perm.
anticipation	unant.	unant.	unant.	unant.	unant.	unant.	unant.	antic.	antic.
measurement	ex-ante	ex-ante	ex-post	ex-post	ex-post	ex-post	ex-post	ex-ante	ex-ante
horizon	short run	long run	short run	long run	short run	long run	short run	announc.	short run
	sub^I	sub^I	τ^F	sub^I	τ^F	sub^I	sub^I	τ^K	sub^I
	τ^F	I^G	sub^I	I^G	τ^W	I^G	C^G	τ^{prof}	τ^F
	τ^{prof}	τ^K	τ^K	τ^K	τ^R	τ^K	I^G	τ^F	τ^{prof}
	τ^K	τ^W	τ^{prof}	τ^F	sub^I	τ^{prof}	τ^F	I^G	τ^K
	I^G	τ^{prof}	I^G	τ^W	C^G	τ^R	τ^{prof}	τ^W	C^G
	C^G	C^G	C^G	τ^{prof}	τ^K	τ^F	τ^W	C^G	I^G
	τ^W	τ^F	τ^W	C^G	τ^{prof}	τ^W	τ^K	τ^R	τ^W
	τ^C	τ^R	τ^C	τ^R	τ^C	C^G	τ^C	sub^L	τ^C
	τ^R	τ^C	τ^R	τ^C	I^G	τ^C	sub^L	τ^C	τ^R
	sub^L	sub^L	sub^L	sub^L	sub^L	sub^L	τ^R	sub^I	sub^L

Note: 'perm.' refers to a permanent shock ($\rho^\epsilon = 1$), 'temp.' to a temporary shock ($\rho^\epsilon = 0.7$). The short-run present-value multiplier is measured after 4 quarters, the long-run multiplier after 30 years. For anticipated shock: Period of announcement ('announc.') is the first quarter. Period of enactment is the fifth quarter. Short-run for an anticipated shock means 4 quarters after enactment, i.e. the eighth quarter. The 'ex-ante' columns contain the ranking based on the ex-ante present-value multipliers $m^Y_{1,t}$, the 'ex-post' columns contain the ranking based on the ex-post present-value multipliers $\bar{m}^Y_{1,t}$.

We show that the concept of ex-post multipliers, which takes self-financing effects into account, reveals economic equivalence between wage and payroll taxation as well as profit and capital taxation in the RBC setting. This equivalence breaks down in the New Keynesian model due to the existence of economic rents and wage stickiness. We argue that to compare and rank fiscal instruments, the ex-post multiplier is the metric of choice which can lead to different conclusions compared to those based on ex-ante multipliers. For example, a persistent average public expenditure shock exceeds an average tax cut shock in terms of the ex-ante multiplier over the entire time horizon. However, this is only true for the first couple of quarters before the pattern reverses if output effects are evaluated using the ex-post multiplier. Table 5.1 reveals that the ranking of instruments does not only depend on the multiplier definition but also on the assumed shock persistence, whether or not shocks are anticipated and the considered time horizon over which multipliers are measured. In case of a temporary shock, short-run multipliers for investment subsidies and transfers to constrained households are higher compared to the case of a permanent shock. In contrast, short-run multipliers for labor, capital and profit taxes fall considerably short of their counterparts for a permanent shock. Although the New Keynesian setting typically includes features that break Ricardian equivalence, we find that multipliers are only mildly sensitive to alternative sluggish budget reaction functions as long as lump-sum taxes are used as financing instrument.

The strong variation in multipliers by instrument has additional implications for how to interpret empirical estimates stemming from SVARs that use fiscal data aggregated over instruments (e.g. only distinguishing between net taxes and spending). A net tax multiplier estimate identified by a series of capital tax reforms is likely to differ from an estimate identified by a series of consumption tax changes. Therefore, researchers have to have a good idea of the type of identifying events in their time series and must be very careful when generalizing the results to all instruments that are part of the same aggregate. Lastly, one should not forget that instrument rankings that focus solely on output and rankings by welfare may yield quite different results.

Our approach of systematic multiplier sensitivity quantification was restricted to the case of a small open economy in a monetary union. Undoubtedly, the focus can easily be shifted to other related model classes where e.g. monetary policy has a more active role, involuntary unemployment is explicitly included or market incompleteness, financial frictions and heterogeneous agents are treated much more rigorously (e.g. Kaplan et al., 2018 or Hagedorn et al., 2019). Another issue that was left untouched was the question concerning state-dependence of multipliers. Apart from predicting higher higher multipliers during periods of monetary accommodation (e.g. zero lower bound), the New Keynesian model has, by design, little capacity to generate multipliers that are substantially countercyclical (Sims and Wolff, 2018a and Sims and Wolff, 2018b). This is more or less in line with empirical findings, as evidence for higher multipliers at the zero lower bound seems to be stronger than for business cycle dependent multipliers, abstracting from the monetary policy reaction effect (Ramey and Zubairy, 2018). Nevertheless, it would still be interesting to gain a deeper analytical understanding of how business cycle states could potentially alter fiscal policy transmission in the New Keynesian framework. The introduction of product market matching frictions (Michaillat and Saez, 2015) could provide helpful insights in this regard.

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A Aggregated optimality conditions

This section presents the remaining aggregated optimality conditions that are necessary for the numerical implementation and that have not been presented in section 2. To analytically aggregate over all households born at different times, we define, for some variable X, the average over all cohorts as $X_t = \left[\sum_{v=-\infty}^{t} X_{v,t} N_{v,t}^U\right] / N_t^U$, with $N_t^U = \pi$. Using the usual aggregation steps for Blanchard (1985)-type models, we can express the block characterizing the average consumption behavior of unconstrained households as

$$C_t^U = \left[A_t^U + H_t - \Delta_t \kappa\gamma C_{t-1}^U\right] / \left[\Lambda_t (P_t^C)^{\sigma}\right] + \kappa\gamma C_{t-1}^U, \tag{A.1}$$

$$A_{t+1}^U = (1 + i_{t+1}^W)\left[A_t^U + W_t^W \hat{L}_t - P_t^C C_t^U - P_t \tau_t^L\right], \tag{A.2}$$

$$H_t = W_t^W \hat{L}_t - P_t \tau_t^L + \gamma H_{t+1}/(1 + i_{t+1}^W), \tag{A.3}$$

$$\Delta_t = P_t^C + \kappa\gamma/(1 + i_{t+1}^W)\Delta_{t+1}, \tag{A.4}$$

$$\Lambda_t = \Delta_t (P_t^C)^{-\sigma} + \beta^{\sigma}(1 + i_{t+1}^W)^{\sigma-1}\gamma\Lambda_{t+1}, \tag{A.5}$$

$$\tilde{C}_t^U = C_t^U - \kappa\gamma C_{t-1}^U. \tag{A.6}$$

Aggregate consumption, aggregate assets and the corresponding law of motion are

$$C_t = \pi C_t^U + (1-\pi) C_t^C, \;\; A_t = \pi A_t^U, \;\; A_{t+1} = (1 + i_{t+1}^W)\left[A_t + W_t^W \hat{L}_t - P_t^C C_t - T_t^L\right]. \tag{A.7}$$

The solutions to the optimal resetting price (P_t^*) and wage (W_t^*) are independent of i and l, respectively, and are given by

$$P_t^* = \frac{\epsilon}{\epsilon - 1}\frac{\Phi_t^1}{\Phi_t^2}, \qquad \Phi_t^1 = MC_t Y_t P_t^{\epsilon} + \theta \varrho_t \Phi_{t+1}^1, \qquad \Phi_t^2 = Y_t P_t^{\epsilon} + \theta \varrho_t \Phi_{t+1}^2, \tag{A.8}$$

$$W_t^* = \frac{\epsilon^w}{\epsilon^w - 1}\frac{\tilde{\Lambda}_t^1}{\tilde{\Lambda}_t^2}, \quad \tilde{\Lambda}_t^1 = \psi W_t^{\epsilon^w} \hat{L}_t (\tilde{L}_t)^{1/\sigma^F} + \theta^w \beta \tilde{\Lambda}_{t+1}^1, \quad \tilde{\Lambda}_t^2 = \tilde{\lambda}_t W_t^{\epsilon^w} \hat{L}_t + \theta^w \beta \tilde{\Lambda}_{t+1}^2, \tag{A.9}$$

with $\tilde{L}_t = (W_t/W_t^*)^{\epsilon^w} \hat{L}_t - \kappa^L L_{t-1}$. Following Yun (1996), we define $\hat{L}_t = \int_0^1 \hat{L}_{i,t} di$ and $\hat{K}_t = \int_0^1 \hat{K}_{i,t} di$, and aggregate individual production to an aggregate production function Y_t which depends on the index of price dispersion v_t, which evolves according to

$$Y_t = \frac{\Phi_t \left[\alpha^{1-\rho} \hat{K}_t^{\rho} + (1-\alpha)^{1-\rho} \hat{L}_t^{\rho}\right]^{1/\rho}}{v_t}, \qquad v_t = (1-\theta)(P_t^*/P_t)^{-\epsilon} + \theta (P_{t-1}/P_t)^{-\epsilon} v_{t-1}. \tag{A.10}$$

Similarly, the index of wage dispersion v_t^w drives a wedge between aggregate labor supply and aggregate homogeneous labor input given by

$$L_t = v_t^w \hat{L}_t, \qquad v_t^w = (1 - \theta^w)(W_t^*/W_t)^{-\epsilon^w} + \theta^w (W_{t-1}/W_t)^{-\epsilon^w} v_{t-1}^w. \tag{A.11}$$

Aggregate before-tax per-period profits of value added producers (Π_t) and the sum of corresponding discounted firm values (V_t) are

$$\Pi_t = P_t \hat{Y}_t - W_t^F \hat{L}_t - P_t^F \hat{K}_t, \quad V_t = \sum_{s=0}^{\infty} (\varrho_{t+s})^s (1 - \tau_{t+s}^{prof}) \Pi_{t+s}. \tag{A.12}$$

Optimal investment (I_t) and capacity utilization (o_t) choices are characterized by

$$I_t = \frac{\varrho_t (V_{t+1}^C - V_{t+1}^R)}{P_t^I (1 - sub_t^I + \partial J_t / \partial I_t)} - (1 - \delta_t) K_t, \quad \text{with} \quad V_t^R = \sum_{s=0}^{\infty} (\varrho_{t+s})^s \left[P_{t+s} sub_{t+s}^L \right], \tag{A.13}$$

$$P_t^K = P_t^I (1 - sub_t^I + \partial J_t / \partial I_t) \left[\delta^1 + \delta^2 (o_t - 1) \right] / (1 - \tau_t^{prof}). \tag{A.14}$$

B A multi-industry extension

In this section we briefly outline the necessary steps to extend the model to a multi-industry setting.[35] The economy is consists of n discrete industries. In each industry, value added is produced by a mass 1 of monopolistically competitive variety producers each producing $Y_{k,i}$, with $k \in \{1, 2, \ldots, n\}$ and $i \in [0, 1]$. In the first stage of the final goods production, value added varieties within an industry are competitively assembled to Y_k at price P_k. While capital is accumulated separately in each industry, labor is assumed to move freely between sectors, resulting in a unique wage rate W. In the second stage, final good F_k is assembled using the composite value added good $\hat{Y}_k = Y_k - FC_k$ as well as final goods from other industries. Demand for other final goods is labeled as $M_{j,k}$, i.e. as demand for final good that stem from sector j and are used as intermediate in sector k. The sectoral production function is given as

$$F_k = \min \left\{ \frac{M_{1k}}{a_{1k}}, \frac{M_{2k}}{a_{2k}}, \ldots, \frac{M_{nk}}{a_{nk}}, \frac{\hat{Y}_k}{a_{0k}} \right\}, \tag{B.1}$$

with a_{jk} denoting the fixed input-output coefficients. Producing one unit of good k therefore requires a_{1k} of good 1, a_{2k} of good 2, a_{kk} of good k itself, etc. as well as a_{0k} of the sector-specific value added good. Each intermediate good M_{jk} can be sourced domestically or from abroad (assuming imperfect substitutability, $\lambda^M = 1.6$[36]). Final demands aggregation is extended by one additional stage, such that $C = \mathrm{CES_C}(C_1, \ldots, C_n)$ and $C_k = \mathrm{CES_{C_k}}(C_k^h, C_k^m)$, $\forall k \in \{1, 2, \ldots, n\}$, etc. Finally, to set sector-specific price semi-elasticities of export demand λ_k^E we weighted λ^E by sector-specific value added.

[35] A detailed description in form of a separate technical appendix is available upon request. We drop all time indices in this section.

[36] Multiplier results are rather insensitive to this parameter choice.

C Additional tables and figures

Table C.1: Marshallian (Hicksian) labor supply elasticities depending on σ and σ^F

New Keynesian model									
σ^F \ σ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.25	-0.20 (0.13)	-0.09 (0.16)	-0.03 (0.17)	0.02 (0.18)	0.05 (0.19)	0.07 (0.20)	0.09 (0.20)	0.11 (0.21)	0.12 (0.21)
0.5	-0.30 (0.18)	-0.15 (0.23)	-0.04 (0.26)	0.03 (0.29)	0.09 (0.31)	0.13 (0.33)	0.17 (0.34)	0.20 (0.36)	0.22 (0.37)
1	-0.39 (0.22)	-0.20 (0.29)	-0.06 (0.36)	0.05 (0.41)	0.14 (0.45)	**0.21 (0.49)**	0.27 (0.53)	0.33 (0.56)	0.37 (0.58)
2	-0.46 (0.24)	-0.25 (0.35)	-0.08 (0.44)	0.06 (0.52)	0.19 (0.59)	0.30 (0.66)	0.40 (0.72)	0.49 (0.77)	0.57 (0.82)
3	-0.49 (0.25)	-0.28 (0.37)	-0.09 (0.47)	0.07 (0.56)	0.22 (0.65)	0.35 (0.74)	0.47 (0.81)	0.59 (0.88)	0.69 (0.95)
4	-0.50 (0.26)	-0.29 (0.38)	-0.10 (0.49)	0.08 (0.59)	0.24 (0.69)	0.39 (0.78)	0.52 (0.87)	0.65 (0.96)	0.77 (1.03)
RBC model									
σ^F \ σ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.25	-0.24 (0.15)	-0.13 (0.17)	-0.06 (0.19)	-0.01 (0.20)	0.02 (0.20)	0.05 (0.21)	0.07 (0.21)	0.09 (0.22)	0.10 (0.22)
0.5	-0.35 (0.21)	-0.20 (0.26)	-0.10 (0.30)	-0.02 (0.33)	0.04 (0.35)	0.09 (0.36)	0.13 (0.37)	0.16 (0.39)	0.19 (0.39)
0.7	-0.40 (0.24)	-0.24 (0.31)	-0.11 (0.36)	-0.02 (0.40)	0.05 (0.43)	0.11 (0.46)	0.16 (0.48)	**0.20 (0.49)**	0.24 (0.51)
1	-0.45 (0.27)	-0.27 (0.36)	-0.14 (0.43)	-0.03 (0.48)	0.06 (0.53)	0.14 (0.57)	0.20 (0.60)	0.26 (0.63)	0.31 (0.65)
2	-0.52 (0.32)	-0.33 (0.44)	-0.17 (0.55)	-0.03 (0.64)	0.09 (0.72)	0.20 (0.80)	0.29 (0.86)	0.38 (0.92)	0.46 (0.97)
3	-0.55 (0.33)	-0.36 (0.48)	-0.19 (0.60)	-0.04 (0.72)	0.10 (0.82)	0.23 (0.92)	0.34 (1.00)	0.45 (1.09)	0.55 (1.16)
4	-0.56 (0.34)	-0.37 (0.50)	-0.20 (0.63)	-0.04 (0.76)	0.11 (0.88)	0.25 (0.99)	0.37 (1.10)	0.49 (1.19)	0.61 (1.28)

Table C.2: Multipliers of industry-specific permanent public consumption shocks

CPA code	industry	$m^Y_{1,4}$	$m^Y_{1,120}$	import share	α_i
A	Agriculture	0.36	0.82	0.26	0.68
B	Mining	0.48	0.79	0.23	0.50
C	Manufacturing	-0.58	0.62	0.93	0.29
D	Energy	0.30	0.75	0.38	0.47
E	Water services	0.66	0.76	0.13	0.53
F	Construction	0.51	0.70	0.25	0.28
G	Wholesale and retail trade	0.63	0.73	0.17	0.29
H	Transportation	0.61	0.75	0.18	0.35
I	Tourism	0.68	0.77	0.16	0.40
J	Information	0.47	0.71	0.26	0.28
K	Financial and insurance services	0.62	0.66	0.17	0.22
L	Real estate	0.84	0.88	0.07	0.76
M	Professional services	0.61	0.72	0.16	0.29
N	Administrative services	0.67	0.74	0.13	0.34
O	Public administration	0.75	0.62	0.12	0.08
P	Education	0.81	0.59	0.07	0.04
Q	Health	0.69	0.65	0.16	0.15
R	Arts and entertainment	0.78	0.78	0.13	0.41
S,T,U	Other services	0.72	0.69	0.13	0.23
correlation with import share		-0.99	-0.26	1.00	0.01
correlation with α_i		-0.06	0.93	0.01	1.00

Note: Effective import shares include indirect imports through intermediates.

Table C.3: Local changes in the ex-ante present-value multiplier ($\Delta m^Y_{1,t}$) for specified parameter changes

symbol	parameters	Δ parameter	C^G		I^G		sub^I		sub^L		τ^C	
			SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
γ	survival rate	+10 years life-expectancy	0.002	0.017	-0.001	-0.005	0.000	0.002	0.008	0.089	0.001	0.016
σ	intertemp. elast. of subst.	+0.1	-0.024	-0.040	0.002	0.047	-0.002	0.047	0.012	0.024	0.019	0.044
σ^F	Frisch labor supply elast.	+1	0.172	0.308	0.027	0.090	0.091	0.204	-0.068	-0.049	0.098	0.175
σ^P	substitution K vs L	+0.1	0.002	-0.005	0.007	0.014	0.029	0.091	-0.001	-0.008	0.000	-0.004
i_0	interest rate	+1 pp (yearly)	-0.008	0.017	-0.005	0.009	-0.120	0.017	0.019	0.083	-0.003	0.014
$1-\pi$	share of constr. househ.	+10 pp	0.000	0.001	0.004	0.013	0.003	-0.004	-0.004	0.001	-0.001	0.001
θ	price stickiness	+1 quarter of av. price duration	0.044	0.001	0.075	0.002	0.056	0.000	0.003	0.001	0.007	0.000
θ^w	wage stickiness	+1 quarter of av. wage duration	-0.020	-0.012	0.127	0.076	0.156	0.071	0.051	-0.006	-0.041	-0.012
$1/(\epsilon-1)$	price markup	+1 pp	0.002	0.005	0.004	0.004	-0.037	-0.017	0.004	0.015	0.001	0.004
$1/(\epsilon^w-1)$	wage markup	+1 pp	0.002	0.001	-0.010	-0.007	-0.012	-0.006	-0.004	0.001	0.003	0.001
δ^2	(invers.) capacity util. elast.	+0.01	-0.006	-0.001	-0.008	-0.003	-0.043	-0.009	-0.001	-0.001	-0.002	-0.001
κ	consumption habits	+0.1	0.016	0.001	-0.001	-0.002	0.005	-0.002	-0.013	0.000	-0.014	-0.001
κ^L	working habits	+0.1	-0.007	-0.002	0.011	0.010	0.012	0.009	0.007	-0.001	-0.007	-0.002
$\overline{FC}$	share of fixed costs	+10 pp	-0.001	-0.005	-0.004	-0.008	0.043	0.017	-0.005	-0.017	-0.001	-0.004
ψ^{DF}	risk premium elast.	+0.01	0.000	0.000	-0.002	-0.002	-0.004	-0.003	-0.001	0.000	0.000	0.000
λ^E	foreign demand price elast.	+1 pp of E/GDP reaction	-0.070	0.006	-0.134	0.026	0.059	0.075	-0.064	-0.010	0.013	0.010
ξ^C	import share C	+10 pp	0.029	0.004	-0.003	0.002	0.002	0.006	-0.011	-0.001	-0.023	-0.001
ξ^{C^G}	import share C^G	+10 pp	-0.092	-0.007	-0.001	0.005	0.000	0.010	0.000	-0.001	0.000	0.001
ξ^I	import share I	+10 pp	-0.018	-0.001	-0.018	-0.002	-0.227	-0.025	0.010	0.004	-0.008	-0.002
ξ^{I^G}	import share I^G	+10 pp	0.000	0.000	-0.184	-0.014	0.000	0.003	0.000	0.000	0.000	0.000
λ^C	subst. dom. vs imp. C	+0.1 pp	-0.002	0.000	-0.004	0.001	0.001	0.002	-0.001	0.000	0.000	0.000
λ^{C^G}	subst. dom. vs imp. C^G	+0.1 pp	-0.001	0.000	-0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
λ^I	subst. dom. vs imp. I	+0.1 pp	-0.002	0.000	-0.003	0.000	0.000	0.001	-0.001	0.000	0.000	0.000
λ^{I^G}	subst. dom. vs imp. I^G	+0.1 pp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
δ^G	depreciation K^G	+1 pp (yearly)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
σ^G	efficiency K^G	+0.1	0.000	0.000	0.015	0.107	0.000	0.000	0.000	0.000	0.000	0.000

Notes: 'SR' refers to short run (after 1 year), 'LR' to long run (after 30 years).

Table C.3 (cont'd): Local change in the ex-ante present-value multiplier ($\Delta m^Y_{1,t}$) for specified parameter changes

symbol	parameters	Δ parameter	τ^W		τ^F		τ^{prof}		τ^K		τ^R	
			SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
γ	survival rate	+10 years life-expectancy	-0.001	-0.008	0.000	-0.003	0.005	0.050	0.002	0.021	0.008	0.088
σ	intertemp. elast. of subst.	+0.1	0.032	0.073	0.029	0.046	0.020	0.041	0.003	0.035	-0.024	0.042
σ^F	Frisch labor supply elast.	+1	0.215	0.354	-0.082	0.114	-0.079	-0.006	0.034	0.109	0.178	0.100
σ^P	substitution K vs L	+0.1	0.001	-0.004	0.011	-0.001	0.002	0.036	0.017	0.054	0.003	0.018
i_0	interest rate	+1 pp (yearly)	-0.013	-0.007	-0.036	0.002	0.084	0.066	-0.060	0.030	-0.025	0.040
$1-\pi$	share of constr. househ.	+10 pp	0.000	0.001	-0.004	-0.002	-0.006	0.001	0.001	-0.002	-0.009	-0.018
θ	price stickiness	+1 quarter of av. price duration	0.013	0.000	-0.163	-0.003	-0.102	-0.002	0.026	0.000	-0.031	-0.002
θ^w	wage stickiness	+1 quarter of av. wage duration	-0.099	-0.020	0.324	0.096	0.131	0.034	0.111	0.043	-0.162	0.012
$1/(\epsilon-1)$	price markup	+1 pp	0.001	0.001	-0.002	-0.001	-0.030	-0.067	0.002	0.027	-0.011	-0.033
$1/(\epsilon^w-1)$	wage markup	+1 pp	0.008	0.002	-0.027	-0.009	-0.011	-0.003	-0.009	-0.004	0.012	-0.001
δ^2	(invers.) capacity util. elast.	+0.01	-0.003	-0.001	-0.002	0.000	-0.076	-0.030	-0.031	-0.007	0.003	0.002
κ	consumption habits	+0.1	-0.021	-0.002	-0.021	-0.001	-0.017	0.000	-0.001	-0.001	0.017	-0.001
κ^L	working habits	+0.1	-0.016	-0.003	0.032	0.012	0.015	0.005	0.009	0.005	-0.020	0.002
$\overline{FC}$	share of fixed costs	+10 pp	0.000	-0.001	0.005	0.001	0.036	0.074	-0.001	-0.031	0.012	0.036
ψ^{DF}	risk premium elast.	+0.01	0.000	0.000	0.001	0.000	0.000	0.000	-0.003	-0.002	0.003	0.000
λ^E	foreign demand price elast.	+1 pp of E/GDP reaction	0.052	0.023	0.302	0.010	0.227	0.020	0.039	0.044	0.170	0.020
ξ^C	import share C	+10 pp	-0.039	-0.002	-0.033	-0.001	-0.020	0.001	-0.002	0.003	0.037	0.002
ξ^{C^G}	import share C^G	+10 pp	0.000	0.003	0.003	0.002	0.002	0.003	0.000	0.006	0.001	0.002
ξ^I	import share I	+10 pp	-0.019	-0.006	-0.043	-0.005	-0.074	-0.009	-0.137	-0.014	-0.026	-0.010
ξ^{I^G}	import share I^G	+10 pp	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.000	0.001
λ^C	subst. dom. vs imp. C	+0.1 pp	0.001	0.001	0.008	0.000	0.006	0.000	0.000	0.001	0.004	0.000
λ^{C^G}	subst. dom. vs imp. C^G	+0.1 pp	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.001	0.000
λ^I	subst. dom. vs imp. I	+0.1 pp	0.001	0.000	0.006	0.000	0.004	0.000	0.000	0.001	0.003	0.000
λ^{I^G}	subst. dom. vs imp. I^G	+0.1 pp	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
δ^G	depreciation K^G	+1 pp (yearly)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
σ^G	efficiency K^G	+0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: 'SR' refers to short run (after 1 year), 'LR' to long run (after 30 years).

Table C.4: Non-linearity check: ratio of the locally measured to globally measured multiplier sensitivity

	C^G		I^G		sub^I		sub^L		τ^C		τ^W		τ^F		τ^{prof}		τ^K		τ^R	
parameters	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
γ	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-	1.0	-	-	-	1.0
σ	0.8	0.9	-	0.9	-	0.8	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.6	0.7	-	0.8	1.8*	0.6
σ^F	1.2	1.3	-	1.3	1.2	1.3	1.1	1.3	1.2	1.3	1.2	1.3	1.0	1.3	1.1	-	-	1.3	1.2	1.3
σ^P	-	-	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-	1.0	-	1.0	-	-
i_0	-	-	-	-	1.1	-	-	1.2	-	-	-	-	-	-	1.1	1.3	1.1	-	-	-
$1-\pi$	-	-	0.2	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
θ	2.1	-	2.2	-	2.2	-	-	-	-	-	-	-	2.1	-	2.1	-	2.2	-	2.3	-
θ^w	-	-	1.0	0.8	1.0	0.8	0.8	-	1.0	-	0.9	-	0.9	0.7	0.8	0.7	1.0	0.8	1.0	-
ϵ	0.3*	-	0.4	-	2.5*	1.6	-	1.5	-	-	-	-	0.1	-	1.4	1.5	0.4*	1.5	1.1	1.5
ϵ^w	-	-	-1.5*	-	-1.5*	-	-1.0*	-	-	-	-1.3*	-	-1.3*	-	-1.2*	-	-1.4*	-	-1.2*	-
δ^2	-	-	-	-	8.6	8.8	-	-	-	-	-	-	-	-	8.6	8.8	8.6	-	-	-
κ	1.1	-	-	-	-	-	-	-	-	-	1.2	-	1.2	-	1.2	-	-	-	1.1	-
κ^L	-	-	0.7	0.5	0.7	0.5	-	-	-	-	0.8	-	0.7	0.4	0.7	-	-	-	0.8	-
$\overline{FC}$	-	-	-	0.8	1.3	1.2	-	1.0	-	-	-	-	-	-	0.8	1.1	-	1.0	1.0	1.0
ψ^{DF}	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
λ^E	1.6	-	1.7	-	-	2.1	2.3	-	-	-	-	-	1.7	-	1.8	-	-	-	2.1	-
ξ^C	1.1	-	-	-	-	-	-	-	1.1	-	1.1	-	1.0	-	1.0	-	-	-	1.0	-
ξ^{C^G}	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ξ^I	1.0	-	1.0	-	1.0	1.0	-	-	-	-	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-
ξ^{I^G}	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
λ^C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
λ^{C^G}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
λ^I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
λ^{I^G}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
δ^G	-	-	1.1	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
σ^G	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: Multiplier sensitivity is measured as the change of the ex-ante present-value multiplier w.r.t. a change in the normalized parameter. 'Locally' refers to the parameter step size as used in table C.3. 'Globally' refers to a parameter step size equal to the range of the parameter interval. Ratios deviating from 1 indicate non-linearity. An asterisk (*) indicates cases in which an extreme value of the multiplier is not located at the boundary of the parameter space. 'SR' refers to short run (after 1 year), 'LR' to long-run (after 30 years). The normalization of each parameter interval to $[0, 1]$ is carried out by $f(x) = \frac{x-\min(x)}{\max(x)-\min(x)}$ for bounded intervals and by $g(x) = \frac{x-\min(x)}{1+x-\min(x)}$ for unbounded intervals. Checks are reported only for cases where the range of the multiplier over the entire parameter interval is at least 0.1.

Figure C.1: Multiplier range for considered parameter space

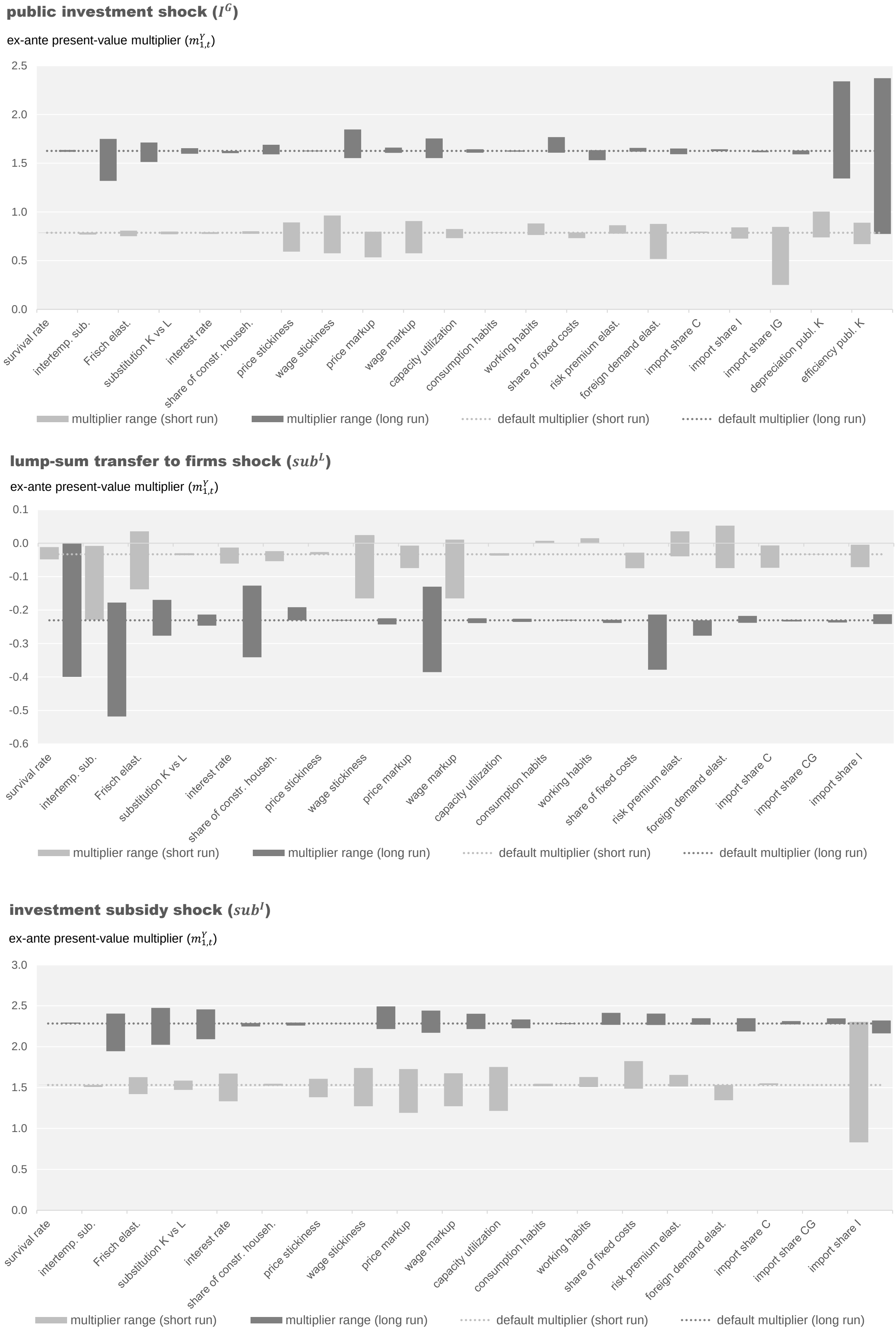
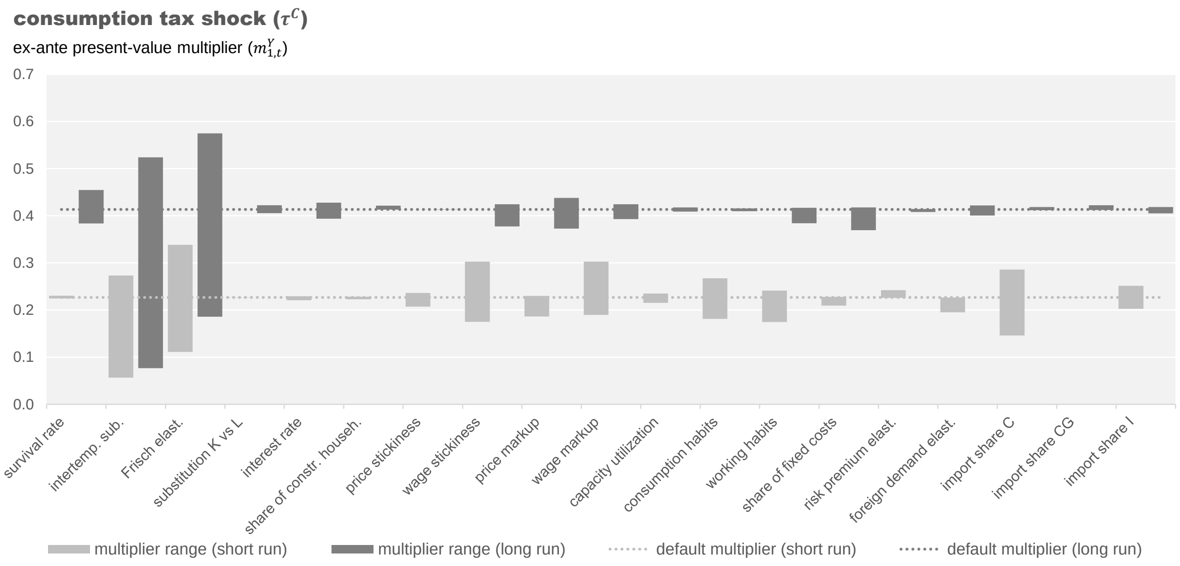
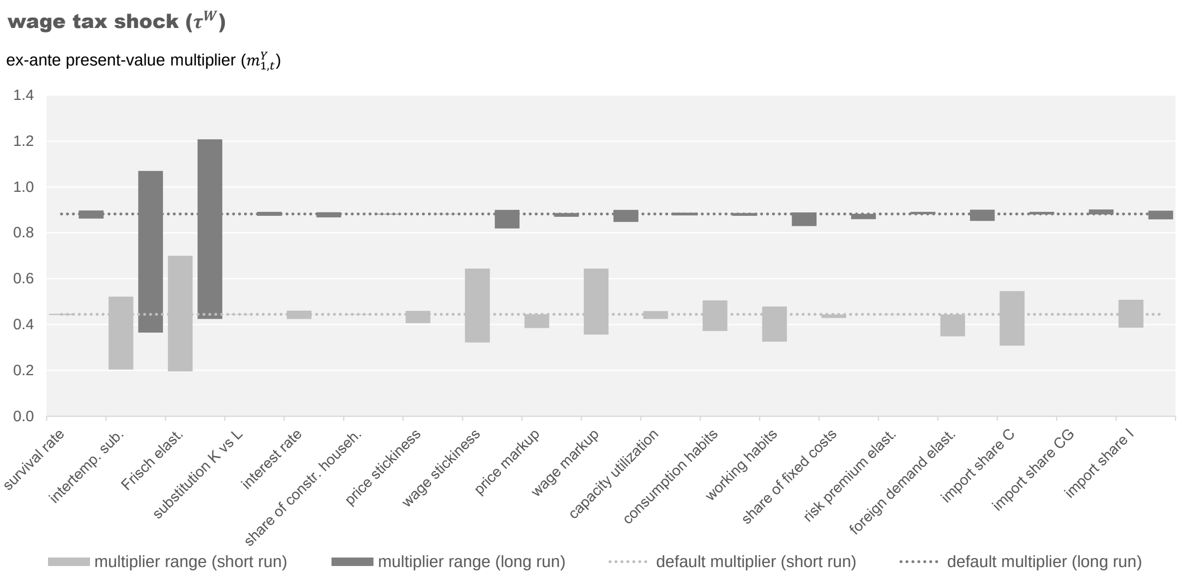


Figure C.1 (cont'd): Multiplier range for considered parameter space





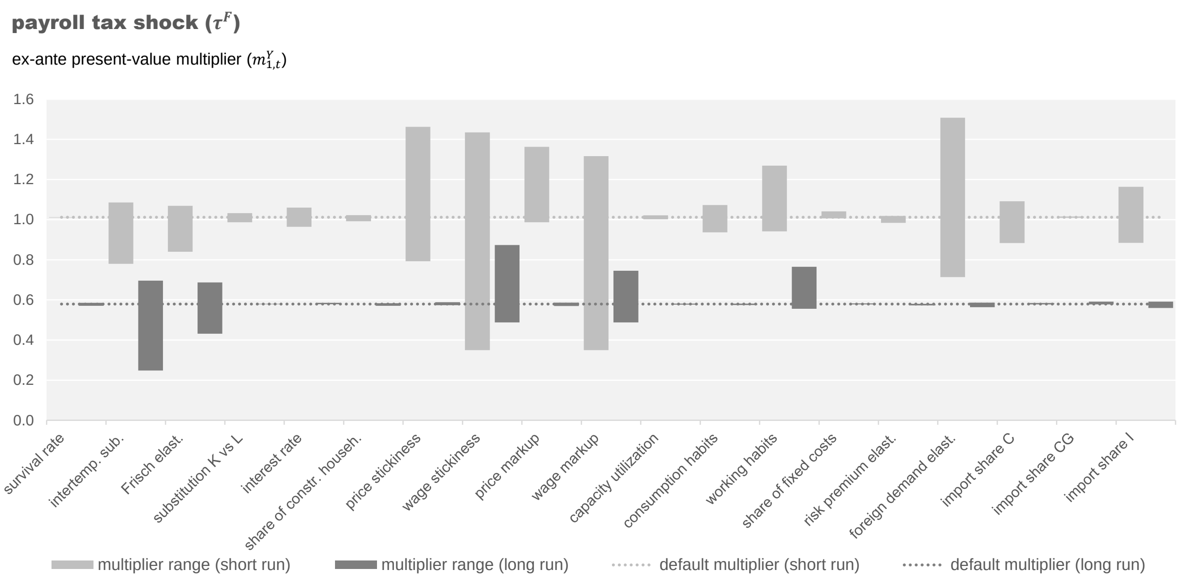
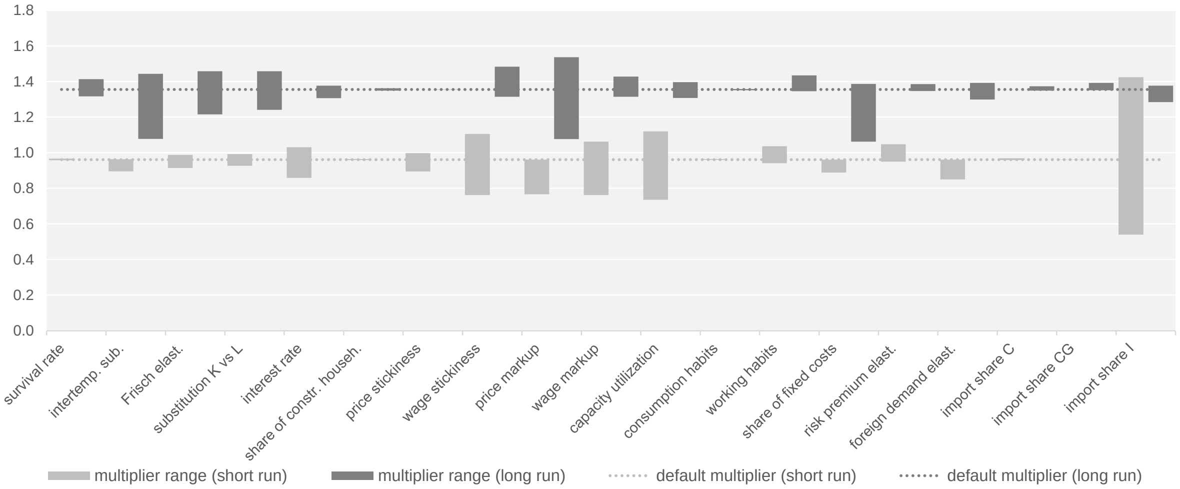


Figure C.1 (cont'd): Multiplier range for considered parameter space

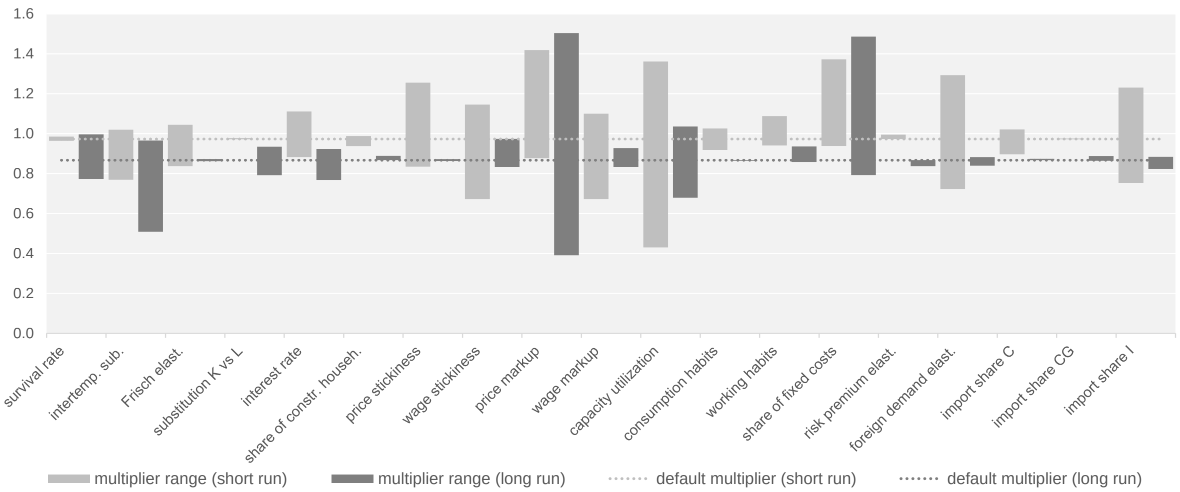
capital tax shock (τ^K)

ex-ante present-value multiplier ($m^Y_{1,t}$)



profit tax shock (τ^{prof})

ex-ante present-value multiplier ($m^Y_{1,t}$)



capital income tax shock (τ^R)

ex-ante present-value multiplier ($m^Y_{1,t}$)