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Durable Consumption, Limited VAT Pass-Through and Stabilization Effects of Temporary VAT Changes

Marius Clemens,* Werner Röger**

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Abstract

This paper revives the question of whether a temporary VAT change is an adequate instrument for crisis stabilization. In empirical assessments, we find that durable goods consumption fluctuates strongly over the business cycle and that VAT rate changes affect durable goods in particular. Therefore, we build a dynamic stochastic general equilibrium (DSGE) model that is capable of addressing this major channel through which temporary VAT changes affect the economy. Furthermore, we allow for an imperfect pass-through of VAT measures to consumer prices via VAT-specific price adjustment costs. We compare the general VAT policy in the crisis with alternative stabilization policies, such as interest rate cuts, spending policies and a VAT cut only for durable goods.

First, we find that considering durable goods in the model generates sizeable stabilization effects of VAT changes on consumption over a broad set of parameter ranges. Second, we find that the VAT policy can mimic monetary policy with minor exceptions. Third, the VAT rate cut has the highest short-term multiplier compared with government spending policies, but not in the medium-term. Fourth, a VAT rate reduction only on durable goods will generate strong GDP effects and even be self-financing in the first year. In contrast, a VAT reduction only on non-durables has small effects on GDP and is not self-financing. In view of our results, we conclude that a temporary VAT cut, when applied to durable goods, is an effective stabilization instrument.

JEL:E62, E63, H21

Keywords: Value added tax, durable consumption, multiplier, business cycle, zero lower bound

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1 Introduction

In this paper, we revive the question of whether a temporary VAT change is an effective stabilization instrument in times of recessions. Recent studies in the empirical literature find strong and significant GDP effects of a temporary VAT change (e.g., Büttner and Madzharova (2017)). However, approaches that rely on general equilibrium modelling show that the temporary VAT change is not an effective stabilization instrument (e.g., Claus (2013)) or find impact multipliers less than one (Sims and Wolff (2018)). Looking through the general equilibrium model lens, other stabilization instruments, such as government spending, seem to be more effective and less incriminatory to the government budget. Another important finding of the recent empirical studies is that the VAT policy works mainly through intertemporal substitution of durable and semi-durable goods (Büttner and Madzharova (2017), Bachmann et al. (2021)). However, the willingness to adjust prices with respect to the temporary VAT policy can also differ from the usual price-setting behavior of firms and should be included in a comprehensive analysis. Finally, households with a high marginal propensity to consume (MPC), such as liquidity-constrained (LC) households, react differently to the VAT policy than households with a low MPC.

Our study relates to two strands of research on the macroeconomic effects of VAT changes. We contribute to the literature on the theoretical effects of a temporary VAT rate change. For the European countries VAT rate case, Sims and Wolff (2018) analyze state-specific tax shocks. They find VAT multipliers of 0.2–0.5 on impact and 0.6–0.8 at the maximum depending on factors, such as the share of LC households. Furthermore, Claus (2013) explicitly analyzes the effectiveness of a VAT rule as a stabilization instrument. She finds that a VAT rule is not as effective as a monetary policy rule. We differ from both studies by incorporating the abovementioned channels and comparing the temporary VAT policy with other stabilization instruments. We set up a standard dynamic stochastic general equilibrium (DSGE) model and features that make it especially suitable to deal with the issues raised above. In the model, we distinguish between durable and non-durable goods. We also consider a limited VAT rate pass-through channel, where the specific price adjustment costs are included in the price-setting function of intermediate and retail firms (see Voigts (2016)). Thus, firms will not fully transmit the VAT-related price changes to consumers. Finally, we explicitly allow LC households to buy and consume durable goods.

We find that ignoring these features leads to a strong underestimation of the temporary VAT impact in DSGE models. The durable goods consumption of LC households is especially sensitive to temporary VAT changes. Without these channels, we confirm the literature results and find a small VAT multiplier of 0.3 in the first year for our benchmark calibration. With LC households the effectiveness increases slightly by 0.1. We find a VAT multiplier of 1.6 if we include durable goods consumption. The VAT multiplier rises above three, if we assume that firms fully transmit VAT changes immediately. In our simulations, the VAT effect diminishes over the medium-term, because of the intertemporal shift of durable goods consumption.

In the second part of our analysis, we further compare the effectiveness of the temporary VAT policy to other often-used stabilization policies, such as interest rate cuts and different spending policies. We find that the VAT rate reduction can almost perfectly mimic an interest rate cut in terms of aggregate consumption, but there are differences in terms of investment, durable goods and consumption of LC households. Compared with temporary

spending policies of the government, the VAT rate cut has the highest short-term multiplier on impact and in the first year, but it is less effective over the medium term. However, a VAT rate reduction only on durable goods will be fully self-financing in the first year, and even in the medium term, when future consumption is weaker due to the intertemporal substitution effect than it would be without the VAT policy, the cumulative multiplier is still larger than one. We conclude that a temporary VAT cut is an effective consumption stabilization instrument in a crisis, especially if it is limited to durable goods.

The paper is organized as follows: In section 2, we empirically motivate our research objective and estimate the general empirical effect of VAT revenue changes with time-series data for Germany and alternative structural vector autoregression (SVAR) identification strategies. In Section 3, we explain our model setup and the model parameterization. In Section 4, we start with an analysis of the mechanisms of how the VAT reduction affects the economy and test the robustness of different parameter specifications. In the next chapter, we evaluate the temporary VAT policy using calculated GDP multipliers and compared to other stabilization policies. Finally, Section 5 concludes.

2 Empirical Evidence

2.1 Consumption Components of the Cycle

To address the question of whether a temporary VAT policy is an effective stabilization instrument, we will first examine whether consumption, which the VAT change is mainly intended to stabilize, is subject to relatively strong fluctuations at all. We summarize the cyclical pattern of main macroeconomic aggregates for selected countries between 1995 and 2019 in Table 1.[1] We confirm the general finding of the literature that (the cyclical component of) private consumption fluctuates on average much less and (the cyclical component of) private investment more over time than the cyclical component of GDP. Business cycle models explain this stylized pattern by the fact that households use part of their income to accumulate savings in order to stabilize their consumption path. Households use savings to stabilize their consumption path; investments fluctuate much more because they are financed by households savings. Furthermore, our empirical pattern confirms that private consumption and private investments are strongly positively correlated with the GDP in most countries. Because of their higher volatility, fiscal stabilization policy often aims to stabilize private investment in particular.

However, we find a different pattern if we distinguish between the durable and non-durable consumer goods categories: Non-durable goods fluctuate significantly less than total consumption; durable goods fluctuate as much as private investment.[2] Aggregate consumption thus fluctuates less than GDP, because non-durable goods are largely in demand and are less dependent on the economic situation.[3] Therefore, government measures, such as a temporary VAT policy, that explicitly reduce the volatility of durable goods during economic crises (and booms)

[1] See Subsection B.2 in the Appendix for detailed data description.

[2] Figure 6 in the Appendix A shows the cyclical correlation of the durable goods in more detail and confirms our results of the average pattern.

[3] Note that by including the COVID-19 period from 2020 to 2021, both the total volatility and the relationships significantly change. Total consumption becomes much more volatile than GDP, mainly because of the increasing fluctuation in durable goods consumption. Furthermore, the correlation between durable goods consumption and GDP increases significantly.

Table 1: Cyclical components[1] for selected countries, 1Q1995–4Q2019

	DEU	FRA	ITA	UK	USA
Standard derivation					
GDP	1.54	1.23	1.56	1.39	1.13
Total consumption	0.89	1.01	1.47	1.34	0.98
Private investment	3.07	2.62	2.76	3.29	3.28
Non-durable goods	0.86	0.90	1.30	1.31	0.97
Durable goods	1.60	2.17	3.04	3.60	2.85
Correlation with GDP					
GDP	1	1	1	1	1
Total consumption	0.56	0.80	0.55	0.88	0.89
Private investment	0.87	0.92	0.75	0.69	0.87
Non-durable goods	0.51	0.87	0.57	0.87	0.76
Durable goods	0.38	0.68	0.48	0.50	0.68

[1] The trend values were calculated based on a Hodrick–Prescott filter with a smoothing parameter of $\lambda = 1600$. The cyclical components of the main macroeconomic variables are defined as the percentage deviation of the actual values from their trend.

could be an effective fiscal policy stabilization instruments.

2.2 SVAR Evidence

In a second step, we provide specific evidence of how VAT rate changes affect durable goods consumption by estimating an SVAR model. Therefore, we use time-series data for VAT revenues, durable and non-durable goods consumption in Germany from 1Q1991:4Q2019. We use different instrument variables to solve the endogeneity problem, that GDP changes can be cause and consequence of VAT revenue change. In our baseline SVAR estimation, we apply the identifying assumption by Blanchard and Perotti (2002) and use evidence from a tax microsimulation model for Germany[4] on the VAT elasticity to consumption in order to construct the cyclically adjusted, reduced-form tax residuals as an instrument.[5] Our basic SVAR representation is

$$X_t = A(L,q)X_{t-1} + U_t, \tag{1}$$

where $X_t \equiv [T_t^{vat}, G_t, C_t^i]'$ is a three-dimensional vector with the logarithm of VAT revenues, public consumption and specific private consumption all in real terms. For private consumption $C_t^i = [ID_t, ND_t]$ we use either durable or non-durable goods consumption. $A(L,q)$ is a four-quarter distributed lag polynomial, and U_t is a corresponding vector of reduced-form residuals, which generally has non-zero cross correlations. Usually, VAT revenues are paid with a delay of around 2 months; however, tax deferrals are a widely used instrument in crisis situations. We consider tax delays and deferrals by allowing for four lags due to the quarterly data structure. Furthermore, we consider quarterly dummies in order to capture specific tax-related seasonality.[6] We apply the VAT elasticity of

[4] See Bach et al. (2006).
[5] See Appendix D for a description of the approach.
[6] We also control for reunification 1Q1991:2Q1992 and the financial crisis 4Q2008:2Q2009. However, neither dummy variables changes the results significantly.

durable and non-durable goods consumption. According to Mourre and Princen (2015) the VAT elasticity to total consumption ranges between 0.9 and 1.4 in the EU. Bach et al. (2006) estimate steady-state VAT elasticities for different consumption groups in Germany. Based on these estimations, we calculate an average tax elasticity of 1.8 for durable goods consumption and 0.8 for non-durable goods consumption.[7] Finally, we control for announcement effects that occur because large permanent tax rate changes were implemented with a duration of up to four quarters. We also run an alternative estimation where we instrument the VAR rate changes with a series of official tax revenue estimates due to legislative tax law changes by the German Federal Ministry of Finance.[8]

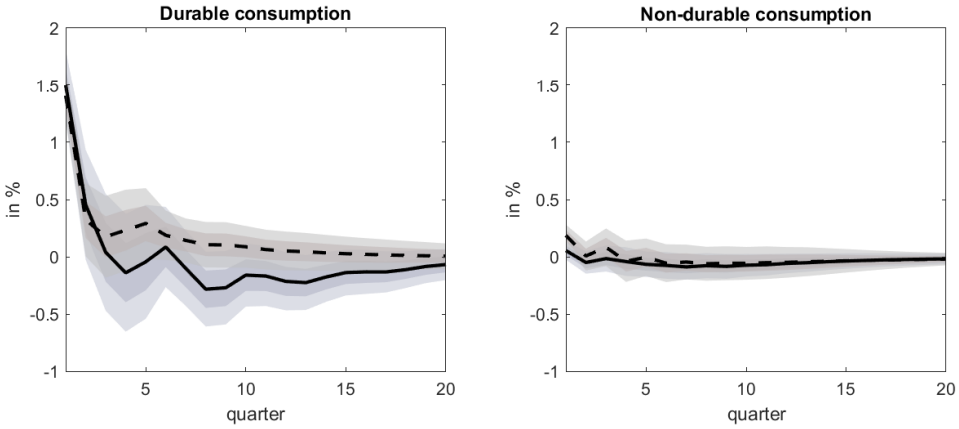

Figure 1: Impulse response in durable and non-durable goods consumption after a 1% decrease of VAT revenues, 1991Q1–2019Q4

straight line, dark gray shaded area: estimation based on Blanchard and Perotti (2002) Identification via tax revenue elasticity, mean, 68% and 95% significance level.
dashed line, light gray shaded area: estimation based on a narrative series of exogenous tax law changes, mean, 68% and 95% significance level.

The estimated impulse response functions are depicted in Figure 1. The shaded areas depict the 68% and 95% significance levels. Our estimations show that a 1% VAT revenue reduction increases durable goods consumption significantly by 1.4–1.5%. Thus, the effect of the VAT reduction is much stronger for durable goods than for non-durable goods, where the 1% VAT revenue reduction increases non-durables by 0.05–0.18%. The positive effect on consumer durable goods is significant for three quarters; afterward, we observe a small negative counteraction. In the case of non-durable goods, the small positive effects smooth out after one year.

This empirical evidence speaks in favor of the VAT rate as an effective stabilization instrument. In the next step we explore the main channels that drive this result in a DSGE model. We will then compare the VAT policy with alternative conventional stabilization policies of the central bank and the government, such as an interest rate cut or an increase in government spending. Both will give us further insights into the effectiveness of temporary VAT changes as a possible stabilization tool instrument in crises.

[7] See Section D in the Appendix for a description.
[8] See Table 3 in the Appendix for the summary.

3 Model

The model considers two infinitely-living household types that differ with respect to their savings behavior. Unrestricted households, also known as Ricardian households, have full access to financial markets, LC households, also known as hand-to-mouth consumers, consume their current-period income. There is a monopolistically competitive retail branch in each sector that sells goods produced in the respective sector to households and pays the VAT. These firms decide about passing the VAT through to consumers.

3.1 Private Households

The economy is populated by two types of representative households, LC and Ricardian households of measure s^L and $1-s^L$, respectively. The Ricardian household is unconstrained and owns capital and the firms. The liquidity status of household types is marked by the superscript l. Both household types $l = R, L$ optimize private consumption and leisure according to the following utility function

$$E_0 \sum_{t=0}^{\infty} e_t^d \beta^t \left(\frac{(C_t^l)^{1-\sigma^c}}{1-\rho} - \omega \frac{(L_t)^{1+\sigma^l}}{1+\rho} \right), \tag{2}$$

where σ^c is the inverse intertemporal substitution elasticity. Both household types consume non-durable goods $P^{N,l}ND^l$ and durable goods $P^{D,l}D^l$. Preferences for durable and non-durable goods are specified as a constant elasticity of substitution (CES) utility function:

$$C_t^l = \left[(\psi^{N,l})^{\frac{1}{\sigma^{ND}}} (ND_t^l)^{\frac{\sigma^{ND}-1}{\sigma^{ND}}} + (\psi^{D,l})^{\frac{1}{\sigma^{ND}}} (D_t^l)^{\frac{\sigma^{ND}-1}{\sigma^{ND}}} \right]^{\frac{\sigma^{ND}}{\sigma^{ND}-1}} \tag{3}$$

with $\psi^{N,l}$ and $\psi^{D,l}$ denoting the shares of durable and non-durable goods. σ^{ND} measures the elasticity of intratemporal substitution between durable and non-durable goods.

3.1.1 Ricardian Household

The household has access to one-period private domestic bonds B_t that pay one unit of the national currency in $t+1$, sell at price R_t^{-1}. Additionally, the Ricardian household can rent out new capital to firms $P_t^I I_t$ and receives after-tax wage income, capital income from renting to firms $R_t^k K_{t-1}$, transfers from the government Z_t^R and profits from firms PR_t. The flow budget constraint for the Ricardian household is

$$\begin{aligned} \left(1+\tau_t^{VAT}\right) P_t^N ND_t^R + \left(1+\tau_t^{VAT}\right) \left(1 + \frac{\gamma^D}{2} \left(\frac{ID_t^R}{D_{t-1}^R} - \delta^D \right)^2 \right) P_t^D ID_t^R + \left(1 + \frac{\gamma^K}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 \right) P_t^I I_t + B_t \\ = R_{t-1} B_{t-1} + \left(1-\overline{\tau}^W\right) W_t L_t^R + R_t^k K_{t-1} - \frac{\gamma^I}{2} P_t^I \left(I_t - I_{t-1}\right)^2 + Z_t^R + PR_t. \end{aligned} \tag{4}$$

The Ricardian household buys non-durable goods ND_t^R and new durable goods consumption ID_t^R with durable goods adjustment costs $\frac{\gamma^D}{2}\left(\frac{ID_t^R}{D_{t-1}^R} - \delta^D\right)^2$. She pays VAT for the use of existing durable goods and for the purchase of new durable goods. P_t^N and P_t^D are the non-durable and durable goods net consumer prices set by

the firms. The total labor income of the Ricardian household is $W_t L_t$. Furthermore, she holds the aggregate capital stock K_t and takes new investments I_t. Capital accumulation come along with capital adjustment costs $\frac{\gamma^K}{2}\left(\frac{I_t}{K_{t-1}}-\delta\right)^2$ and with investment adjustment costs $\frac{\gamma^I}{2}\left(I_t-I_{t-1}\right)^2$. The aggregate capital stock K_t evolve according to the following definition:

$$K_t = (1-\delta)K_{t-1} + I_t. \tag{5}$$

where δ is the rate at which the capital stock depreciated. The relative price for capital q_t can be derived from the first order conditions under:

$$E_t R^k_{t+1} = \frac{\left(1+E_t\pi^{C,R}_{t+1}\right)U^{C,R}_t q_t}{\beta\left(U^{C,R}_{t+1}\right)\left(E_t q_{t+1}\right)} - (1-\delta). \tag{6}$$

The stocks of durable goods D^R_t that the Ricardian household consumes follow the following accumulation rule:

$$D^R_t = (1-\delta^D)D^R_{t-1} + ID^R_t, \tag{7}$$

where ID^R_t denotes the Ricardian household purchases of (new) durable good consumption.[9]

The first-order conditions of the optimization problem give the intertemporal consumption and investment Euler equations, labor supply, optimal durable and non-durable goods consumption.[10] Here, we focus on how the demand for durable and non-durable goods responds to actual and expected VAT changes. The Euler equation for the consumption aggregate is

$$\frac{E_t C^R_{t+1}}{C^R_t} = \beta(1+i_t)\frac{P^{C,R}_t}{E_t P^{C,R}_{t+1}}, \tag{8}$$

where the ideal consumer price deflator for the Ricardian household consists of the price for non-durable goods and the service price for durable goods.

$$P^{C,R}_t = \left(\overline{\psi}^{N,R}\left(\left(1+\tau^{VAT}_t\right)P^{ret,N}_t\right)^{1-\sigma^{ND}} + \overline{\psi}^{D,R}\left(\left(1+\tau^{VAT}_t\right)P^{ret,D}_t R^{D,R}_t\right)^{1-\sigma^{ND}}\right)^{\frac{1}{1-\sigma^{ND}}}, \tag{9}$$

where $\overline{\psi}^{N,R}$ and $\overline{\psi}^{D,R}$ are the consumption shares for durable and non-durable goods consumption. A temporary reduction of the VAT rate leads to an increase of current consumption because of an expected consumer price inflation effect. The demand functions for durable and non-durable goods are given by

$$ND^R_t = \overline{\psi}^{N,R}\left(\frac{\left(1+\tau^{VAT}_t\right)P^{ret,N}_t}{P^{C,R}_t}\right)^{-\sigma^{ND}} C^R_t, \tag{10}$$

$$D^R_t = \overline{\psi}^{D,R}\left(\frac{\left(1+\tau^{VAT}_t\right)\left(1+\gamma^D\left(\frac{ID^R_t}{D^R_{t-1}}-\delta^D\right)\right)P^{ret,D}_t}{P^{C,R}_t}R^{D,R}_t\right)^{-\sigma^{ND}} C^R_t, \tag{11}$$

[9] Note that, by assumption, durable goods are produced under perfectly competitive markets and according to a linear production technology. Thus, the aggregate durable goods price P^D is equal to the producer price P^y.

[10] See model description in Appendix E.

where the rental rate for durable goods $R_t^{D,R}$ is given by

$$R_t^{D,R} = r_t - \left(E_t \pi_{t+1}^{ret,D} - E_t \pi^Y{}_{t+1}\right) - \gamma^D \left(\frac{E_t ID_{t+1}^R}{D_t^R} - \frac{ID_t^R}{D_{t-1}^R}\right) + \delta^D - \left(E_t \tau_{t+1}^{VAT} - \tau_t^{VAT}\right). \tag{12}$$

R_t^D shows that in the case of a temporary reduction of VAT in period t, there is an additional positive VAT effect on the demand for durable goods because households base their investment decisions on the price differential between t and $t+1$. Putting the demand functions (10) and (11) together, we obtain the relative demand function for the Ricardian household

$$\left(\frac{\overline{\psi}^{D,R}}{\overline{\psi}^{N,R}}\right)^{\frac{1}{\sigma^{ND}}} \left(\frac{ND_t^R}{D_t^R}\right)^{\frac{1}{\sigma^{ND}}} = \frac{P_t^{ret,D}}{P_t^{ret,N}} R_t^{D,R}, \tag{13}$$

which shows that households increase the relative demand for durable goods if they expect an increase in VAT in the next period. It should also be noted that even a small increase of the stock of durable goods will lead to large differences in durable goods consumption.

3.1.2 LC Households

We assume that the LC household has the same preferences for durable and non-durable goods as the Ricardian household. When choosing between durable and non-durable goods, the LC household must also solve an intertemporal maximization problem (2) subject to a sequence of period budget constraints

$$\left(1 + \tau_t^{VAT}\right) ND_t^L + \left(1 + \tau_t^{VAT}\right) ID_t^L = \left(1 - \overline{\tau}^W\right) W_t L_t + Z_t^L, \tag{14}$$

where $W_t L_t$ is labor income, and Z_t^L is the transfer income of the LC household. ID_t^L denotes the LC household purchases of new durable goods with adjustment costs $\frac{\gamma^D}{2}\left(\frac{ID_t^L}{D_t^L} - \delta^D\right)^2$. Furthermore, LC households face an accumulation constrained for durable goods:

$$D_t^L = \left(1 - \delta^D\right) D_{t-1}^L + ID_t^L. \tag{15}$$

No access to financial markets implies that expenditure on non-durable and new durable goods is constrained by current net income. Because LC households spend their entire net income each period, aggregate consumption is not subject to expected changes in the VAT rate, but is subject to a real income effect. However, there is substitution between durable and non-durable goods in the case of a temporary VAT reduction.

The allocation of spending across durable and non-durable goods is determined by the following first-order conditions:

$$ND_t^L = \overline{\psi}^{N,L} \left(\frac{\left(1 + \tau_t^{VAT}\right) P_t^{ret,N}}{P_t^{C,L}}\right)^{-\sigma^{ND}} C_t^L, \tag{16}$$

$$D_t^L = \overline{\psi}^{D,L} \left(\frac{\left(1 + \tau_t^{VAT}\right) \left(1 + \gamma^D \left(\frac{ID_t^L}{D_{t-1}^L} - \delta^D\right)\right) P_t^{ret,D}}{P_t^{C,L}} R_t^{D,L}\right)^{-\sigma^{ND}} C_t^L. \tag{17}$$

Combining both demand functions, we derive the relative demand conditions similar to the case of unconstrained consumers.

$$\left(\frac{\overline{\psi}^{D,L}}{\overline{\psi}^{N,L}}\right)^{\frac{1}{\sigma^{ND}}}\left(\frac{ND_t^L}{D_t^L}\right)^{\frac{1}{\sigma^{ND}}}=\frac{P_t^{ret,D}}{P_t^{ret,N}}R_t^{D,L}. \tag{18}$$

In particular, there is a shadow rental rate for durable goods $R_t^{D,L}$ which, in the absence of an interest rate for LC households, is determined by the marginal rate of substitution between current and future consumption plus the inflation differential between the ideal consumer price deflator and the deflator for durable goods:

$$R_t^{D,L}=\rho+\left(E_tC_{t+1}^L-C_t^L\right)+E_t\pi_{t+1}^Y-E_t\pi_{t+1}^{ret,D}-\gamma^D\left(\frac{E_tID_{t+1}^L}{D_t^L}-\frac{ID_t^L}{D_{t-1}^L}\right)+\delta^D-\left(E_t\tau_{t+1}^{VAT}-\tau_t^{VAT}\right). \tag{19}$$

The shadow rental rate for durable goods responds to expected VAT changes in the same way the rental rate for the Ricardian household does. Thus, an expected increase in VAT induces the LC household to shift consumption spending from non-durable to durable goods.

3.2 Intermediate Goods Producers

A continuum of intermediate firms indexed by $i\in[0,1]$ exists in the economy. Each firm i produces an intermediate good according to the following production technology:

$$Y_t(i)=A\,K_t(i)^{\alpha^K}L_t(i)^{\alpha^L}\left(K_t^G\right)^{\alpha^{KG}}, \tag{20}$$

where $\alpha^K,\alpha^L\in[0,1]$ are the partial production elasticities. A is the total factor productivity in each sector. Cost minimization under an identical production technology implies that firms have identical marginal costs per unit of output

$$MC_t=MC_t(i)=(\alpha^L)^{-\alpha^L}(\alpha^K)^{-\alpha^K}(W_t)^{\alpha^L}\left(R_t^k\right)^{\alpha^K}\left(K_t^G\right)^{\frac{\alpha^{KG}}{\alpha^{KG}-1}}. \tag{21}$$

The demand for firm i's output is given by

$$Y_t(i)=\left(\frac{P_t(i)}{P_t}\right)^{-\eta^P}Y_t, \tag{22}$$

where Y_t is the final demand, and P_t is the producer price. The prices are set according to Rotemberg (1982) via quadratic adjustment costs that include the VAT:

$$\Delta_t^P=\frac{\gamma^P}{2}Y_t\left[\frac{P_t(i)}{\Pi_{t-1}^{s^P}\overline{\Pi}_t^{1-s^P}P_{t-1}(i)}-1\right]^2. \tag{23}$$

Maximizing the firm profit PR_t

$$PR_t=E_t\sum_{t=0}^{\infty}(\beta)^t\left(\left(\frac{P_t(i)}{P_t}\right)Y_t-\frac{W_tL_t(i)}{P_t}-\frac{\gamma^P}{2}Y_t\left[\frac{P_t(i)}{\Pi_{t-1}^{s^P}\overline{\Pi}_t^{1-s^P}P_{t-1}(i)}-1\right]^2\right), \tag{24}$$

with respect to the demand equation (22) and the production function (20) gives the price-setting equation (assuming $s^P = 0$):

$$MC_t = \left(1 + \frac{1}{\eta^P}\right) + \beta \frac{\gamma^P}{\eta^P} \left(E_t \pi_{t+1}^Y - \frac{\gamma^P}{\eta^P} \pi_t^Y\right). \tag{25}$$

3.3 Retail Sector

Firm i in the retail sector transforms final goods $Y(i)_t$ into consumer goods $Y_t^C(i)$. We assume that retailers operate under monopolistic competition and have market power and face quadratic costs of adjusting prices (including VAT). The retailer buys inputs at price P_t and sells them at price $P_t^{ret}(i)\left(1+\tau^{VAT}\right)$. The sales price for the firm is $P_t^S(i) = (1+\tau^{VAT})P_t^{ret}(i)$. Firm i maximizes profits

$$PR_t^{ret} = P_t^{ret}(i)\left(1+\tau_t^{VAT}\right)Y_t^C(i) - P_t Y_t - \frac{\gamma^P}{2}\left[\frac{(P_t^S(i))^{\gamma^{VAT}}(P_t^{ret}(i))^{1-\gamma^{VAT}}}{(\Pi_{t-1})^{s^P}(\Pi_t^T)^{1-s^P}P_t^S(i))^{\gamma^{VAT}}(P_t^{ret}(i))^{1-\gamma^{VAT}}} - 1\right]^2 - \tau_t^{VAT} P_t(i) Y_t(i) \tag{26}$$

subject to a simple linear production technology

$$Y_t^C(i) = Y_t(i) \tag{27}$$

and the demand equation

$$Y_t^C(i) = \left(\frac{P_t^{ret}(i)\left(1+\tau_t^{VAT}\right)}{P_t^{ret}\left(1+\tau_t^{VAT}\right)}\right)^{-\eta^P}, \tag{28}$$

where the VAT is not relevant because competitors face the same VAT. Considering that the firm knows that all competitors also pay VAT, the price-setting problem simplifies, and VAT only appears in the price adjustment cost term. The problem firm i faces when there is an exogenous change in τ_t^{VAT} is how to set the price $P_t^{ret}(i)$ such that the price adjustment cost for $P_t^{ret}(i)\left(1+\tau_t^{VAT}\right)$ is minimized. From the profit maximization decision of the retail firm, we then can derive the price-setting function (assuming $s^P = 0$):

$$P_t^{ret} = 1 + \mu_t^{ret} + \gamma^{P,ret}\left(\beta\left(E_t \pi_{t+1}^{ret} + \frac{\gamma^{VAT}}{1+\tau^{VAT}} E_t \Delta\tau_{t+1}^{VAT}\right) - \left(\pi_t^{ret} + \frac{\gamma^{VAT}}{1+\tau^{VAT}}\Delta\tau_t^{VAT}\right)\right), \tag{29}$$

where we write adjustment cost as a weighted average of the sales price and the price with weights γ^{VAT} and $1-\gamma^{VAT}$, respectively. In the case of $\gamma^{VAT} = 1$, price adjustment costs do not depend on the source of the price change. In the case of $\gamma^{VAT} = 0$, the firm faces no cost with changed prices due to VAT changes. In all cases between of $\gamma^{VAT} = 0$ and of $\gamma^{VAT} = 1$, the firm faces positive but smaller costs of price adjustment due to VAT changes.

Suppose there is a VAT reduction in t and an expected increase (returning to the previous level) in $t+1$. From the equation above we can see that it is optimal for the firm to increase the mark up temporarily. Both $\tau_t^{VAT} - \tau_{t-1}^{VAT} < 0$ and $E_t\tau_{t+1}^{VAT} - \tau_t^{VAT} > 0$ affect the mark up positively. This implies that an expected temporary reduction of the mark up leads to a larger increase in the mark up than a permanent reduction of τ_t^{VAT} or an expected permanent increase of $E_t\tau_{t+1}^{VAT}$. In this case it is optimal for the firm to increase the mark up already in t

such as to avoid adjustment costs from an abrupt change of prices in $t+1$.

3.4 Labor Agency

Each household supplies a continuum of differentiated labor services indexed by k. These differentiated labor services are supplied by both Ricardian and LC households. A competitive labor agency combines the differentiated labor services into a homogeneous sector-specific labor input that is sold to the intermediate firms in both sectors. There is no labor mobility between sectors. The labor demand function for different labor types k is

$$L_t(k) = L_t \left(\frac{W_t(k)}{W_t} \right)^{-\frac{1+\eta_t^w}{\eta_t^w}}, \tag{30}$$

where L_t is the demand for composite labor services, and W_t is the nominal wage that satisfies $W_t = \left(\int_0^1 W_t(k)^{\frac{1}{\eta_t^w}} dk \right)^{\eta_t^w}$.

The real wage can be derived by solving the optimal labor supply decision of the households:

$$w_t^C = \frac{(-U'(L_t)) \left(1 + \mu^W + \gamma^W \left(\beta E_t \pi_{t+1}^W - \pi_t^W\right)\right)}{\left(s^L U'(C_t^L) + U'(C_t^R)\left(1 - s^L\right)\right)\left(1 - \tau^w\right)}, \tag{31}$$

where $U'(L_t) = -\omega^j L_t^\rho$ is the marginal utility of supplying an extra unit of labor, and $U'(C_t^L)$ and $U'(C_t^R)$ are the marginal utilities of consumption for the LC and the Ricardian household. The dynamic wage equation can be transformed into the well-known wage Phillips curve.[11]

3.5 Monetary and Fiscal Policy

Monetary policy is conducted by the central bank according to the following rule:

$$i_t = \left(\frac{1-\beta}{\beta}\right) e_t^{ZLB} + \left(1 - e_t^{ZLB}\right) \left(\max \left[\underline{i}, (1-\phi^i) \left(\bar{r} + \phi^\pi \pi_t^Y + \phi^{dy} \left(Y_t - Y_{t-1}\right) + \phi^y \frac{Y_t}{\overline{Y}} \right) + \phi^i i_{t-1} + e_t^i \right] \right), \tag{32}$$

where ϕ^π, ϕ^y and ϕ^{dy} denote the weights for the central bank's inflation, output gap and growth targets. If the interest rate is above the lower bound $\underline{i}$, the central bank follows a Taylor-type rule in which nominal interest rate i_t responds to its lagged value, the current inflation rate, output gap and output growth. Furthermore, we include a binary variable e_t^{ZLB} which is 1 if we consider the announcement of a constant interest rate policy for period t.

We assume a simplified government budget function, where the government spends a constant fraction of steady-state GDP $G_t = gY_t$ and public investment $I_t^G = ig^Y Y_t$ and finances its expenditures either with new debt $B_t - B_{t-1}$ or different taxes on value added τ^{VAT}, labor income τ^w, and a lump-sum tax or transfer T_t (if negative). Furthermore, the government pays interest rates on issued debt $r_{t-1}^B B_{t-1}$:

$$B_t = G_t + I_t^G + \left(1 + r_{t-1}^B\right) B_{t-1} - L_t W_t \tau^w + Z_t - ND_t \tau_t^{VAT} - ID_t \tau_t^{VAT} - T_t. \tag{33}$$

The public capital stock influences firm production and follows $K_t^G = (1-\delta) K_{t-1}^G + I_t^G$. The real interest rate on government debt differs from the real rate by its risk premium $\Delta_t^{rb-r} = \left(\frac{u_t^b}{U'(C_t^S)} \right)$. The VAT rate follows

[11] See Orlandi et al. (2018).

a mean-reverting process $\tau_t^{VAT} = \overline{\tau}^{VAT} + \epsilon_t^{VAT}$, where ϵ_t^{VAT} is a VAT rate shock with mean zero and positive variance. The government follows a fiscal debt rule, where lump-sum taxes or transfers (if negative) are set according to the recent debt-to-GDP ratio.

$$T_t = \phi_T T_{t-1} + (1-\phi_T)\left(\phi_{by}\left(\frac{B_t}{y_t} - \frac{\overline{B}}{\overline{y}}\right) + \phi_b\left(B_t - B_{t-1}\right)\right), \tag{34}$$

where ϕ_T is a persistence parameter of the fiscal rule, and ϕ_{by} measures the responsiveness of the lump-sum tax to deviations in the debt-to-GDP ratio from its target value. Furthermore, the responsiveness of new debt issued is weighted by ϕ_b within the fiscal rule. Finally, market clearing implies that supply must equal aggregate demand:

$$Y_t = s^L ID_t^L + (1-s^L) ID_t^R + s^L ND_t^L + (1-s^L) ND_t^R + I_t + G_t + I_t^G. \tag{35}$$

3.6 Parameterization

The empirical validation of our model is provided by setting parameters such that they match empirical observations for Germany. Table 7 in the Appendix summarizes our parameterization. We calibrate either by relying on values commonly used in the literature or by matching long-run trends and policy targets.[12].

We assume that the utility function is logarithmic in consumption and set the inverse of the intertemporal substitution elasticity σ^c equal to one. Furthermore, the time preference factor β is set to 0.996 to match a steady-state interest rate of 1.6%. The capital share $\alpha^K = 0.325$ corresponds to the average capital-to-output ratio in Germany between 1991 and 2019 (see Table 4). The parameter that determines the Frisch elasticity (at the intensive and extensive margin) of total labor volume (supply) ρ is 0.5 following the discussion in Burgert et al. (2020). The share of LC households s^L is set to 0.28 according to Grabka and Halbmeier (2019). The quarterly depreciation rate for private investments δ is set to 0.015 as in Coenen et al. (2013). We set the depreciation rate to $\delta^D = 0.025$ for the durable goods to consider higher annual depreciation rates of goods, such as vehicles.[13] We set the steady-state ratios of government consumption per GDP $\overline{g}/\overline{y}$ and durable goods consumption per total consumption ψ^D to 20% according to the observed time series average value; the public investment share is 3%.

The second parameter blocks consist of adjustment costs. According to the literature, we set price adjustment costs in both sectors to $\gamma^P = 20$.[14] We proceed similarly for wage $\gamma^W = 120$ and capital adjustment costs $\gamma^K = 20$. We do not consider price indexation and set $s^P = 0$. The investment and durable goods consumption adjustment cost parameters are set to $\gamma^I = 5$ and $\gamma^D = 3$ to match the relative standard deviation of investments and durable goods over the cycle. The non-durable goods consumption per GDP ratio is set to the empirical counterpart of 0.43. We choose a low substitution elasticity between durable and non-durable goods, $\sigma^D = 0.75$, which is the mean average of empirical estimates.[15] We set the VAT-specific price adjustment cost parameter to $\gamma^{VAT} = 0.4$ such that firms face positive but smaller costs of price adjustment due to VAT changes than for other price shocks.

[12] See Table 4 in the Appendix and, e.g., Burgert et al. (2020).

[13] See for example Harmenberg and Öberg (2021). They calibrate their depreciation rate using cars, furniture, and appliances and find a quarterly depreciation rate for durable goods of 0.023.

[14] See Burgert et al. (2020).

[15] See Ogaki and Reinhart (1998), Pakoš (2011), Barsky et al. (2019) and McKay and Wieland (2021) who find values between 0.5 and close to one.

With $\gamma^{VAT} = 0.4$, we match the price reaction due to VAT changes. A 1-pp cut in the VAT rate would thus be associated with a 0.6-pp reduction in the consumer price inflation (CPI) rate, which is within the average range of values of 45–84%, currently estimated by empirical studies.[16]

Monetary and fiscal policy parameters are set mainly according to the literature. As for the monetary policy rule - if it applies - we set the weight for interest rate smoothing ϕ^i to 0.9, the CPI inflation stabilizing weight ϕ^π to 1.5, and the output gap target parameter ϕ^y and the output growth target ϕ^{dy} both to zero. By the latter, we consider that the central bank does not counteract fiscal policy effects. In the fiscal sector, we set the steady-state government debt-to-GDP ratio $\overline{b}/\overline{y}$ equal to 60% on an annual basis. The steady-state VAT rate $\overline{\tau}^{vat}$ is equal to 0.175, which matches the average VAT rate.[17] The parameter ϕ_{by} captures the strength of the reaction of lump-sum taxes to deviations of total government debt level from the target and is set to 0.63. The parameter that accounts for issuing new debt ϕ_b is set to 0.06.

4 Results

4.1 Main Channels of a Temporary VAT Reduction

We start with a general model-based assessment of the temporary VAT reduction.[18] The objective is to describe the main channels at work and classify our results regarding the inclusion of consumer durable goods and an incomplete pass-through according to the relevant literature.

Our model distinguishes between major channels through which the VAT affects economic activity via the substitution, income and durable goods effect.[19] The effects are measured in the form of the VAT multiplier and are quantified via different model simulations. The VAT multiplier is defined as cumulative change of GDP divided by the cumulative change of VAT revenues $\frac{\sum_{t=0}^{k} \Delta y_{t+k}}{\sum_{t=0}^{k} \Delta T_{t+k}^{VAT}}$ in reaction to a 1-pp reduction of the VAT rate. Figure 2 summarizes the results. In general, we distinguish between the first year effect ($k = 4$, first bar) and the cumulative 5-year (medium term) multipliers ($k = 20$, second bar). Furthermore, we distinguish between situations with a full (left-hand side) and a limited (right-hand side) VAT pass-through.

In the first step, we set the share of durable goods equal to zero to make our model simulations comparable to existing study results that do not consider durable goods explicitly. Furthermore, we only consider Ricardian households (brown bar) by setting the share of LC households to zero. The main channel through which the VAT policy works is the intertemporal substitution effect. Households shift non-durable goods consumption across time; thus, total consumption increases on impact, but the cumulative effect diminishes in the subsequent periods. In total, the VAT multiplier is almost 0.5 on impact and 0.3 cumulative over 5 years, considering only the substitution effect in Ricardian households.[20] In the next step, we include the reaction of LC households by setting their share

[16] See Carbonnier (2007), Kosonen (2015), Montag et al. (2020), Fuest et al. (2020).

[17] Note that the VAT rate for most consumption goods is 19%. Some consumption goods, such as food and necessities, have reduced tax rates of 7%.

[18] In this exercise, we solve the model with respect to a 1-percentage point decrease of the VAT rate and a nominal interest rate announced to remain at the zero lower bound for the next 2 years.

[19] See Barrell and Weale (2009).

[20] see Table 5 in Appendix.

to 28%. Although the effectivity of the VAT policy increases slightly, the multiplier is still less than one. Thus, our model simulations confirm the results of previous studies for the quantitative effects of temporary VAT reductions in the literature[21] and the implications that the VAT reduction is not a very effective instrument to stabilize the business cycle.[22]

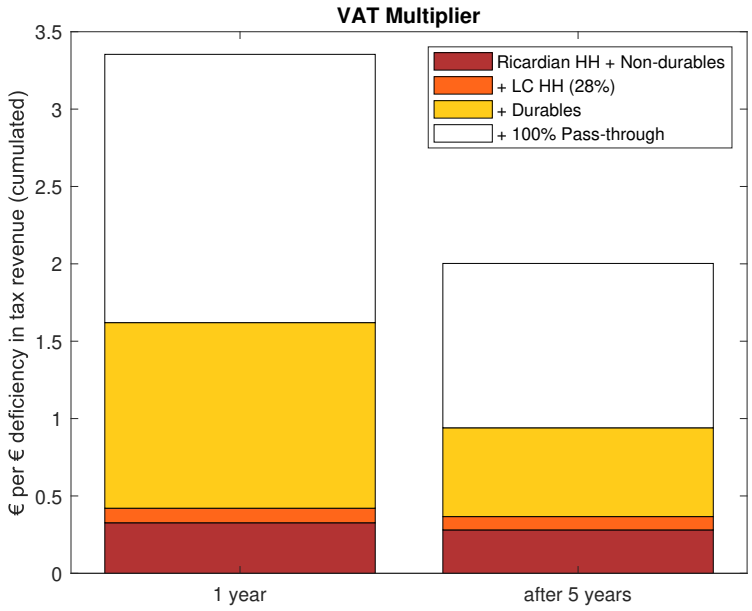

Figure 2: Decomposition of the VAT Multiplier

However, the effectivity changes significantly if we consider durable goods consumption. As shown in the model, the expected VAT change directly affects the prices for durable goods and thus total consumption. If we include durable goods consumption, the multiplier increases significantly to 1.6 in the first year and close to 1 over the medium term. Furthermore, the durable goods effect almost doubles when we simulate the model with a full pass-through. We come to our first conclusion that a temporary VAT change becomes an effective stabilization instrument if the VAT rate for durable goods is similarly reduced. However, the cumulative GDP effect diminishes over the medium term to values significantly less than one. Thus, it is not efficient in terms of budget sustainability, which means that it does not pay back into the government's budget for longer periods.

4.2 Parameter Robustness

In this section, we test the robustness of our results with respect to the chosen parameter set. We set a maximum and minimum range of plausible values for specific policy and behavioral parameters based on the literature review. Thereby, we want to detect crucial parameters that significantly drive the macroeconomic effects of the VAT change and to provide further robustness to our results.

[21] See Sims and Wolff (2018).
[22] See Claus (2013).

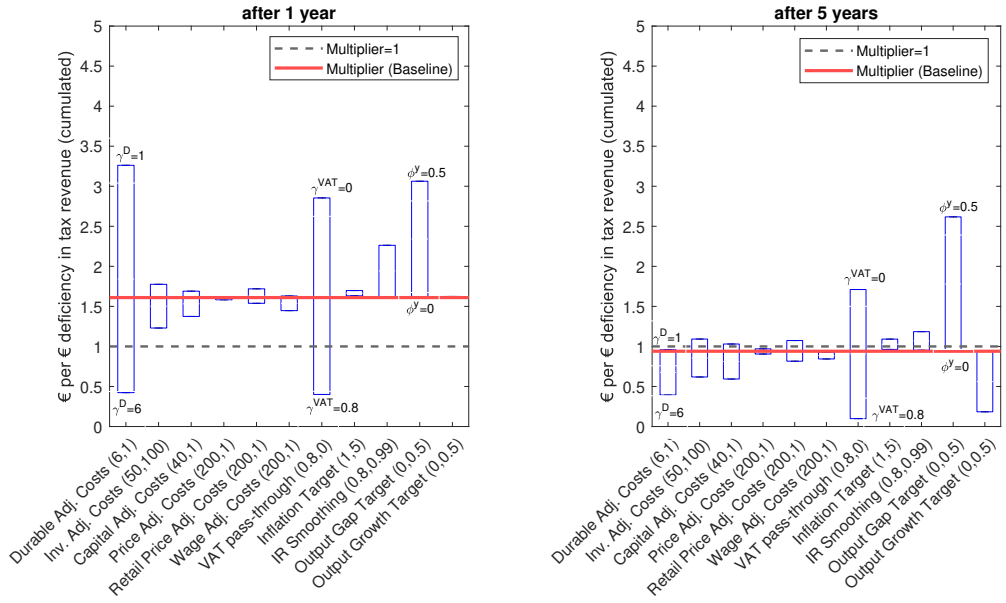

Figure 3: Decomposition of the VAT Multiplier

Figure 3 summarizes our robustness exercise. Three aspects are noteworthy: First, for the bulk of price, wage, investment and capital adjustment costs, the VAT multiplier does not change significantly. It ranges between 1.3 and 1.7 for realistic values of these parameters. Second, the two relevant parameters leading to a VAT multiplier less than or greater than 1 are the durable goods adjustment costs γ^D and the VAT pass-through or VAT-specific price adjustment parameter γ^{VAT}. With low durable goods adjustment costs, the GDP effect is above 3 in the first year and close to 1 over the medium term. If the VAT pass-through parameter γ^{VAT} is close to zero, firms have lower price adjustment costs due to the VAT change. In this specific case, the VAT change translates one to one into CPI inflation, and the consumption response is the strongest. However, if γ^{VAT} is equal to 1, consumer price dynamics are mainly reflected by general sales and intermediate price-setting behavior. The consumption and GDP reactions to the VAT policy do not differ from responses to general price fluctuations, for example due to mark up changes. Third, the direction of monetary policy strongly impacts the effectiveness of the VAT change, especially the output gap parameter. If the central bank has no output gap, the effects of the VAT reduction are smaller. The reason is complex: If we assume a VAT reduction, CPI inflation falls. Under the zero lower bound (ZLB), the central bank does not reduce the interest rate, which could accommodate the VAT policy. However, agents expect an increasing inflation rate and a negative output gap if the VAT rate returns to its steady-state value. If the central bank has an output gap target, the agents expect a weaker interest rate increase when the ZLB period and the VAT policy end. Therefore, they shift even more consumption to today than they would if the central bank has a pure inflation target.

4.3 Comparison with Other Stabilization Policies

According to our simulations, the VAT policy is an effective stabilization instrument, but it should also be compared with other stabilization policies for a comprehensive analysis and evaluation. Hereby, we focus on the central bank's interest rate cuts and the government's specific expenditure policies. In the no-policy baseline, we model a crisis shock that consists of a temporary time preference shock and a private investment shock. This combined shock reduces the GDP and non-durable goods consumption by roughly 7% and 6%, and durable goods consumption and investment by 11% and 13%.[23]

4.3.1 VAT vs. Monetary Policy

In the first experiment, we compare the 1-period 1-pp VAT rate reduction with an interest rate cut that leads to the same GDP stabilization effect of 0.8% compared to the no-policy baseline. We want to analyze the similarities and differences between these two policy alternatives. Figure 4 illustrates the impulse response functions of the no-policy baseline (black line), the VAT reduction under ZLB (red line) and the interest rate cut (dashed blue line).

As expected, we can see that both the VAT reduction and the interest rate cut can stabilize the economy because the lines indicating the no-policy baseline responses of major macroeconomic variables, for example, GDP, consumption, and investment, are below the the lines indicating the policy-based responses (dashed red and blue lines). However, the major finding is that the VAT reduction is a suitable alternative stabilization instrument in the case that monetary policy is restricted to the ZLB. It is particularly interesting that both policies predominantly stabilize the cyclically sensitive durable goods consumption component. The 1-pp VAT reduction leads to the same GDP and consumption responses as a 0.6-pp interest rate cut. However, there are some differences: the VAT reduction reduces the real rate through the actual and expected CPI inflation path while monetary policy generates it directly through the nominal interest rate cut. This leads to two major differences. First, in the case of the VAT reduction, the real wages increase, which stabilizes the purchasing power of LC households and thus LC-household consumption. Because they also consume durable goods, the purchasing power is channeled to durable goods consumption that is more stabilized than after an interest rate cut. This is a desirable property of the VAT instrument because the consumption of LC households is cyclically more sensitive. Second, the VAT-related CPI inflation change has almost no effect on investments, but a nominal interest rate cut does affect investment demand. However, the effect is relatively small: private investment is stabilized by 0.7 pp compared with the baseline. Thus, if the government wants to mimic monetary policy one to one, it could mix the VAT policy with a slight temporary increase in the tax depreciation allowance. Finally, note that the budgetary perspective of the government in the case of the VAT policy is less beneficial because the VAT revenues reduce. Therefore, the government must issue new debt. In contrast, an interest rate reduction stabilizes the VAT revenues and leads to a lower debt status.

[23] We set the composition of both shocks such that response relations of durable and non-durable goods consumption and private investment compared to GDP match the observed relative volatility. See Table 1 in the Appendix.

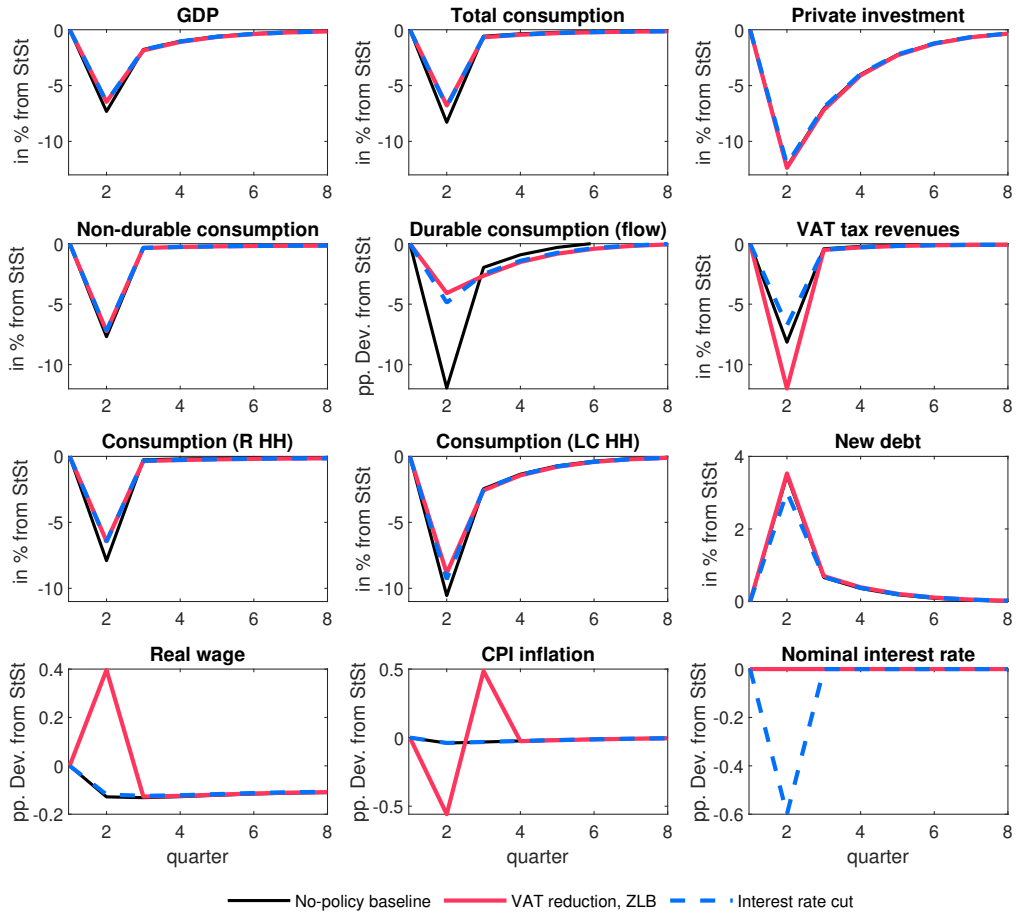

Figure 4: Comparison of VAT reduction (by 1 pp) vs. interest rate cut (by 0.6 bp)

4.3.2 VAT vs. Fiscal Expenditures

In the second experiment, we compare the VAT policy (red line) with different government spending policies, that is public consumption (yellow), public investment (dashed blue) and transfers to LC households (dashed green) under the same no-policy crisis scenario (black line). Again we normalize the policy reactions to the crisis shock such that they stabilize GDP identically.

Figure 5 summarizes the results.[24] The VAT reduction (red line) has the strongest impact effect on durable goodsconsumption. It stabilizes total consumption as strongly as direct transfers to LC households (dashed green). While direct transfers only affect the consumption of LC households, the VAT reduction dampens consumption losses for both household types.[25] Furthermore, the VAT reduction is less costly on impact than other instruments, as can be seen by the new debt reaction. Here, the direct transfer to the LC household is significantly more expensive. However, the VAT policy is less effective in the following periods when the VAT rate returns to its

[24] The multiplier effects of each fiscal instrument can be found in Table 6 of the Appendix

[25] Note that the transfer multiplier becomes significantly less than one if we assume the government pays lump-sum transfers to both household types in a similar fashion.

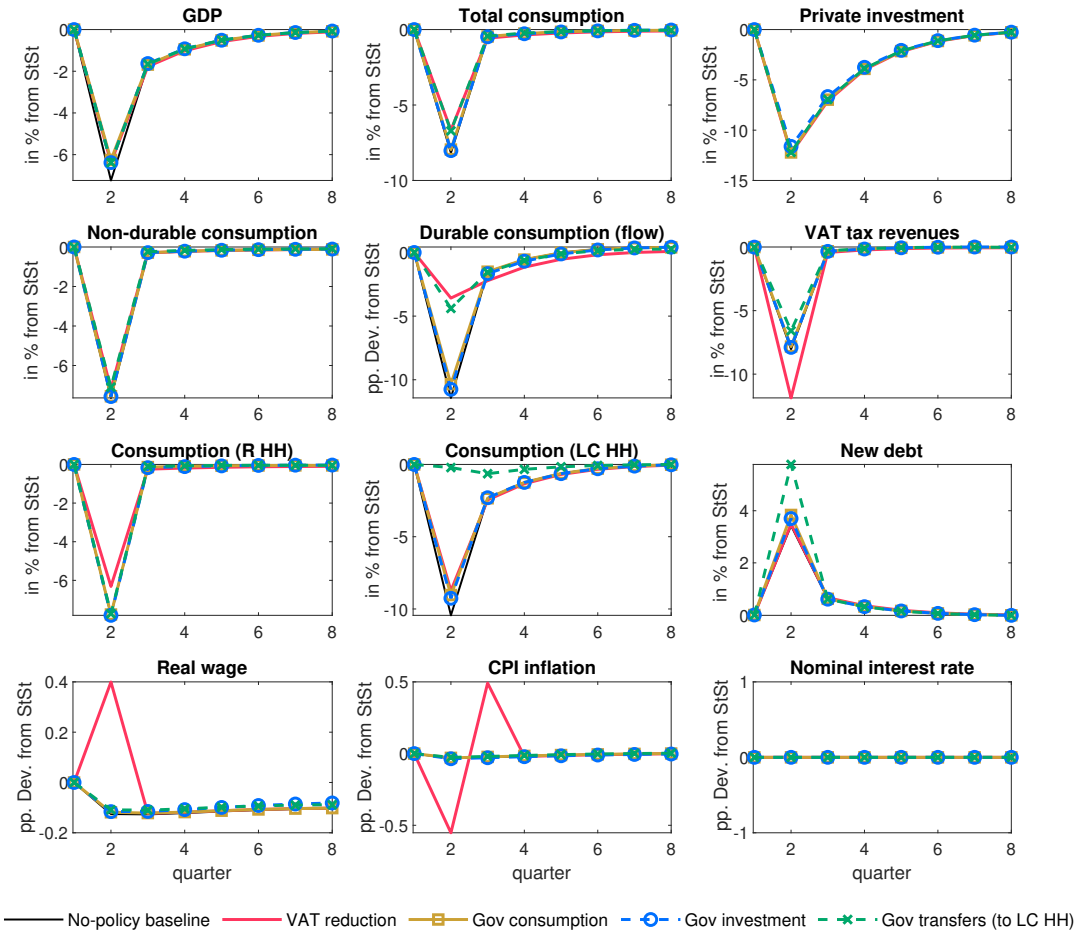

Figure 5: Comparison of VAT reduction (by 1 pp) vs. expenditure policy

steady-state value. Figure 5 shows that the durable goods consumption path is lower than alternative paths through other fiscal measures, and new debt in the subsequent periods is higher. While consumption components are strongly affected due to the intertemporal substitution of mainly durable goods, private investment is less affected by the VAT policy than other fiscal instruments, in particular public investments (dashed blue). These observed patterns can be confirmed by examining the fiscal multipliers (see Table 6 in the Appendix). The VAT multiplier is the largest on impact and after one year. In the subsequent periods, the cumulative VAT multiplier becomes smaller and less effective than public investment and direct transfers (to LC households).

4.3.3 Different Temporary VAT Policies

We have seen in the previous analysis that the VAT reduction is effective because it stimulates consumer durable goods in particular. Therefore, the question arises whether the government can increase the effectiveness of the measure by a good-specific VAT rate reduction only on durable goods consumption. This could possibly stabilize consumption even more in a crisis and reduce the negative financing effects on the government budget. Based

on our reference crisis scenario, we simulate two further experiments in addition to the 1-pp general VAT rate reduction on all consumer goods. In the first experiment, we reduce the VAT rate only for non-durable consumer goods; in the second, we only reduce the VAT rate for durable consumer goods. The results are summarized in Table 2 in form of the cumulative effects of the VAT policies on GDP and the VAT revenues.

Table 2: GDP and Tax Revenue Effect

Frequency	**impact**	**after 1 year**	**after 3 years**	**after 5 years**
Cumulative Real GDP Effect (percent from steady state)				
Non-durables goods only	0.21	0.17	0.17	0.16
Durable goods only	0.58	0.44	0.26	0.21
Non-durable and durable goods	0.80	0.61	0.42	0.37
Cumulative VAT Revenue Effect (pp from GDP)				
Non-durables goods only	-0.39	-0.39	-0.39	-0.40
Durable goods only	+0.03	+0.01	-0.02	-0.03
Non-durable and durable goods	-0.36	-0.38	-0.41	-0.42

Note: We simulate an unexpected VAT rate reduction of -1 pp for one quarter. The VAT multiplier is defined as the cumulative change of GDP divided by the cumulative change of VAT.

As expected, both VAT policies have very different effects on GDP and tax revenues. If the VAT rate is reduced only for non-durable goods, GDP increases by 0.2 percentage points, and VAT revenues decrease by 0.39 percentage points as a share of GDP, resulting in a multiplier of 0.5. Cumulatively, the GDP effect declines as the reversal of the VAT cut is accompanied by opposite effects that weaken GDP development in the following years compared to the no-policy scenario. As the effects on revenues remain roughly constant, the cumulative VAT multiplier falls to around 0.4 over the medium term. A VAT reduction only for non-durable goods is not effective. However, our result reflects the finding from other studies that analyze VAT policy without taking durable goods into account.[26].

The assessment changes fundamentally if we consider the scenario with a VAT reduction only for durable goods. Here, GDP increases by almost 0.6% on impact, although durable goods account for a much smaller share of all consumer goods. The VAT revenues even increase by 0.03 pp as a share of GDP on impact, so it is not possible to calculate the tax multiplier. Thus, the VAT reduction only for durable goods is completely self-financing, at least in the first year. In the medium term, similar to the non-durable goods, the GDP effect declines due to the readjustment of the VAT cut and because durable good purchases have been brought forward and will be demanded to a lesser extent in the future. Cumulative revenues become negative as a result, but the cumulative VAT multiplier of 7 is still significantly higher than that of all other fiscal stabilization instruments.[27] The government can increase the stabilization effect of the VAT policy by limiting it to durable goods only.

[26] See, e.g., Sims and Wolff (2018), Claus (2013)

[27] Note, by putting both VAT policies together, we obtain the already-discussed macroeconomic effects of the general VAT reduction.

5 Conclusion

This paper investigates the macroeconomic stabilization effects of a temporary VAT change. We start with an empirical assessment and use SVAR identification, German National Official Statistics data, and a narrative VAT revenue law series from 1Q1991:4Q2019 to estimate the average effects of VAT changes on durable and non-durable goods consumption. We find robust evidence for strong positive immediate effects on consumer durable goods on average. For non-durable goods, the average VAT effect is significant but less intense. We thereby confirm results from the microeconometric models (see Büttner and Madzharova (2017)). However, our empirical model neither explains the macro channels at work nor accounts for the crisis situations and monetary policy at the ZLB.

Therefore, we set up a DSGE model with monetary policy operating at the ZLB. We extend the model further by specific features such as durable and non-durable goods consumption and an imperfect VAT pass-through, making it especially suitable for analyzing the channels at work and comparing the VAT policy with other stabilization policies, such as interest rate cuts and expenditure policy.

We find that a VAT reduction decreases the cost of living during the period of the reduction, and agents shift consumption forward. Without distinguishing between durable and non-durable goods consumption, both effects are relatively small. Incorporating consumer durable goods into the model significantly increases the effectiveness of a temporary VAT reduction in the model. In this case, the VAT reduction directly reduces the rental price of the durable good substantially (durable goods investment effect), which leads to stronger intertemporal substitution. We find sizable effects of VAT measures on consumption, especially durable goods, with a short-term multiplier significantly above one. Furthermore, the robustness tests of our model results over a broad set of parameter ranges confirms our benchmark results regarding the strong durable goods investment effect. We thus conclude that the temporary VAT reduction is an effective consumption stabilization instrument in the crisis. However, the cumulative VAT multiplier decreases over the medium term to values less than 1. In this respect, VAT reductions are quite costly from the perspective of medium-term fiscal budget stability, as 1 euro of reduced tax revenue leads to less than 1 euro of additional output in the medium term.

Finally, we examine whether temporary VAT cuts in crisis situations also compare favorably with other conventional stabilization policies, such as interest rate cuts by the central bank or expansionary spending policies by the government. We do this by simulating a crisis situation in one period using common negative preferences and investment shocks with and without the respective stabilization policy measure. As policy measures, we simulate a VAT rate cut of 1 pp, an interest rate cut and an expansion of public spending (consumption, investment or transfers to LC households) during the crisis period. We adjust the alternative measures to have the same stabilizing effect on GDP. This means, for example, that the central bank interest rate would need to be lowered by 0.6 bp to achieve an identical GDP stabilization as a 1-pp reduction in the VAT rate.

We find that the VAT cut can almost perfectly mimic an interest rate cut in terms of aggregate consumption because both entail a real interest rate cut of the same magnitude. It is particularly interesting to observe that the stabilizing effect of both measures operates strongly via stabilization of durable goods. Differences exist, however, in the response of consumption by LC households, durable goods, and private investment. These differences arise

because the VAT cut affects the real interest rate via prices, while central bank policy affects the nominal interest rate. The VAT rate cut can stabilize better than the nominal rate cut for LC households, consumption and durable goods. This is because temporarily falling prices lead to a temporary increase in the real purchasing power of all households. While Ricardian households smooth the resulting consumption gain over time, LC households immediately spend the additional income on consumer goods, especially durable goods. In terms of investment, monetary policy stabilization has a slight advantage, as the central bank interest rate cut directly stimulates private investment activity, albeit to a lesser extent. If monetary policy is at the ZLB, a temporary VAT policy combined with an investment stimulus, for example, a temporary reduction of the tax depreciation rate, could offer a perfect substitute.

When monetary policy is not possible due to the ZLB, a VAT rate cut has the highest multiplier on impact and in the first year compared with temporary spending policies of the government. However, if medium-term developments are also considered, public investment is more effective in terms of the cumulative 5-year multiplier. The observation that the effect of a VAT shock is mostly transmitted via durable goods suggests that the efficiency of VAT measures can be increased by changes that are targeted to VAT of durable goods. If we introduce a goods-specific VAT rate reduction only on durable goods, the measure will even be fully self-financing in the first year; that is, the government will benefit through additional revenues. In the medium term, when future consumption is weaker due to the intertemporal substitution effect than it would be without VAT policy, the cumulative revenue shortfall is relatively small, but the cumulative GDP effect remains high. Thus, a temporary VAT cut only to durable goods is a very effective stabilization instrument in a crisis. In view of these results and given the fact that sales of durable goods fluctuate relatively strongly over the business cycle, similar to private investment, temporary VAT policies should be part of the repertoire of government stimulus programs.

Appendix

A Figures

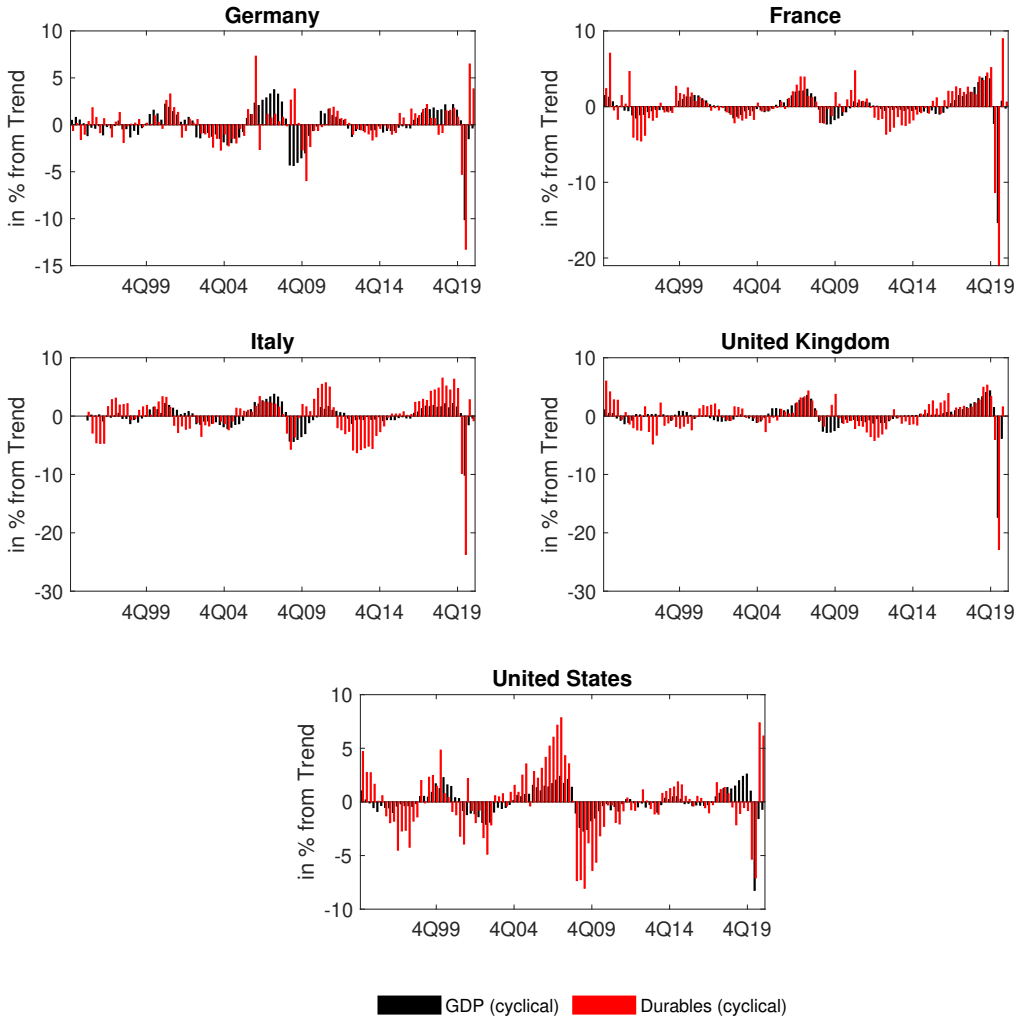

Figure 6: Cyclical component GDP and Durable Consumption for Selected Countries, 1Q1995–4Q2020

The trend values were calculated based on a HP-filter with a smoothing parameter of $\lambda = 1600$. The cyclical components (of GDP and Durable Consumption) are defined as the percentage deviation of the actual values from their trend.

B Data

B.1 Historical VAT tax law changes in Germany

Table 3: Legislative Changes of the VAT Tax in Germany, 1Q1990-4Q2019

Date	Title	Announcement	Resolution	Volume (annually, in bn)€	Duration
30/03/1990	2nd VAT change law	1Q1990	2Q1990	-0.118	permanent
18/05/1990	Temporary VAT cut claim	2Q1990	3Q1990	-0.358	2Q1991
25/02/1992	VAT increase 14% to 15%	1Q1992	1Q1993	+6.204	permanent
25/08/1992	VAT single market law	3Q1992	3Q1992	-0.284	permanent
21/12/1993	VAT law change 1993	4Q1993	4Q1993	-0.432	permanent
09/08/1994	VAT law change 1994	3Q1994	1Q1995	-0.056	permanent
19/12/1997	VAT increase 15% to 16%	4Q1997	1Q1998	+5.778	permanent
24/03/1999	Tax reduction law 1999	1Q1999	2Q1999	+1.674	permanent
20/12/2001	Tax evasion law 2001	4Q2001	4Q2001	+2.500	permanent
15/12/2003	Tax law change 2003	4Q2003	1Q2004	+0.312	permanent
23/04/2004	Interim VAT law change	2Q2004	2Q2004	-0.090	4Q2004
21/07/2004	Interim VAT law change	3Q2004	3Q2004	-0.250	1Q2006
26/4/2006	Tax relief of growth end employment	2Q2006	3Q2006	-1.230	1Q2007
26/4/2006	Tax relief of growth end employment	2Q2006	1Q2007	-0.250	1Q2008
29/6/2006	VAT increase 16% to 19%	2Q2006	1Q2007	+22.946	permanent
19/12/2008	Tax law 2009	4Q2008	1Q2009	-0.185	permanent
22/12/2009	Acclerating growth law	4Q2009	1Q2010	-0.945	permanent
08/04/2010	Tax law change 2010	2Q2010	3Q2010	+0.300	permanent
08/04/2010	Tax law change 2010	2Q2010	3Q2010	+0.300	permanent

Source: German federal government, German Ministry of Finance

B.2 Data description

Gross Domestic Product: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Gross Domestic Product, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Consumption: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Private Consumption, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Expandable consumption: Federal Statistic Office, National Accounts Statistics, Series 18 1.2: Private Consumption and Disposable Income, Expandable Consumption, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Short-lived consumption: Federal Statistic Office, National Accounts Statistics, Series 18 1.2: Short-lived Consumption and Disposable Income, Expandable Consumption, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Long-lived consumption: Federal Statistic Office, National Accounts Statistics, Series 18 1.2: Private Consumption and Disposable Income, Long-lived Consumption, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Services: Federal Statistic Office, National Accounts Statistics, Series 18 1.2: Private Consumption and Disposable Income, Services, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Non-durable consumption: Expandable consumption + Services.

Durable consumption: Short-lived consumption + long-lived consumption.

Private investments: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Non-governmental investments, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

CPI inflation rate: Federal Statistic Office, National Accounts Statistics, Series 18 1.2, Private consumption price deflator, price-adjusted (chain-linked volume), seasonally-adjusted, 1Q1991-4Q2020.

Nominal interest rate: FRED, Immediate Rates: Less than 24 Hours: Call Money/Interbank Rate for Germany, 1Q1991-4Q2020.

Ex-ante real interest rate: Nominal interest rate - CPI inflation rate.

C Tables

Table 4: Matching Macro and Fiscal Policy

	Notation	Value	DEU
Macroeconomy			
Private consumption	$\frac{\overline{C}}{\overline{Y}}$	% of GDP	0.56
Durable & semi-durable consumption	$\frac{\overline{ID}}{\overline{Y}}$	% of GDP	0.2
Private investment	$\frac{\overline{I}}{\overline{Y}}$	% of GDP	0.18
Net exports	$\frac{\overline{NX}}{\overline{Y}}$	% of GDP	0.05
Wage income per GDP	$\frac{\overline{wL}}{\overline{Y}}$	% of GDP	0.53
Capital-output ratio	$\frac{\overline{k}}{\overline{Y}}$	% of GDP	2.99
Expenditures per GDP			
Public consumption	$\frac{\overline{G}}{\overline{Y}}$	% of GDP	0.19
Public investment	$\frac{\overline{IG}}{\overline{Y}}$	% of GDP	0.02
Interest rate payments	$\frac{\overline{IG}}{\overline{Y}}$	% of GDP	0.02
Fiscal balance			
Transfers/Tax[1]	$\frac{\overline{T}}{\overline{Y}}$	% of GDP	0.33
Debt-to-GDP ratio	$\frac{\overline{b}}{\overline{Y}}$	% of GDP	0.60

Source: AMECO, OECD National Accounts, OECD Tax Database. [1] Empirically, this component is defined as other expenditures (mainly transfers) minus other revenues (mainly other taxes and social contributions). In the model this variable is an indicator of fiscal surpluses/deficits and thus it measures the fiscal space.

Table 5: VAT Multiplier - Main Channels (Baseline model)

Frequency	**impact**	**1 year**	**3 years**	**5 years**
Ricardian HH & non-durable goods	0.45	0.41	0.35	0.34
+ LC HH (28%)	0.56	0.51	0.45	0.43
+ Durable goods (incomplete pass-through)	2.22	1.62	1.08	0.94
+ Durable goods (full pass-through)	4.41	3.25	2.08	1.83

Note: We simulate an unexpected VAT rate reduction of -1 pp for 1 quarter. The VAT multiplier is defined as cumulative change of GDP divided by the cumulative change of VAT.

Table 6: VAT Multiplier - Comparison with other fiscal instruments

Frequency	**impact**	**after 1 year**	**after 3 years**	**after 5 years**
VAT	2.22	1.62	1.08	0.94
Government consumption	1.05	0.78	0.35	0.21
Government investment	1.25	1.18	1.06	1.27
Transfer (only LC HH)	1.01	1.11	1.10	0.96

Note: We simulate an unexpected VAT rate reduction of -1 pp for 1 quarter. The VAT multiplier is defined as cumulative change of GDP divided by the cumulative change of VAT.

D SVAR approach

Our baseline VAR specification is

$$X_t = A(L,q)X_{t-1} + U_t \tag{36}$$

where $X_t \equiv [T_t^{vat}, G_t, C_t^i]'$ is a three dimensional vector with the logarithm of tax revenues, public consumption and specific private consumption all in real terms. $A(L,q)$ is a four-quarter distributed lag polynomial and U_t is a corresponding vector of reduced form residuals which in general have non-zero cross correlations.

The reduced form residual vector has little economic significance because its elements are linear combinations of the structural VAT, public and private consumption shocks. Therefore, we use micro-level evidence for estimating the tax elasticity for durable and non-durable consumption. Here we follow who found a VAT elasticity between 0.9 and 1.4 for total consumption and 0.005 for public consumption. Bach et al. (2006) estimate steady-state VAT elasticities for different consumption groups. They report tax elasticities above 2 for the group of furnishing, household equipment, transport, education, which with the exception of education all belong to the segment how we define consumer durables.[28] Bach et al. (2006) also reports steady-state tax elasticities from a microsimulation model for Germany. They find above one elasticities for health (1.3) and recreation (1.1) which also counts partly to consumer durables. Non-duable goods have rather below one elasticities, as food (0.5), beverages (0.05), clothing (0.96), water (0.59), fuels (0.41), communication (0.40), restaurants (0.98), only the financial services (1.3) has above unity elasticities. Housing (0.8) is a special case, because the acquisition of housing and land is not recorded as a consumer durable in the national accounts but as investment. Housing services consumed and produced by households living in dwellings owned by them are reflected in household consumption as services. Weighting the tax elasticities with the consumption gives 1.76 for durable consumption and 0.8 for non-durable consumption:

$$\mathrm{A} = \begin{bmatrix} 1 & -0.005 & \bar{a}_{1,3} \\ 0 & 1 & 0 \\ 0 & a_{3,2} & 1 \end{bmatrix}, \ \mathrm{B} = \begin{bmatrix} b_{1,1} & 0 & 0 \\ b_{2,1} & b_{2,2} & 0 \\ b_{3,1} & 0 & b_{3,3} \end{bmatrix},$$

where we set $\bar{a}_{1,3} = -1.76$ in case of durable and $\bar{a}_{1,3} = -0.8$ in case of non-durable consumption goods. We control for the German reunification between 1Q1991 to 4Q1992 and the financial crisis between 4Q2008 and 2Q2009 and consider seasonal dummy variables for each quarter. Further, we control for the time between announcement and implementation by considering the expected tax revenue change, this is the difference between announced and actual revenue change, as an exogenous variable. We estimate the model with 4 lags and a linear as well as a quadratic trend.

In our alternative VAR specification, instead of the full VAT revenue series, which may consider endogenous reactions of the VAT revenue, we consider only the expected VAT revenue changes due to adjustments of the VAT tax law as an exogenous instrument.

[28] Consumer durable goods include furniture and household appliances (including kitchen equipment), personal transport equipment (i.e. vehicles), recreational and entertainment goods (including computers and communications equipment), other goods such as jewellery, clocks and watches, and therapeutic medical appliances and equipment. See Casalis and Krustev (2020).

E Model

(1) Production function

$$Y_t = A K_t^{\alpha^K} L_t^{\alpha^L} (K_t^G)^{\alpha^{KG}} \tag{37}$$

(2) Labor demand

$$w_t = \alpha^L \frac{Y_t}{L_t} \left(1 - \mu^P - \gamma^P \beta \left(\pi_{t+1}^Y + \gamma^{VAT} \Delta\tau_{t+1}^{VAT}\right) + \gamma^P \left(\pi_t^Y + \gamma^{VAT} \Delta\tau_t^{VAT}\right)\right) \tag{38}$$

(3) Investment price

$$Q_t = \left(\alpha^K \frac{Y_t}{K_t} \left(1 - \left(\mu^P + \gamma^P \left(\beta E_t \pi_{t+1}^Y\right) - \pi_t^Y\right)\right) + 1 - \delta\right) \left(1 - \tau^C\right) \frac{\beta E_t Q_{t+1}}{1 + r_t} \tag{39}$$

(4) Investment demand

$$Q_t = 1 + \gamma^K \left(\frac{I_t}{K_{t-1}} - \bar{I}^K\right) + \gamma^I (I_t - I_{t-1}) - \gamma^I \frac{\beta U'(E_t C_{t+1}^R)}{U'(C_t^R)} (E_t I_{t+1} - I_t) \tag{40}$$

(5) Capital accumulation

$$I_t = K_t - (1 - \delta) K_{t-1} \tag{41}$$

(6) Retail price setting (non-durable goods)

$$P_t^{ret,N} = 1 + \mu^{P,ret} + \gamma^{P,ret} \left(\beta \left(E_t \pi_{t+1}^{ret,N} + \gamma^{VAT} E_t \Delta\tau_{t+1}^{VAT,N}\right) - \left(\pi_t^{ret,N} + \gamma^{VAT} \Delta\tau_t^{VAT,N}\right)\right) \tag{42}$$

(7) Retail price inflation (non-durable goods)

$$\pi_t^{ret,N} - \pi_t^Y = \frac{P_t^{ret,N}}{P_{t-1}^{ret,N}} - 1 \tag{43}$$

(8) Retail price setting (durable goods)

$$P_t^{ret,D} = 1 + \mu^{P,ret} + \gamma^{P,ret} \left(\beta \left(E_t \pi_{t+1}^{ret,D} + \gamma^{VAT} E_t \Delta\tau_{t+1}^{VAT,D}\right) - \left(\pi_t^{ret,D} + \gamma^{VAT} \Delta\tau_t^{VAT,D}\right)\right) \tag{44}$$

(9) Retail price inflation (durable goods)

$$\pi_t^{ret,D} - \pi_t^Y = \frac{P_t^{ret,D}}{P_{t-1}^{ret,D}} - 1 \tag{45}$$

(10) Marginal utility of labor

$$U'(L_t) = -\omega L_t^{\rho} \tag{46}$$

(11) Real wage (in terms of CPI)

$$w_t^{CPI} = \frac{w_t}{P_t^C} \tag{47}$$

(12) Wage setting

$$\frac{-U'(L_t)}{1-\overline{\tau}^W}\left(1+\mu^W+\gamma^W\left(\beta E_t\pi_{t+1}^W-\pi_t^W\right)\right)=w_t^C\left(s^L U'(C_t^L)+\left(1-s^L\right)U'(C_t^R)\right) \tag{48}$$

(13) Aggregate resource constraint

$$Y_t=I_t+s^L\left(ND_t^L+ID_t^L\right)+\left(1-s^L\right)\left(ND_t^R+ID_t^R\right)+G_t+I_t^G \tag{49}$$

(14) Non-durable goods composition

$$ND_t=s^L ND_t^L+\left(1-s^L\right)ND_t^R \tag{50}$$

(15) Durable goods consumption flow

$$ID_t=s^L ID_t^L+\left(1-s^L\right)ID_t^R \tag{51}$$

(16) Durable consumption stock

$$D_t=s^L D_t^L+\left(1-s^L\right)D_t^R \tag{52}$$

(17) Marginal utility of consumption (Ricardian HH)

$$U'(C_t^R)=\frac{1}{C_t^{R\sigma}} \tag{53}$$

(18) Intertemporal consumption (Ricardian HH)

$$\frac{U'(C_t^R)}{U'(E_t C_{t+1}^R)}=\frac{\beta\left(1+i_t\right)}{1+E_t\pi_{t+1}^{C,R}} \tag{54}$$

(19) Consumer price index (Ricardian HH)

$$(P_t^{C,R})^{1-\sigma^{ND}}=\psi^{N,R}\left(P_t^{ret,N}\left(1+\tau_t^{VAT,N}\right)\right)^{1-\sigma^{ND}}+\psi^{D,R}\left(P_t^{ret,D}\left(1+\tau_t^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^R}{D_t^R}-\delta^D\right)\right)\right)^{1-\sigma^{ND}}$$
$$\left(\delta^D+r_t-\left(E_t\pi_{t+1}^{ret,D}-E_t\pi_{t+1}^Y\right)-E_t\Delta\tau_{t+1}^{VAT,D}\right)^{1-\sigma^{ND}} \tag{55}$$

(20) Consumer price inflation (Ricardian HH)

$$\pi_t^{C,R}=\frac{P_t^{C,R}}{P_{t-1}^{C,R}}-1 \tag{56}$$

(21) Non-durable goods consumption (Ricardian HH)

$$ND_t^R=C_t^R\psi^{N,R}\left(\frac{P_t^{C,R}}{P_t^{ret,N}\left(1+\tau_t^{VAT,N}\right)}\right)^{\sigma^{ND}} \tag{57}$$

(22) Durable goods consumption (Ricardian HH)

$$D_t^R = C_t^R \psi^{D,R} \left(\frac{\frac{P_t^{C,R}}{P_t^{ret,D}\left(1+\tau_t^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^R}{D_t^R}-\delta^D\right)\right)}}{\delta^D + r_t - \left(E_t\pi_{t+1}^{ret,D} - E_t\pi_{t+1}^{Y}\right) - \gamma^D\left(\frac{E_t ID_{t+1}^R}{D_t^R}-\delta^D\right) + \gamma^D\left(\frac{ID_t^R}{D_{t-1}^R}-\delta^D\right) - E_t\Delta\tau_{t+1}^{VAT,D}} \right)^{\sigma^{ND}} \tag{58}$$

(23) Durable consumption stock (Ricardian HH)

$$D_t^R = ID_t^R + D_{t-1}^R\left(1-\delta^D\right) \tag{59}$$

(24) Marginal utility of consumption (liquidity-constrained HH)

$$U'(C_t^L) = \frac{1}{C_t^{L^\sigma}} \tag{60}$$

(25) Budget constraint (liquidity-constrained HH)

$$ND_t^L\left(1+\tau_t^{VAT,N}\right) + ID_t^L\left(1+\tau_t^{VAT,D}\right) = L_t W_t\left(1-\overline{\tau}^W\right) + Z_t^L \tag{61}$$

(26) Consumer price index (liquidity-constrained HH)

$$(P_t^{C,L})^{1-\sigma^{ND}} = \psi^{N,L}\left(P_t^{ret,N}\left(1+\tau_t^{VAT,N}\right)\right)^{1-\sigma^{ND}} + \psi^{D,L}\left(P_t^{ret,D}\left(1+\tau_t^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^L}{D_t^L}-\delta^D\right)\right)\right)^{1-\sigma^{ND}}$$
$$\left(\delta^D + \frac{1-\beta}{\beta} - \left(E_t\pi_{t+1}^{ret,D} - E_t\pi^Y{}_{t+1}\right) + E_t g_{t+1}^{C,L} + E_t\pi_{t+1}^{C,L} - E_t\Delta\tau_{t+1}^{VAT,D}\right)^{1-\sigma^{ND}} \tag{62}$$

(27) Consumer price inflation (liquidity-constrained HH)

$$\pi_t^{C,L} = \frac{P_t^{C,L}}{P_{t-1}^{C,L}} - 1 \tag{63}$$

(28) Non-durable goods consumption (liquidity-constrained HH)

$$ND_t^L = C_t^L \psi^{N,L}\left(\frac{P_t^{C,L}}{P_t^{ret,N}\left(1+\tau_t^{VAT,N}\right)}\right)^{\sigma^{ND}} \tag{64}$$

(29) Durable goods consumption (liquidity-constrained HH)

$$D_t^L = C_t^L \psi^{D,L}\left(\frac{\frac{P_t^{C,L}}{P_t^{ret,D}\left(1+\tau_t^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^L}{D_t^L}-\delta^D\right)\right)}}{\delta^D + \frac{1-\beta}{\beta} - \left(E_t\pi_{t+1}^{ret,D} - E_t\pi_{t+1}^{Y}\right) + E_t g_{t+1}^{C,L} + E_t\pi_{t+1}^{C,L} - \gamma^D\left(\frac{E_t ID_{t+1}^L}{D_t^L} - \frac{ID_t^L}{D_{t-1}^L}\right) - E_t\Delta\tau_{t+1}^{VAT,D}}\right)^{\sigma^{ND}} \tag{65}$$

(30) Consumption growth rate (liquidity-constrained HH)

$$g_t^{C,L} = \frac{C_t^L}{C_{t-1}^L} - 1 \tag{66}$$

(31) Durable consumption stock (liquidity-constrained HH)

$$D_t^L = ID_t^L + \left(1 - \delta^D\right) D_{t-1}^L \tag{67}$$

(32) Implicit discount factor (liquidity-constrained HH)

$$r_t^L = E_t g_{t+1}^{C,L} + E_t \pi_{t+1}^{C,L} \tag{68}$$

(33) Government bonds yield

$$1 + r_t^B = (1 + r_t) \left(1 - \frac{u_t^B}{U'(C_t^R)}\right) \tag{69}$$

(34) Government budget

$$B_t = \left(1 - \frac{u_t^B}{U'(C_t^R)}\right) (1 + r_{t-1})\, B_{t-1} + I_t^G + G_t + Z_t^R + Z_t^L - W_t \overline{\tau}^W L_t - ND_t\, \tau_t^{VAT,N} - ID_t\, \tau_t^{VAT,D} - T_t \tag{70}$$

(35) Lump sum tax/transfer rule

$$T_t = \phi_T T_{t-1} + (1 - \phi_T) \left(\phi_{by} \left(\frac{B_t}{y_t} - \frac{\overline{B}}{\overline{y}}\right) + \phi_b \left(B_t - B_{t-1}\right)\right), \tag{71}$$

(36) VAT rate shock (durable goods)

$$\tau_t^{VAT,N} = \overline{\tau}^{VAT} - u_t^{\tau,VAT,N} \tag{72}$$

(37) VAT rate shock (non-durable goods)

$$\tau_t^{VAT,D} = \overline{\tau}^{VAT} - u_t^{\tau,VAT,D} \tag{73}$$

(38) VAT rate change (in PP, non-durable goods)

$$\Delta\tau_t^{VAT,N} = \tau_t^{VAT,N} - \tau_{t-1}^{VAT,N} \tag{74}$$

(39) VAT rate change (in PP, durable goods)

$$\Delta\tau_t^{VAT,D} = \tau_t^{VAT,D} - \tau_{t-1}^{VAT,D} \tag{75}$$

(40) Public consumption

$$G_t = Gg^Y + (1 - G) g^Y Y_t \tag{76}$$

(41) Public investment

$$I_t^G = Gg^{I,Y} + (1 - G) g^{I,Y} Y_t \tag{77}$$

(42) Public capital Stock

$$K_t^G = I_t^G + (1-\delta)\, K_{t-1}^G \tag{78}$$

(43) Lump sum tax rule

$$T_t = \phi_T T_{t-1} + (1-\phi_T)\left(\phi_{by}\left(\frac{B_t}{y_t} - \frac{\overline{B}}{\overline{y}}\right) + \phi_b\left(B_t - B_{t-1}\right)\right), \tag{79}$$

(44) Value added tax revenue

$$T_t^{VAT,REV} = ND_t\, \tau_t^{VAT,N} + ID_t\, \tau_t^{VAT,D} \tag{80}$$

(45) Nominal interest rate

$$i_t = r_t + E_t \pi_{t+1}^Y \tag{81}$$

(46) Monetary policy rate

$$i_t = \left(\frac{1-\beta}{\beta}\right) e_t^{ZLB} + \left(1 - e_t^{ZLB}\right)\left(\max\left[\underline{i}, (1-\phi^i)\left(\bar{r} + \phi^\pi \pi_t^C + \phi^{dy}\left(Y_t - Y_{t-1}\right) + \phi^y \frac{Y_t}{\overline{Y}}\right) + \phi^i i_{t-1} + e_t^i\right]\right) \tag{82}$$

(47) Real wage dynamics

$$w_t = \frac{w_{t-1}\left(1+\pi_t^W\right)}{1+\pi_t^Y} \tag{83}$$

(48) Value added tax shock (non-durable goods)

$$u_t^{\tau,VAT,N} = \rho^{\tau^{VAT}}\, u_{t-1}^{\tau,VAT,N} + e_t^{\tau^{VAT,N}} \tag{84}$$

(49) Value added tax shock (durable goods)

$$u_t^{\tau,VAT,D} = \rho^{\tau^{VAT}}\, u_{t-1}^{\tau,VAT,D} + e_t^{\tau^{VAT,N}} \tag{85}$$

(50) Public consumption shock

$$u_t^G = \rho^G\, u_{t-1}^G + e_t^G \tag{86}$$

(51) Public investment shock

$$u_t^{IG} = \rho^{IG}\, u_{t-1}^{IG} + e_t^{IG} \tag{87}$$

(52) Bond premium shock

$$u_t^B = \rho^B\, u_{t-1}^B + e_t^B \tag{88}$$

(53) Flight-to-quality shock

$$u_t^{ftq} = \rho^{ftq}\, u_{t-1}^{ftq} + e_t^{ftq} \tag{89}$$

(55) Total consumption

$$C_t = ND_t + ID_t \tag{90}$$

(56) Consumption price index

$$P_t^C = P_t^{ret,N} s^{ND} \left(1 + \tau_t^{VAT,N}\right) + P_t^{ret,D} \left(1 - s^{ND}\right) \left(1 + \tau_t^{VAT,D}\right) \tag{91}$$

(57) Consumption price inflation

$$1 + \pi_t^C = \left(1 + \pi_t^Y\right) \frac{P_t^C}{P_{t-1}^C} \tag{92}$$

F Calibration

Table 7: Parameter Values

Name	Parameter	Value	Target
Structural parameter			
Labor prod. elasticity	α^L	0.675	$\frac{\overline{w}\overline{L}}{\overline{Y}}$
Private capital prod. elasticity	α^K	0.325	$1-\alpha^L$
Public capital prod. elasticity	α^{KG}	0.05	See Ramey (2020)
Time preference	β	0.996	annualized $r = 1.6\%$
Depreciation rate (investment)	δ	0.015	$\frac{K}{Y}$
Labour supply elasticity	ρ	0.5	See text
Price markup	μ^P	0.1	10% price markup
Wage markup	μ^W	0.1	10% wage markup
Share of LC households	s^L	0.28	Direct Match
Government consumption per GDP	g^Y	0.2	See table 4
Pub investment per GDP	ig^Y	0.025	See table 4
Adjustment costs			
Price adj. costs	γ^P	20	See Burgert et al. (2020)
Wage adj. costs	γ^W	120	See Burgert et al. (2020)
Capital adj. costs	γ^K	20	See Burgert et al. (2020)
Inv adj. costs	γ^I	5	Rel. std.dev. of cyclical investment
Retail price adj. costs	$\gamma^{P,ret}$	20	Price adj. costs
Durable, non-durable goods and investments			
Depreciation rate (durable goods)	δ^D	0.025	See text
Durable & semi-durable consumption/consumption	$\psi^{D,l}$	0.2	See table 4
SE between durable and non-durable goods	σ^{ND}	0.75	See text
Fiscal policy			
VAT pass-through	γ^{VAT}	0.4	See text
Value added tax rate	$\overline{\tau}^{VAT}$	0.175	See table 4
Debt-to-GDP reaction parameter	ϕ_{by}	0.63	See text
New debt reaction parameter	ϕ_b	0.06	See text
Monetary policy			
Interest smoothing	ϕ^i	0.9	See text
Inflation target	ϕ^π	1.5	See text
Output gap target	ϕ^y	0.0	See text

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