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Andrej Drygalla, Oliver Holtemöller, Konstantin Kiesel

Authors

Andrej Drygalla
Corresponding author
Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association,
Department of Macroeconomics
E-mail: andrej.drygalla@iwh-halle.de
Tel +49 345 7753 812

Oliver Holtemöller
Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association,
Department of Macroeconomics, and
Martin Luther University Halle-Wittenberg
E-mail: oliver.holtemoeller@iwh-halle.de
Tel +49 345 7753 800

Konstantin Kiesel
Fulda University of Applied Sciences

Editor

Halle Institute for Economic Research (IWH) –
Member of the Leibniz Association

Address: Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany
Postal Address: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60
Fax +49 345 7753 820

www.iwh-halle.de

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The Effects of Fiscal Policy in an Estimated DSGE Model – The Case of the German Stimulus Packages During the Great Recession

Abstract

In this paper, we analyse the effects of the stimulus packages adopted by the German government during the Great Recession. We employ a standard medium-scale dynamic stochastic general equilibrium (DSGE) model extended by non-optimising households and a detailed fiscal sector. In particular, the dynamics of spending and revenue variables are modeled as feedback rules with respect to the cyclical component of output. Based on the estimated rules, fiscal shocks are identified. According to the results, fiscal policy, in particular public consumption, investment, transfers and changes in labour tax rates including social security contributions prevented a sharper and prolonged decline of German output at the beginning of the Great Recession, suggesting a timely response of fiscal policy. The overall effects, however, are small when compared to other domestic and international shocks that contributed to the economic downturn. Our overall findings are not sensitive to the allowance of fiscal foresight.

Keywords: fiscal policy shocks, DSGE model, Bayesian inference, stimulus packages

JEL Classification: C32, E32, E62

1 Introduction

The recession of 2008 and 2009 was the most severe contraction in post-World War II Germany. Gross domestic product (GDP) fell by 5.1 percent in 2009, and the negative output gap amounted to 5 percent, a level that had not been reached since the 1973 oil crisis (Institut für Wirtschaftsforschung Halle & Kiel Economics, 2015). A number of other countries faced severe recessions as well. Against this background, the German government enacted a series of measures to spur economic activity - the 2009 and 2010 stimulus packages were the most prominent of these measures. The recessionary period lasted a relatively short period of time and the recovery that followed was strong. In early 2011, the pre-crisis level of output had already been reached again. Thus, the recovery was stronger than expected in 2009.[1] However, the degree to which the recovery can be attributed to the stimulus measures cannot be answered in a straightforward manner. Our analysis within an estimated dynamic stochastic general equilibrium (DSGE) framework points at a positive albeit small impact of discretionary fiscal policy on economic activity.

Since the crisis originated in the financial sector, the initial focus of policy action aimed at financial support for individual banks and the overall banking sector and included measures such as liquidity injections, loan guarantees, capital injections, asset purchases and (partial) nationalizations. However, in light of a contraction in real output and further subdued growth prospects, steps to counteract the effects on the real economy gained prominence. These included measures to reduce the tax burden of firms and households, increases in transfer payments and incentives to spur investment. In total, discretionary fiscal policies during this time amounted to 104 billion euros (e.g. Institut für Wirtschaftsforschung Halle & Kiel Economics (2015)). Given this magnitude, there has been a revival of the discussion of the effects of fiscal stimulus packages on economic activity.

A certain amount of research has been devoted to the estimation of DSGE models featuring a detailed fiscal sector prior to the financial crisis (e.g. Ratto et al. (2009)). With the subsequent implementation of stimulus packages, analyses of these measures have become more widespread. The domestic effects of fiscal stimulus packages have been evaluated by Coenen et al. (2012), among others. They demonstrate the effects of fiscal policies based on seven structural DSGE models used by policy-making institutions. The same holds true for the work of Cogan et al. (2010), who estimate a similar model for the United States; Bhattarai and Trzeciakiewicz (2017) conduct a comparable analysis for the United Kingdom. Gadatsch et al. (2016) analyze the effects of the German stimulus measures, however, with a particular focus on their international transmission. Cwik

[1] See Projektgruppe Gemeinschaftsdiagnose (2009a,b) for macroeconomic forecasts of that time.

(2012) examines the macroeconomic implications of fiscal consolidation in the context of the newly introduced "debt brake". In a similar context, Rannenberg et al. (2015) analyze the effects of fiscal consolidation on output for the euro area. Our work takes place within a context of substantial literature on fiscal policies dealing inter alia with cross-country spillovers (Corsetti et al., 2010) and the effects during crisis periods (Müller, 2014; Flotho, 2015).[2]

This paper contributes to the literature by systematically documenting the stimulus packages that were passed on the German economy from 2009 till 2012, comparing them to the identified discretionary impulses and by providing a detailed quantitative evaluation of their effects within a DSGE model. Besides evaluating the contributions of fiscal measures in comparison to other factors such as preference shocks and technology shocks, our approach additionally allows to analyze the effectiveness of different fiscal instruments relative to each other and thus provides an important guidance for their future use in comparable setups. To do so, we specify a rich but parsimonious open-economy DSGE model that distinguishes discretionary fiscal policy effects from those caused by automatic stabilizers. We use the benchmark model of Smets and Wouters (2003) and extend it by including non-optimizing households (Gali et al. (2007)), foreign trade and, in particular, by incorporating the fiscal authority in a rich way. In addition to public debt, we also account for three public revenue variables, consumption, capital and labor taxes, and three expenditure variables, public consumption, public investment and transfers. In contrast to similar studies, our model applies the fiscal policy rules as proposed recently by Kliem and Kriwoluzky (2014). In doing so, we model the dynamics of effective factor income taxes as reaction functions to hours worked and private investment. In addition, we let the dynamics of transfers be dependent on the amount of hours worked to better capture the important systematic dynamics of unemployment benefits payments. In our benchmark specification we further allow for anticipation of fiscal policy by private households as proposed by Leeper et al. (2013) or Schmitt-Grohé and Uribe (2012), among others. We show, however, that our overall results do not change when fiscal foresight is excluded from our model.

Our results reveal a positive albeit small contribution from discretionary fiscal policies on the cyclical output component during the Great Recession. At maximum, the effect on output growth amounted to 0.5 percentage points. In light of the nearly 5 percent decline in GDP, fiscal measures helped to offset the decline to some degree. However, given the impact of foreign and private shocks, fiscal policy proved to be of minor importance. The

[2] A theoretical analysis of fiscal policy in its relation to public capital is provided by Gómez (2004). Rossi (2014) elaborates on determinacy properties of fiscal policy rules in a small-scale New Keynesian model.

results are broadly in line with recent contributions for Germany (Gadatsch et al., 2016) and the Euro area (Coenen et al., 2012, 2013; Albonico et al., 2016).

The remainder of the paper is structured as follows. Section 2 provides an overview of the fiscal stimulus packages. Section 3 describes the details of our DSGE model with an emphasis on the fiscal sector. Section 4 elaborates on the data and our estimation strategy. In section 5, we present the empirical results on the effects of the fiscal stimulus packages. Next, section 6 analyzes the results in terms of their sensitivity. Finally, section 7 concludes.

2 The German stimulus packages

The German stimulus measures targeted three areas. The first was taxation, and accordingly, the measures were intended to reduce the tax burden. The second was social security transfers, which aimed at supporting those households whose income and income prospects were subject to strong decreases. The third was investment; the intention was to provide either increased public investment or to incentivize households and entrepreneurs not to abandon planned investments.

In terms of implementation, the stimulus measures consisted of four packages that were successively enacted by the German parliament in October and November 2008 and in January and November 2009. Table 1 provides a detailed overview of each single measure arranged according to the four packages. Moreover, the volume of the measure (in billions of euros) is reported for each of the years from 2009 to 2012. The numbers presented state their nominal change compared to the year 2008, the last year before the start of the additional discretionary fiscal policies.

Modeling each single measure within a dynamic stochastic general equilibrium model would be very complex and thus likely unfeasible; nevertheless an analysis should be able to distinguish among different fiscal policy instruments. Our model takes this into account by incorporating six fiscal instruments (see section 3). Table 1 also provides a classification of each single measure concerning its representation in our model. Consistent with our framework, these are public consumption and investment, taxes on consumption, private capital and labor and, finally, transfer payments.

Fiscal Measure	Classification	2009	2010	2011	2012
Package I (Enacted in Oct. 2008)					
Increase in children's allowance	Transfers/Labor Tax	2.3	2.2	2.2	2.2
Decrease in unemployment insurance premium	Labor Tax	4.0	4.0	2.0	2.0
Improved deductibility of health insurance premia	Labor Tax		8.1	10.5	10.6
Package II (Enacted in Nov. 2008)					
Transport infrastructure investments	Gov. Consumption/ Gov. Investment	1.0	1.0	-0.5	-0.5
Better financial deductibility for small- and medium-sized firms	Capital Tax	2.2	4.7	4.4	2.4
Tax exemption for new registered cars	Transfers	0.4	0.1		
Deductibility of craftsmen services	Consumption Tax	0.0	0.9	1.5	1.5
Program on building restoration	Gov. Investment	1.3	1.3	0.8	0.5
Package III (Enacted in Jan. 2009)					
Federal investments	Gov. Consumption/ Gov. Investment	2.0	2.0		
Federal and state investments	Gov. Consumption/ Gov. Investment	6.7	6.7		
Revision of car taxes	Transfers	0.1	0.2	0.4	0.4
Car scrapping incentive	Transfers	4.1	0.9		
Decrease in income tax	Labor Tax/Capital Tax	3.1	5.8	6.2	6.2
Children bonus	Transfers	1.5			
Increase in children's allowance for 6-13 years old	Transfers	0.2	0.3	0.3	0.3
Change of short-time work compensation	Labor Tax/Capital Tax	1.1	1.2	0.8	0.3
Program on qualifications for rehiring temporary workers	Gov. Consumption/ Gov. Investment	0.2	0.2		
Expansion on further education of low-qualified workers	Gov. Consumption/ Gov. Investment	0.2	0.2	0.1	0.0
Additional resources for employment qualification measures	Gov. Consumption/ Gov. Investment	1.0	1.0		
Decrease in state health insurance premia	Labor Tax	3.1	6.3	0.5	
Program on innovations in mid-sized companies	Transfers	0.3	0.3	0.3	0.0
Fostering of promising vehicle motors	Transfers	0.2	0.2	0.1	0.0
Package IV (Enacted in Nov. 2009)					
Increase in children's allowance	Transfers/Labor Tax		4.3	4.5	4.7
Decrease in VAT of lodging	Consumption Tax		0.8	1.0	1.0
Change of heritage and energy laws	Transfers		0.3	0.5	0.4
Change of depreciation allowances	Capital Tax		0.7	2.2	2.8
Total		35.0	53.7	37.8	34.8

Table 1: Fiscal stimulus measures and announced volumes
In billions of euro. The numbers reflect the nominal change in relation to the year 2008 and are based on Institut für Wirtschaftsforschung Halle & Kiel Economics (2015).

3 The model

The model consists of six types of agents and blocks: Ricardian households, non-Ricardian households, monopolistically competitive producers, a domestic fiscal authority, a monetary authority, and an aggregated foreign block. Further, the model features two types of frictions. Real frictions originate from habit formation and adjustment costs for investment and capital utilization. Nominal frictions are caused by rigidities in prices and wages and their partial indexation to their respective past inflation rate. In this section, we describe the behavior of the agents and their linkages and explain the potential channels of fiscal policies. Because the model largely builds on the work of Smets and Wouters (2003), we focus on the additional features. The full set of log-linearized equations is presented in appendix B.

3.1 Households

The domestic economy is represented by a continuum of two types of private households. A share of $(1-\mu)$ is assumed to have full access to financial markets and thus be able to optimize intertemporally. In the remainder of the paper, we refer to this type of agent as Ricardian households or optimizers. The remaining households are assumed to be excluded from saving and borrowing. As a consequence, these types of households consume their entire disposable income each period. We refer to them as non-Ricardian or rule-of-thumb households.

Ricardian households Optimizing households maximize their lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^o, L_t^o), \tag{1}$$

which is a function of consumption C_t^o and hours worked L_t^o

$$U(C_t^o, L_t^o) = \frac{\epsilon_t^b (C_t^o - hC_{t-1}^o)^{1-\sigma}}{1-\sigma} - \psi_l \frac{\epsilon_t^l (L_t^o)^{1+\varphi}}{1+\varphi}, \tag{2}$$

with h denoting the degree of habit persistence, L_t^o the hours worked and σ the intertemporal elasticity of substitution. The inverse Frisch elasticity φ reflects the elasticity of hours worked with respect to the real wage (when keeping marginal utility of wealth constant). ϵ^b and ϵ^l are shocks to consumption preferences and labor supply that both follow AR(1) processes in logs with i.i.d. normal shocks η^{cb} and η^l. ψ_l is a scaling parameter than governs the steady-state amount of hours worked. Optimizing households receive wage income W_t^o from labor, interest income on savings in domestic and foreign bonds B_t^o and $B_{F,t}^o$,[3] income on real capital K_t^o rented to the production sector at the rental rate R_t^k, transfers TR_t^o from the government and profits Π_t from the firm sector. Income is spent on consumption C_t^o and investment I_t^o in private physical capital. In addition, Ricardian households are assumed to pay lump-sum taxes LS_t^o that are levied in order to balance the government's budget. For the representative Ricardian household's budget constraint, it thus follows:

$$\begin{aligned} P_t C_t^o \left(1+\tau_t^c\right) \quad & + P_t I_t^o + \frac{B_t^o}{\epsilon_t^{rp}} + e_t B_{F,t}^o = \left(1-\tau_t^w\right) W_t^o L_t^o + R_{t-1}\left(B_{t-1}^o + e_t B_{F,t-1}^o \phi_t\left(NFA_t\right)\right) \\ & + \left(1-\tau_t^k\right)\left[R_{k,t} u_t - a(u_t) P_t\right] K_{t-1}^o + \tau_t^k \delta P_t K_{t-1}^o + \Pi_t + TR_t^o - LS_t^o, \end{aligned} \tag{3}$$

where P_t is the price level, τ_t^c, τ_t^k and τ_t^w denote taxes on consumption, capital and labor, R_t is the one-period gross nominal return on domestic and other euro area countries' government bonds, W_t^o is the nominal wage, u_t specifies the degree of capital utilization, with $a\left(u_t\right)$ being the cost associated with its variations. Following Christiano et al. (2005), we assume that in the steady state the capital utilization rate is $\bar{u} = 1$ and $a\left(\bar{u}\right) = 0$. We further follow Schmitt-Grohé and Uribe (2003), among others, in assuming the presence of a debt-elastic interest rate premium $\phi_t\left(NFA_t\right)$ on foreign bonds being a function of the home country's net foreign assets in relation to steady-state output (NFA_t):

$$\phi_t = \exp\left(-\kappa\left(NFA_t + \epsilon_t^{uip}\right)\right), \tag{4}$$

where ϵ_t^{uip} is a foreign risk-premium shock. The accumulation of private physical capital is determined according to the following law of motion:

$$K_t^o = \left(1-\delta\right) K_{t-1}^o + \left(1 - S\left(\cdot\right)\right) I_t^o, \tag{5}$$

where $S\left(\cdot\right)$ is the investment adjustment cost function:

$$S\left(\frac{I_t^o}{I_{t-1}^o}\right) = \frac{\sigma_i}{2}\left(\frac{I_t^o}{I_{t-1}^o} - 1\right)^2. \tag{6}$$

The function reflects the assumption that adjusting investment is costly. σ_i captures the investment adjustment cost, and ϵ_t^i, in turn, can be regarded as a disturbance to the process that transforms investment goods into productive capital (Justiniano et al., 2011) and follows a first-order autoregressive process in logs with an i.i.d. normal error term

[3] For simplicity, we assume that domestic households can purchase bonds of other euro area countries, whereas only domestic households can save in domestic bonds. In the remainder of the paper, the rest of the world is restricted to the rest of the euro area.

with zero mean and variance $\sigma^2_{\eta i}$.

Ricardian households maximize their utility subject to their budget constraint and the capital accumulation function with respect to consumption, labor, domestic and foreign bond holdings, investment, the size of next period's capital stock and its rate of utilization.[4] Appropriate No-Ponzi and transversality constraints are assumed to hold.

Rule-of-thumb households Non-Ricardian households are assumed to have no access to financial markets; thus, they do not own assets and do not have liabilities or conduct investments. Accordingly, their entire current income, which is composed of net labor income and transfer receipts from the government, is spent for consumption purposes:

$$(1 + \tau^c_t)C^{nr}_t = (1 - \tau^w_t)L^{nr}_t W^{nr}_t + TR^{nr}_t. \tag{7}$$

Household aggregation Given that rule-of-thumb households constitute a share μ of total households and do not invest in capital, save in government bonds or pay lump-sum taxes, aggregate variables are given by:

$$\begin{aligned} C_t &= \mu C^o_t + (1 - \mu)C^{nr}_t, \\ TR_t &= \mu TR^o_t + (1 - \mu)TR^{nr}_t, \\ I_t &= \mu I^o_t, \\ K_t &= \mu K^o_t, \\ B_t &= \mu B^o_t, \\ B_{F,t} &= \mu B^o_{F,t}, \\ LS_t &= \mu LS^o_t. \end{aligned}$$

We further assume that in steady state the ratios of non-Ricardian consumption to Ricardian consumption as well as the share of transfers paid to optimizing households are $\chi = C^{nr}/C^o \leq 1$ and $\xi = TR^o/TR^{nr} \leq 1$, respectively.

Wage setting We follow Erceg et al. (2000) in assuming that monopolistically competitive Ricardian households supply their differentiated labor service to an employment agency that bundles individual labor services to a labor index. Each period, a random fraction of $1 - \theta^w$ households is 'allowed' to optimize its wage, whereas the remaining fraction adjusts its wage according to a simple indexation rule, with the degree of indexation measured by χ^w. Optimizing households set their wage to $\tilde{W}_t$ taking into account

[4] The first-order conditions are outlined in Appendix A.

the demand for their individual labor service and the probability of future adjustments. The employment agency sells the composite labor index to the production sector at the aggregate wage index W_t. Given the individual wages set by each of the households, the employment agency minimizes the cost for the production of a given amount of the labor index.

Under the assumption of complete markets for government bonds, consumption is identical for all Ricardian households. For the dynamics of the aggregate wage index, it then follows:

$$W_t = \left[(1-\theta^w) \left(\tilde{W}_t\right)^{-\frac{1}{\lambda^w}} + \theta^w \left(\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\chi^w} W_{t-1} \right)^{-\frac{1}{\lambda^w}} \right]^{-\lambda^w}, \tag{8}$$

with λ_W being the net wage markup as a result of the households' market power.

Aggregation over the continuum of households is standard, implying that the degree of wage dispersion across differentiated labor services is equal to one in steady state. We assume that non-Ricardian households set their wage to the aggregate wage of optimizing households and that the demand for labor services of non-optimizers is therefore the same as for the aggregate of Ricardian households. Consequently, labor hours and wages will be identical for both types of consumers, so that $L_t = L_t^o = L_t^{nr}$ and $W_t = W_t^o = W_t^{nr}$.

3.2 Firms

Production The economy consists of a continuum of firms $x \in [0, 1]$, each of which produces a differentiated good according to a Cobb-Douglas technology:

$$Y_t^h(x) = Z_t L_t(x)^{1-\alpha} (u_t K_{t-1}(x))^{\alpha} (K_{t-1}^g)^{\zeta} - \Phi, \tag{9}$$

where Z_t represents a shock to total factor productivity that follows a first-order autoregressive process with i.i.d normal shock η_t^z. K_{t-1}^g is the public capital stock, whereas Φ measures the fixed cost of production.[5] The firm takes factor prices as given and minimizes the costs for a particular level of output subject to the production technology. Labor demand is identical for all firms and given by:

$$L_t = \frac{1-\alpha}{\alpha} K_{t-1} \frac{r_{k_t}}{W_t}, \tag{10}$$

[5] The assumption of increasing returns to scale with respect to public capital can be found in Baxter and King (1993), Glomm and Ravikumar (1997), Turnovsky (2004), and Leeper et al. (2010). The condition $\alpha + \zeta < 1$ is necessary to ensure a stable balanced growth path (see Turnovsky (2004)).

whereas marginal costs are:

$$MC_t^h = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} Z_t^{-1} K_{t-1}^{g^{-\zeta}} W_t^{1-\alpha} r_{k,t}^{\alpha}. \tag{11}$$

We assume that domestic producers can discriminate prices between goods sold on the domestic market and exports X_t, so that the price for the latter is P_t^x. Total demand for domestic goods abroad is given by:

$$X_t = (1-\omega^*) \frac{1-n}{n} \left(\frac{P_t^x}{P_t^*}\right)^{-\eta^*} Y_t^*, \tag{12}$$

where ω^* is the degree of home bias in foreign demand, n is the population share of the domestic economy in the (model) world, P_t^* is the foreign consumer price index, η^* measures the foreign elasticity of substitution between imported and domestic goods and Y_t^* is total demand abroad.

Real marginal costs of goods produced for external demand are then given by:

$$MC_t^x = \frac{P_t MC_t}{P_t^x}. \tag{13}$$

Firms set their prices in a Calvo (1983) fashion. Each period, a random fraction $(1-\theta^h)$ and $(1-\theta^x) \in [0,1]$ of firms adjust their domestic and export prices to the optimal levels $\tilde{P}_t^h$ and $\tilde{P}_t^x$. Firms that are not able to adjust index their prices to past inflation, with the degree of indexation given by χ^h and $\chi^x \in [0,1]$. Moreover, monopolistic competition leads to gross markups λ^h and $\lambda^x \in [1,\infty]$ of the optimal price over marginal cost for each producer.

The resulting profits of the firms are assumed to be passed on to the optimizing households as dividends.

Domestic retailers Individual producers' goods are aggregated to a final goods index by a competitive retail firm according to a Dixit-Stiglitz function. For the domestic and export price indices, it follows from the demand for individual goods in the final goods indices as well as the price setting behavior of adjusters and non-adjusters:

$$P_t^h = \left[(1-\theta^h) \tilde{P}_t^{h\,\frac{1}{1-\lambda^h}} + \theta^h \left(\left(\frac{P_{t-1}^h}{P_{t-2}^h}\right)^{\chi^h} P_{t-1}^h \right)^{\frac{1}{1-\lambda^h}} \right]^{1-\lambda^h}, \tag{14}$$

and

$$P_t^x = \left[(1-\theta^x)\tilde{P^x}_t^{\frac{1}{1-\lambda^x}} + \theta^x \left(\left(\frac{P_{t-1}^x}{P_{t-2}^x} \right)^{\chi^x} P_{t-1}^x \right)^{\frac{1}{1-\lambda^x}} \right]^{1-\lambda^x} . \tag{15}$$

Import retailers Monopolistically competitive retailers of imported goods bundle foreign differentiated goods and sell them on the domestic market. Analogously to domestic retailers, only a random fraction $(1-\theta^m) \in [0,1]$ of importers firms adjust their prices to the optimal level $\tilde{P}_t^m$. Retailers that are not able to adjust index their prices to past inflation, with the degree of indexation given by $\chi^m \in [0,1]$. Importers face the following demand for foreign goods:

$$M_t = (1-\omega) \left(\frac{P_t^m}{P_t} \right)^{-\eta} (C_t + I_t) , \tag{16}$$

where ω is the domestic degree of home bias, and η measures the elasticity of substitution between imported and domestic goods. We restrict import demand to private consumption and investment as government expenditures can almost entirely be assumed to be directed to spending on domestic goods. Import retailers take the demand and the aggregate price level as given and maximize their expected value of future profits subject to their marginal costs given by:

$$MC_t^m = \frac{P^*}{P_t^m}, \tag{17}$$

where P^* is the foreign price level.

It follows for the aggregate import price index:

$$P_t^m = \left[(1-\theta^m)\tilde{P^m}_t^{\frac{1}{1-\lambda^m}} + \theta^m \left(\left(\frac{P_{t-1}^m}{P_{t-2}^m} \right)^{\chi^m} P_{t-1}^m \right)^{\frac{1}{1-\lambda^m}} \right]^{1-\lambda^m} , \tag{18}$$

where $\lambda^m \in [1, \infty]$ is a gross markup of the optimal price over marginal cost due to monopolistic competition.

3.3 Fiscal authority

The fiscal authority is characterized by eight variables: public consumption G_t^c, public investment G_t^i, tax rates on consumption τ_t^c, private capital income τ_t^k and labor income τ_t^W, transfer payments TR_t, lump-sum taxes LS_t and the stock of public bonds issued B_t. Analogously to private capital, public capital is accumulated according to the following law of motion:

$$K_t^g = (1-\delta^g)K_{t-1}^g + G_t^i. \tag{19}$$

The government faces a flow budget constraint that balances its expenses on interest and debt payments, transfers and consumption and investment with its revenues from taxes on consumption, wages and private capital and cash returns from bonds issued in the current period. For the government budget constraint, it thus follows:

$$B_{t-1}R_{t-1}+TR_t+P_tG_t^c+P_tG_t^i = \tau_t^cP_tC_t+\tau_t^k(r_t^ku_t-(a(u_t)+\delta))P_tK_{t-1}+\tau_t^wW_tL_t+LS_t+B_t. \tag{20}$$

We broadly follow Leeper et al. (2010) in specifying spending and revenue rules for the fiscal sector. However, we slightly modifiy them according to the proposals made by Kliem and Kriwoluzky (2014). Government expenditures on consumption and investment are assumed to respond in a countercyclical manner to deviations of output and debt from their respective steady states. Due to a large proportion of unemployment benefits in government transfers, we specify the rule for this kind of fiscal expenditure in reaction to the contemporaneous cyclical component of hours worked. In addition, we allow for pre-announcement effects as proposed by Leeper et al. (2013) with a weight of ψ_x. For the spending rules, it follows (in log-linear approximation):

$$g_t^c = \rho_{gc}g_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{gc,y}y_t + \varphi_{gc,b}b_{t-1}\right) + (1-\psi_{gc})\,\eta_t^{gc} + \psi_{gc}\eta_{t-1}^{gc}, \tag{21}$$
$$g_t^i = \rho_{gi}g_{t-1}^i + (1-\rho_{\tau c})\left(\varphi_{gi,y}y_t + \varphi_{gi,b}b_{t-1}\right) + (1-\psi_{gi})\,\eta_t^{gi} + \psi_{gi}\eta_{t-1}^{gi}, \tag{22}$$
$$tr_t = \rho_{tr}tr_{t-1} + (1-\rho_{\tau c})\left(\varphi_{tr,l}l_t + \varphi_{tr,b}b_{t-1}\right) + (1-\psi_{tr})\,\eta_t^{tr} + \psi_{tr}\eta_{t-1}^{tr}, \tag{23}$$

where ψ_{gc}, ψ_{gi} and $\psi_{tr} \in [0,1]$ and η_t^{gc}, η_t^{gi} and η_t^{tr} being i.i.d. shocks with zero mean and variances $\sigma^2_{\eta gc}$, $\sigma^2_{\eta gi}$ and $\sigma^2_{\eta tr}$.

On the revenue side, consumption, labor and capital tax rates can also be assumed to adjust in a way that stabilizes the economy. Thus, feedback rules can be specified to react to cyclical movements. We follow Kliem and Kriwoluzky (2014) and model the dynamics of labor and capital tax rates as reactions to hours worked and private investment, respectively, whereas consumption taxes are adjusted to output movements. On the revenue side, and similar to expenditures, the government is assumed to act in terms of a debt brake rule if debt is above its steady-state value, forcing it to increase taxes. Alternatively, in the case of a debt increase below trend, the government will make use of the leeway in the next period by lowering taxes.[6] In log-linear approximation, it

[6] From a technical perspective, including public debt in fiscal rules is a method to ensure stability.

follows that:

$$\tau_t^c = \rho_{\tau c}\tau_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{\tau c,y}y_t + \varphi_{\tau c,b}b_{t-1}\right) + (1-\psi_{\tau c})\,\eta_t^{\tau c} + \psi_{\tau c}\eta_{t-1}^{\tau c}, \quad (24)$$

$$\tau_t^w = \rho_{\tau w}\tau_{t-1}^w + (1-\rho_{\tau w})\left(\varphi_{\tau w,l}l_t + \varphi_{\tau w,b}b_{t-1}\right) + (1-\psi_{\tau w})\,\eta_t^{\tau w} + \psi_{\tau w}\eta_{t-1}^{\tau w}, \quad (25)$$

$$\tau_t^k = \rho_{\tau k}\tau_{t-1}^k + (1-\rho_{\tau k})\left(\varphi_{\tau k,i}i_t + \varphi_{\tau k,b}b_{t-1}\right) + (1-\psi_{\tau k})\,\eta_t^{\tau k} + \psi_{\tau k}\eta_{t-1}^{\tau k}, \quad (26)$$

where $\psi_{\tau c}$, $\psi_{\tau w}$ and $\psi_{\tau k} \in [0,1]$ and $\eta_t^{\tau c}$, $\eta_t^{\tau w}$ and $\eta_t^{\tau k}$ being i.i.d. shocks with zero mean and variances $\sigma^2_{\eta\tau c}$, $\sigma^2_{\eta\tau w}$ and $\sigma^2_{\eta\tau k}$. Lump-sum taxes are assumed to be set in reaction to the evolution of debt only.

3.4 Monetary policy

The monetary authority acts according to a feedback rule in the spirit of Taylor (1993). In addition, we allow for interest rate smoothing as in (Clarida et al., 2000). Because Germany is a member of a monetary union, its interest rate equals the one set by policy makers who consider the whole euro area. Accordingly, the Taylor rule specifies the interest rate as a reaction function of average (GDP-weighted) inflation rates and output gaps of Germany and the rest of the euro area (REA):

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(\rho_\pi \pi_t^{EA} + \rho_y y_t^{EA}) + \eta_t^r, \quad (27)$$

where $\pi_t^{EA} = n\pi_t + (1-n)\,\pi_t^{REA}$, $y_t^{EA} = ny_t + (1-n)\,y_t^{REA}$ and η_t^r is an i.i.d. normal error term with zero mean and variance $\sigma^2_{\eta r}$ that captures non-systematic deviations of the interest rate from the monetary policy rule. We follow Justiniano and Preston (2010), among others, and model both REA variables as VAR(2) processes in logs, with the area-wide interest rate considered as an endogenous component:[7]

$$\begin{bmatrix} y_t^{REA} \\ \pi_t^{REA} \end{bmatrix} = \rho_1 \begin{bmatrix} y_{t-1}^{REA} \\ \pi_{t-1}^{REA} \\ r_{t-1} \end{bmatrix} + \rho_2 \begin{bmatrix} y_{t-2}^{REA} \\ \pi_{t-2}^{REA} \\ r_{t-2} \end{bmatrix} + \begin{bmatrix} \eta_t^{y^{REA}} \\ \eta_t^{\pi^{REA}} \end{bmatrix}, \quad (28)$$

where ρ_1 and ρ_2 are 2×3 matrices of coefficients and $\eta_t^{y^{REA}}$ and $\eta_t^{\pi^{REA}}$ are i.i.d. normal shocks with zero mean and variances $\sigma^2_{\eta y^{REA}}$ and $\sigma^2_{\eta\pi^{REA}}$.

[7] We are aware of the simplistic modeling of the foreign block. However, since for estimation we use time series for both REA variables we are able to account for their influence on the area-wide monetary policy without putting too much attention on international spillovers that are beyond the focus of this paper.

3.5 Market clearing and relative prices

Goods market clearing requires the output produced net of utilization costs to equal the domestic demand for private as well as public consumption and investment as well as exports. Aggregation over the continuum of firms and retailers is standard, implying that the degree of price dispersion accross differentiated goods is equal to one in steady state. It then follows that:

$$Y_t = C_t + I_t + a(u_t) K_{t-1} + \frac{P_{H,t}}{P_t}\left(G_t^c + G_t^i\right) + \frac{P_{X,t}}{P_t} X_t - \frac{P_{M,t}}{P_t} M_t, \tag{29}$$

For the equilibrium in the asset market it holds that:

$$B_{F,t} - R_{t-1} B_{F,t-1} \phi_t (NFA_t) = P_{X,t} X_t - P_{M,t} M_t. \tag{30}$$

Combining the households' optimality conditions for domestic and foreign bond holdings with the definition of the dynamics of the real exchange rate $\Delta S_t = \pi_t^{REA}/\pi_t$ we arrive at an expression for an uncovered interest parity (UIP) condition:

$$\frac{S_{t+1}}{S_t} = \frac{\pi_{t+1}^{REA}}{\pi_{t+1}} \epsilon_t^{rp} \phi (NFA_t) \epsilon_t^{uip}, \tag{31}$$

where ϵ_t^{uip} follows an AR(1) process in logs with i.i.d. normal shock η^{uip} that can be interpreted as a disturbance to the law of one price or an additional (international) risk-premium shock.

Finally, we define the following relative prices:

$$T_t^h = \frac{P_t^h}{P_t}, \tag{32}$$

$$T_t^x = \frac{P_t^x}{P_t^{REA}}, \tag{33}$$

$$T_t^m = \frac{P_t^m}{P_t}. \tag{34}$$

4 Estimation

4.1 Data and priors

For the Bayesian estimation of the model, 17 quarterly time series are used, including domestic series for GDP, private and government consumption, private and government investment, government transfers, effective tax rates for consumption, labor and capital income, hours, wages, as well as consumer, export and import price inflation. In addition, we use the euro area short-term interest rate as well as series for GDP and inflation in the rest of the euro area. The latter two aggregates are constructed as evolving GDP-weighted averages of the respective EMU members' time series. German GDP aggregates, transfers as well as hours and wages are divided by the working-age population time series to obtain per capita values and to remove the common trend in these series. Effective tax rates are calculated following Mendoza et al. (1994). To correctly account for the structural break resulting from the introduction of the single European monetary policy, all series are from 1999 to 2012. All variables used for estimation are linearly detrended.[8]

Priors for the estimated parameters broadly reflect standard choices in the literature (Table 3). The prior for the ratio of non-Ricardian to Ricardian consumption χ is set roughly in line with the specification by Coenen et al. (2013). For the parameters of the fiscal rules, we use uninformative priors to let the data "speak". We follow Justiniano and Preston (2010) for the specification of the priors for the REA parameters and center the priors narrowly around the respective coefficients obtained from individual pre-sample estimations. Some structural parameters that are difficult to identify correctly are set according to the respective sample means or to values that are widely used in the relevant literature (Table 2). In particular, the depreciation rates for private and public capital are both set to $\delta = \delta^g = 0.015$, implying an annual depreciation of 6 percent, and the gross wage markup parameter is set to $\lambda^w = 1.35$. The share of private capital in the production function α is calibrated to the implied steady-state share of capital income to GDP (0.3) which is in line with the sample average of labor income to GDP of around 70 percent. The discount factor β is set to 0.9950 implying an annual steady-state real interest rate of 2 percent. Our choice for the value of β minimizes the deviation of the implied steady-state ratios of private consumption and investment from their respective sample means without assuming implausibly low values for the capital share α or the depreciation rate δ. Steady-state tax rates and the ratios of the remaining GDP aggregates and transfers to output are set at their historical average ratios, while the ratio of government debt to quarterly GDP is set to 2.4 in line with the 60 percent ceiling imposed by the Maastricht criteria. The steady-state lump-sum tax to GDP ratio is then obtained from the government budget constraint, while the private capital to GDP ratio is obtained from its law of motion. The steady-state return on private capital r^K reflects the values for the steady-state capital tax rate, the private depreciation rate, and the discount factor β. The elasticity of output to public capital ζ is set to 0.1 following Ratto et al. (2009).[9]

[8] For the consumption tax rate we have included a dummy from 2007 onwards to better account for the large and permanent VAT increase in 2007.

[9] Meta-analyses of the contribution of public capital to output also conclude values of around 0.10 (e.g. Bom and Ligthart (2008), Núñez-Serrano and Velázquez (2016)).

Private and public capital depreciation rates	δ, δ_G	0.0150
Share of capital in production function	α	0.3000
Share of public capital in production function	ζ	0.1000
Steady-state wage markup parameter	λ_w	1.3500
Steady-state labor tax rate	τ_w	0.4511
Steady-state consumption tax rate	τ_c	0.1543
Steady-state capital tax rate	τ_k	0.2754
Steady-state public consumption to GDP ratio	G^C/Y	0.1860
Steady-state public investment to GDP ratio	G^I/Y	0.0220
Steady-state transfer payments to GDP ratio	TR/Y	0.1783
Steady-state public debt to GDP ratio	B/Y	2.4000
Discount factor	β	0.9950
Steady-state return on capital	r^K	0.0219
Share Germany in Euro area	n	0.2800
Degree of domestic home bias	ω	0.5523
Degree of foreign home bias	ω^*	0.8259
Debt-elastic interest rate premium	κ	0.0100

Table 2: Calibrated model parameters

Parameter κ that governs the foreign debt-elastic interest rate premium is set to 0.01. Finally, we calibrate n, the population share of Germany within the Euro area, to 0.28 and the degrees of home bias in both regions to roughly 0.55 and 0.83, close to the calibrations in Hristov (2016) and Pytlarczyk (2005), to clear the goods market in steady state.

We employ the Matlab pre-processor Dynare (Adjemian et al., 2011) for the estimation of the model. In particular, we compute the posterior mode using the *csminwel* algorithm developed by Christopher Sims. The inverse Hessian at the posterior mode has then be used to define the proposal covariance matrix. Subsequently, a Metropolis-Hastings algorithm has been implementd to simulate the posterior distributions. We run two parallel chains with 3,000,000 draws each, dropping the first 50%. Model parameters were adjusted for every draw to match the respective calibration targets. The proposal covariance matrix has been scaled to achieve an acceptance rate of roughly one third (32.8729 and 32.8775 per cent).

4.2 Posterior means

Results for the posterior distribution of the estimated parameters and shock variances are presented in Table 3. Concerning the relevant parameters for the assessment of fiscal policy, the estimation reveals a share of non-Ricardian households of nearly 43%, which is remarkably larger than estimated in other studies for advanced countries (Bhattarai and Trzeciakiewicz, 2017; Iwata, 2009). In steady-state, these households consume around 90% of optimizers. In combination with their relative shares in the economy, this implies that optimizing households receive around 47% of the transfers received by non-Ricardians.

Posterior means for the reaction coefficients in the fiscal policy rules reveal countercyclical dynamics for five out of six instruments. These include all revenue variables. Consumption and capital taxes are estimated to react strongly to movements of the cyclical component of output and private investment, respectively. Countercyclical reactions are also identified for the labor tax rate.

On the expenditure side, the estimation reveals a strong countercyclical reaction of transfers. Consisting of a large share of unemployment payments, these can be regarded as a prime example for automatic stabilizers so that this finding reflects economic intuition. Government consumption, on the other hand, to a larger degree consists of outlays that are independent of the business cycle. The estimated reaction coefficient on output in the respective spending rule captures this fact accordingly by pointing at a weaker cyclical behavior of public consumption expenditures. Public investment spending, although commonly regarded as a measure to stimulate economic activity in the context of fiscal stimulus packages, is estimated to be the only fiscal variable that does react to the dynamics of the business cycle in a countercyclical way. Concerning the reaction to movements of public debt, we find lump-sum taxes and, to a smaller degree, transfers to behave in stabilizing way.

All six fiscal variables are estimated to exhibit a medium-high degree of smoothing, with the respective AR(1) parameters ranging from 0.68 to 0.88. Finally, posterior means close to 0.9 suggest that fiscal foresight is particularly pronounced with respect to investment, consumption and labor taxes. It is a little bit less important for transfers and almost not-characteristic for the dynamics of public consumption and capital taxes.

4.3 Shock identification

Based on the estimates of the rules' parameters, smoothed shocks for all six fiscal variables are obtained. For the three spending variables, stimulating measures can be identified during the time of the stimulus packages. Measures that can be attributed to public consumption and transfers exceeded levels expected by the estimated rule by an average of around one per cent per quarter. Stimulus efforts in the area of government investment prove to be markedly higher. They exceed the levels implied by the respective rule by more than five percent in all but one quarter of 2009. On the revenue side, expansive measures can be identified for the labor tax rate, including social security contributions,

			Prior		Posterior		
Parameter		Distr.	Mean	S.d.	Mean	HPD inf	HPD sup
Habit persistence	h	beta	0.50	0.1000	0.3886	0.2464	0.5283
Share of non-Ricardians	μ	beta	0.50	0.1000	0.4284	0.3018	0.5533
Non-Ricard. Cons. Share	χ	beta	0.90	0.0500	0.9066	0.8368	0.9794
Consumption utility	σ	norm	1.00	0.3800	1.4528	0.9634	1.9418
Labor utility	φ	norm	2.00	0.5000	2.0766	1.3165	2.8235
Calvo domestic prices	θ^h	beta	0.50	0.1000	0.5534	0.4863	0.6213
Indexation domestic prices	ξ^h	beta	0.40	0.1500	0.1435	0.0389	0.2427
Calvo export prices	θ^x	beta	0.50	0.1000	0.8192	0.7756	0.8638
Indexation export prices	ξ^x	beta	0.40	0.1500	0.3231	0.1414	0.4964
Calvo import prices	θ^m	beta	0.50	0.1000	0.6112	0.5044	0.7191
Indexation import prices	ξ^m	beta	0.40	0.1500	0.3670	0.1505	0.5769
Elasticity imports	η	norm	1.50	0.7500	2.4719	2.0972	2.8511
Elasticity exports	η^x	norm	1.50	0.7500	2.6092	1.9244	3.2828
Calvo wages	θ^w	beta	0.50	0.1000	0.3783	0.2651	0.4896
Indexation wages	ξ^w	beta	0.40	0.1500	0.3878	0.1453	0.6177
Capital utilization adj.	σ_u	norm	0.40	0.1000	0.4358	0.2810	0.5921
Fixed cost	ϕ	norm	1.35	0.1000	1.5955	1.4566	1.7322
Investment adj. cost	$\varkappa$	norm	4.00	1.5000	4.0204	2.4170	5.5846
AR(1) technology shock	ρ_z	beta	0.80	0.1000	0.8147	0.7391	0.8926
AR(1) investment shock	$\rho_{\varepsilon,i}$	beta	0.80	0.1000	0.5570	0.3904	0.7237
AR(1) preference shock	$\rho_{\varepsilon,c}$	beta	0.80	0.1000	0.7072	0.5574	0.8605
AR(1) risk premium shock	$\rho_{\varepsilon,rp}$	beta	0.80	0.1000	0.8321	0.7667	0.9008
AR(1) labor supply	$\rho_{\varepsilon,l}$	beta	0.80	0.1000	0.3907	0.2452	0.5338
AR(1) cost push domestic	$\rho_{\varepsilon,cph}$	beta	0.80	0.1000	0.7156	0.6293	0.8052
AR(1) cost push exports	$\rho_{\varepsilon,cpx}$	beta	0.80	0.1000	0.8869	0.7894	0.9866
AR(1) cost push imports	$\rho_{\varepsilon,cpm}$	beta	0.80	0.1000	0.9055	0.8478	0.9644
AR(1) UIP condition	$\rho_{\varepsilon,uip}$	beta	0.80	0.1000	0.7285	0.5990	0.8589
Interest rate smoothing	ρ_r	beta	0.80	0.1000	0.9204	0.8809	0.9614
Taylor coeff. inflation	ρ_π	norm	1.50	0.1000	1.4950	1.3326	1.6602
Taylor coeff. output	ρ_y	norm	0.10	0.0500	0.0716	0.0017	0.1412
AR(1) gov. consumption	ρ_{gc}	beta	0.80	0.1000	0.8833	0.8246	0.9453
AR(1) gov. investment	ρ_{gi}	beta	0.80	0.1000	0.7814	0.6722	0.8909
AR(1) gov. transfers	ρ_{tr}	beta	0.80	0.1000	0.7409	0.6357	0.8486
AR(1) cons. tax rule	$\rho_{\tau c}$	beta	0.80	0.1000	0.6754	0.5131	0.8468
AR(1) labor tax rule	$\rho_{\tau w}$	beta	0.80	0.1000	0.7625	0.6224	0.9099
AR(1) capital tax rule	$\rho_{\tau k}$	beta	0.80	0.1000	0.7534	0.6154	0.8994
Gov. Cons. Output Reac.	$\rho_{gc,y}$	norm	0.00	0.5000	-0.0683	-0.6493	0.5050
Gov. Cons. Debt Reac.	$\rho_{gc,b}$	norm	0.00	0.5000	0.3106	-0.1229	0.7361
Gov. Inv. Output Reac.	$\rho_{gi,y}$	norm	0.00	0.5000	0.0199	-0.7532	0.7843
Gov. Inv. Debt Reac.	$\rho_{gi,b}$	norm	0.00	0.5000	0.0865	-0.5786	0.7526
Gov. Tran. Labor Reac.	$\rho_{tr,l}$	norm	0.00	0.5000	-0.6800	-1.0173	-0.3296
Gov. Tran. Debt Reac.	$\rho_{tr,b}$	norm	0.00	0.5000	-0.0528	-0.2454	0.1391
Cons. Tax Output Reac.	$\rho_{\tau c,y}$	norm	0.00	0.5000	0.1775	0.0269	0.3297
Cons. Tax Debt Reac.	$\rho_{\tau c,b}$	norm	0.00	0.5000	-0.0178	-0.1022	0.0723
Labor Tax Labor Reac.	$\rho_{\tau w,y}$	norm	0.00	0.5000	0.0574	-0.1170	0.2388
Labor Tax Debt Reac.	$\rho_{\tau w,b}$	norm	0.00	0.5000	-0.0831	-0.1928	0.0245
Capital Tax Investm. Reac.	$\rho_{\tau k,y}$	norm	0.00	0.5000	0.1886	-0.1404	0.5139
Capital Tax Debt Reac.	$\rho_{\tau k,b}$	norm	0.00	0.5000	-0.1216	-0.5487	0.2997
Lump-sum Debt Reac.	$\rho_{ls,b}$	norm	0.00	0.5000	0.4753	-0.3939	1.3493
Pre-ann. gov. consumption	ψ_{gc}	beta	0.50	0.2000	0.1112	0.0240	0.1952
Pre-ann. gov. investment	ψ_{gi}	beta	0.50	0.2000	0.8896	0.8085	0.9790
Pre-ann. gov. transfers	ψ_{tr}	beta	0.50	0.2000	0.7888	0.6851	0.8900
Pre-ann. cons. tax rule	$\psi_{\tau c}$	beta	0.50	0.2000	0.8963	0.8190	0.9778
Pre-ann. labor tax rule	$\psi_{\tau w}$	beta	0.50	0.2000	0.8739	0.7910	0.9611
Pre-ann. capital tax rule	$\psi_{\tau k}$	beta	0.50	0.2000	0.0937	0.0194	0.1635
S.d. gov. consump. shock	η^{gc}	invg	0.01	2.0000	0.0087	0.0069	0.0105
S.d. gov. investm. shock	η^{gi}	invg	0.01	2.0000	0.0461	0.0368	0.0551
S.d. gov. transf. shock	η^{tr}	invg	0.01	2.0000	0.0088	0.0069	0.0106
S.d. cons. tax shock	$\eta^{\tau c}$	invg	0.01	2.0000	0.0043	0.0035	0.0052
S.d. labor tax shock	$\eta^{\tau w}$	invg	0.01	2.0000	0.0034	0.0027	0.0040
S.d. capital tax shock	$\eta^{\tau k}$	invg	0.01	2.0000	0.0202	0.0163	0.0240
S.d. technology shock	η^z	invg	0.01	2.0000	0.0052	0.0043	0.0061
S.d. investment shock	η^i	invg	0.01	2.0000	0.0874	0.0521	0.1212
S.d. preference shock	η^c	invg	0.01	2.0000	0.0292	0.0179	0.0404
S.d. risk premium shock	η^{rp}	invg	0.01	2.0000	0.0032	0.0021	0.0043
S.d. labor supply shock	η^l	invg	0.01	2.0000	0.1329	0.0587	0.2053
S.d. dom. cost push shock	η^{cph}	invg	0.01	2.0000	0.0172	0.0115	0.0226
S.d. exp cost push shock	η^{cpx}	invg	0.01	2.0000	0.0636	0.0395	0.0876
S.d. imp. cost push shock	η^{cpm}	invg	0.01	2.0000	0.0523	0.0328	0.0719
S.d. UIP condition shock	η^{uip}	invg	0.01	2.0000	0.0034	0.0022	0.0046
S.d. monetary policy	η^r	invg	0.01	2.0000	0.0015	0.0013	0.0017
S.d. foreign output shock	η^{yrea}	invg	0.01	2.0000	0.0142	0.0120	0.0164
S.d. foreign infl. shock	$\eta^{\pi rea}$	invg	0.01	2.0000	0.0040	0.0033	0.0047

Table 3: Priors and posteriors of model parameters and standard deviations of shocks

"norm", "beta" and "invg" indicate normal, beta and inverse gamma prior distributions.

but to a much lower extent. The slightly expansive nature of consumption taxes in the time period under consideration can almost be entirely assigned to the decrease in the VAT for accomodation at the beginning of 2009. The capital tax rate strongly deviated from its implied long-run rule value in an restrictive way in the first half of 2009 and became only expansive in the quarters thereafter.

It is important to distinguish the smoothed fiscal shocks from the official measures presented in Table 1. This is true for at least three reasons:

1. Implementation Lags. The announced numbers are precise at the moment when they are announced but might prove to be different as time moves on. For example, the planning horizon for a public investment might take more time than was originally foreseen, and hence, its start can be delayed.

2. Unknown Counterfactual. The corresponding spending and revenue patterns that would have occurred if fiscal stimulus packages had not been implemented are unknown. Discretionary public investment plans for several years ahead, for example, do not necessarily reflect the fact that some of the projects starting at a later point in time would have been financed by other resources in the future anyway. Moreover, the increased willingness to spend money that is a decisive feature of stimulus packages might incentivize client politics. If this were the case, projects would be financed that had been part of a political agenda for a long time but had not found enough support, e.g., due to political or economic reasons.

3. Detection of Discretion. Some of the measures included in the official announcements regarding fiscal stimuli involve a time horizon that is actually unrestricted, hence it is important to detect their discretionary component. The increase in the child allowance is an example. Compared to the base year 2008, official sources declare them with additional expenses of 2.3 billion in 2009 and 2.2 billion for all following years and unrelated to the recession.

Figure 1 compares the year-to-year change of the size of the official measures from Table 1 with the yearly average of the smoothed fiscal shocks. Additionally, we add the size of the measures induced by implied automatic stabilizers and by the inertia assumption that underlies the models' fiscal reaction function. This can be demonstrated for public consumption:

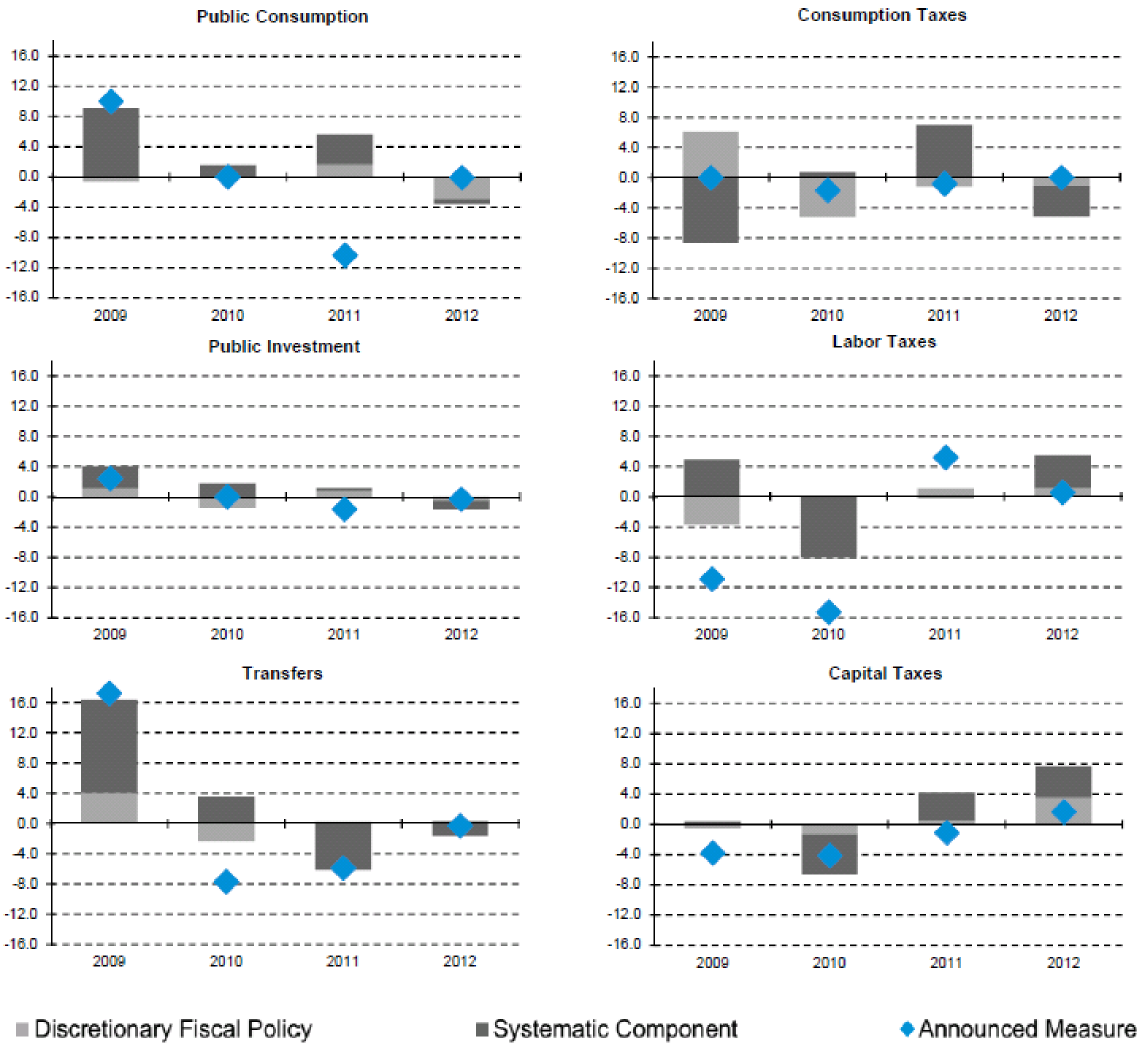

Figure 1: Discretionary fiscal measures: Amount announced and model shocks (year-on-year, in billions of euros)

$$g_t^c = \underbrace{\rho_{gc} g_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{gc,y} y_t + \varphi_{gc,b} b_{t-1}\right)}_{\text{Systematic Component}} + \underbrace{(1-\psi_{gc})\,\eta_t^{gc} + \psi_{gc}\eta_{t-1}^{gc}}_{\text{Discretionary Fiscal Policy}}. \tag{35}$$

For several instruments and time periods, the sum of the models' smoothed shocks plus the systematic components reaches a size that is similar to the magnitude of the announced fiscal measures. However, due to the above mentioned reasons it is not surprising to see also several observations where this is not the case.

In sum, the approach applied in this paper provides a superior identification of discretionary fiscal policy measures. A direct comparison of identified shocks and the officially announced numbers is prone to misunderstanding and thus should be addressed carefully.

5 Effects of the stimulus packages

5.1 Impulse responses

In order to assess the effectiveness of different fiscal policy measures on output, we perform impulse response analyses based on the estimated model and on the posterior estimates of the shocks' standard deviations in particular. To make the individual responses comparable to each other, we scale the shock sizes such that the respective expenditures (revenues) are increased (decreased) by a magnitude that corresponds to 1 percent of steady-state GDP (without feedback effects).[10] The impulse responses for positive spending and negative tax rate shocks over a horizon of 20 quarters are shown in Figure 2. In addition, we compute the respective impact and k-periods ahead cumulative present value multipliers (CPVM) according to the formula proposed by Mountford and Uhlig (2009):

$$CPVM^k = \frac{E_t \sum_{j=0}^{k} (1+R)^{-j} \Delta y_{t+j}}{E_t \sum_{j=0}^{k} (1+R)^{-j} \Delta f_{t+j}}, \tag{36}$$

with the respective fiscal variable f_t. The multipliers on impact as well as for selected horizons up to 5 years ahead are presented in Table 4.

All of the fiscal shocks considered have a positive effect on output on impact. However, the responses differ markedly in terms of size and duration. Government consumption shocks have the largest effect on impact (1.7 percent) and fade out after three years. The respective present value multiplier gradually reduces to 1 after five years. Government investment shocks have almost no effect on impact as private activity is crowded out and public capital becomes productive only with a lag. The positive effects in the subsequent quarters are partly subdued as higher wages from an increased productivity lead households to substitute work for leisure. Due to the associated increase of the productive capital stock the overall positive effect on output is larger and more persistent compared to a government consumption shock. The cumulative present value multiplier is 1.9 after five years. The effectiveness of government investment depends crucially on the elasticity parameter of public capital in the production function that we have calibrated to 0.1. We provide a sensitivity analysis by estimating the model with the respective parameter set to 0.01. In that case the short-run crowding out and substitution effects are smaller than in the baseline case as is the resulting long-run multiplier of 1.2. Nonetheless, in both cases, government investment spending proves to be the most effective measure. However, its positive effects on output materialize only with a substantial lag. Transfer

[10] In addition, we account for the different sizes of the pre-announcement parameters and scale the initial impulse by $(1-\psi)$.

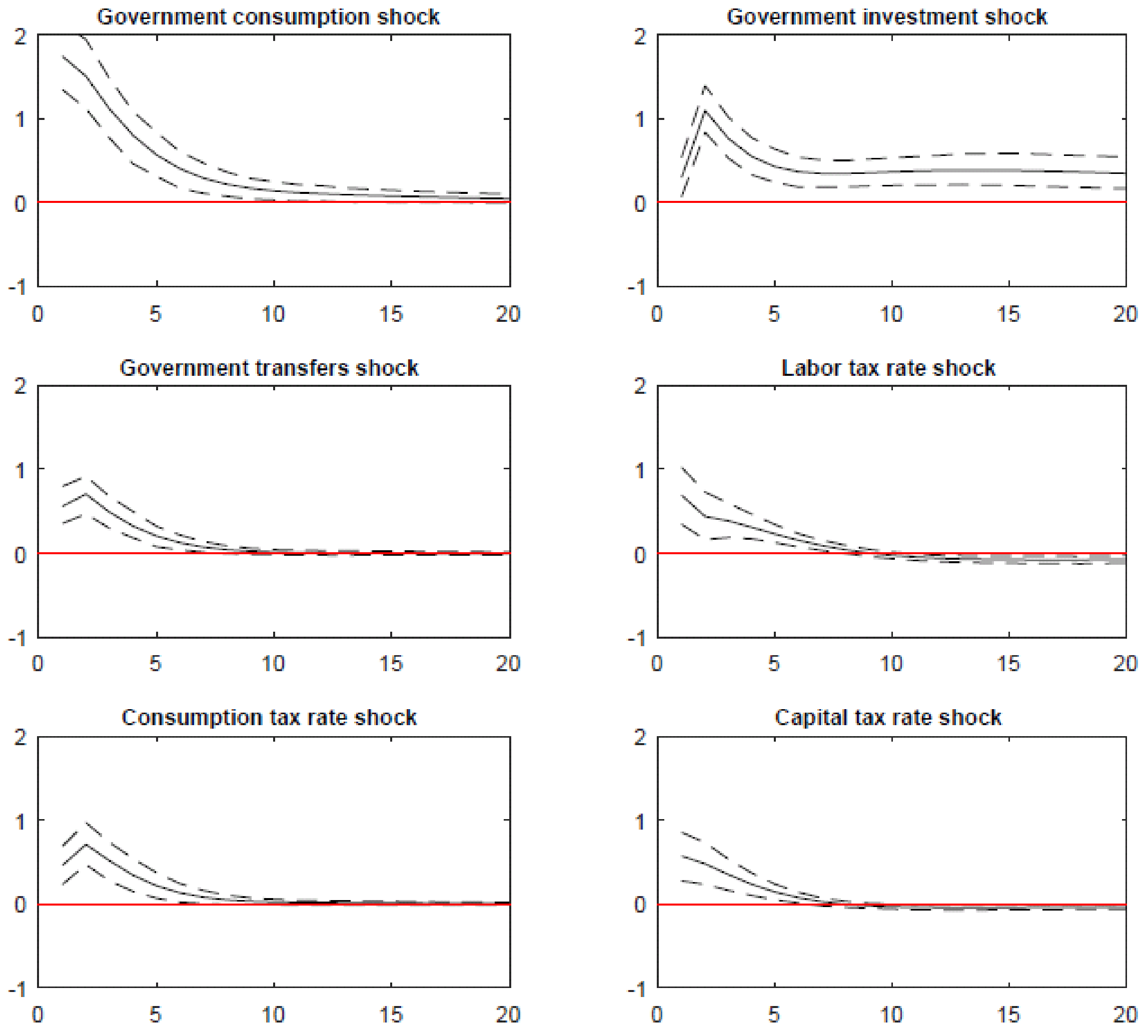

Figure 2: Mean impulse responses of output to fiscal shocks equal to 1 percent of GDP (in percent)
Mean (solid) and HPDsup and HPDinf (90%, dashed).

payments directly transfer to higher incomes and expenditures of non-Ricardian households and increase domestic output on impact by about 0.6 percent. The positive effects fade out after roughly five years, peaking at a cumulative present value multiplier of 0.7. Reductions in the tax rates on labor and capital income effectively reduce the respective factor prices for intermediate goods producers and shift the composition of inputs to the relatively cheaper factor. In the case of a labor tax reduction, the increased demand for labor raises the incomes of households, in particular the non-Ricardians, and by that increasing consumption and output. On impact, it increases by 0.7 percent. In contrast, the reduction of the capital tax rate reduces demand for labor and the households' incomes, reducing the positive effects on consumption from lower prices. Increased investment by firms does not fully compensate for that. Since in addition investment decisions are

Shock	Impact	1 year	2 years	3 years	4 years	5 years
Government consumption	1.74	1.49	1.23	1.11	1.06	1.04
Government investment	0.30	1.16	1.21	1.42	1.66	1.89
Government transfers	0.56	0.84	0.73	0.69	0.67	0.66
Labor tax rate	0.69	0.73	0.62	0.52	0.44	0.38
Consumption tax rate	0.46	0.90	0.83	0.81	0.80	0.80
Capital tax rate	0.57	0.58	0.48	0.41	0.37	0.33

Table 4: Impact and cumulative present value multipliers

affected by capital tax rate changes with a lag, the immediate effect on output is slightly lower (0.6). This changes in the following quarters as the capital stock resulting from the increased investment incentives becomes productive. Over the medium-term horizon the multipliers of capital and labor tax rate cuts are nearly identical (0.3 and 0.4). Compared to other taxes, the immediate effect of an equally-sized shock on output is the lowest for consumption taxes (0.5). Private households increase their consumption as the tax reduction increases their purchasing power. In addition, optimizing households will demand higher wages to balance their optimal choice of leisure and labor supply, preserving the expansionary effect on output even as the consumption tax rate quickly returns to its steady state. This results in an increasing cumulative present value multiplier over the medium-term horizon that amounts to 0.8 after five years.

5.2 Historical decomposition

After the assessment of the general effectiveness of fiscal policy measures in the previous subsection, we now turn to the analysis of the effects of discretionary fiscal policy on output during the Great Recession. Figure 3 shows the historical decomposition of demeaned German output growth from 2008 to 2012. The 18 shocks are grouped into four categories: foreign shocks, consisting of the deviations in GDP and inflation of the rest of the euro area from their respective long run dynamics, export and import price disturbances as well as foreign risk premium shocks; monetary policy shocks, which capture non-systematic deviations in the policy rate from the estimated Taylor rule; fiscal shocks, which contain the six fiscal rule disturbances; and domestic shocks, which include the remaining shocks in the model.

Over the whole time period considered, fiscal shocks had only marginal effects on output. In none of the 56 quarters did fiscal shocks have an impact on output growth of more than 0.7 percentage points. During the Great Recession and the implementation of the stimulus packages, the effects of fiscal policy were also limited. Economic expansion has been stimulated strongest in the fourth quarter of 2008 and the second quarter of

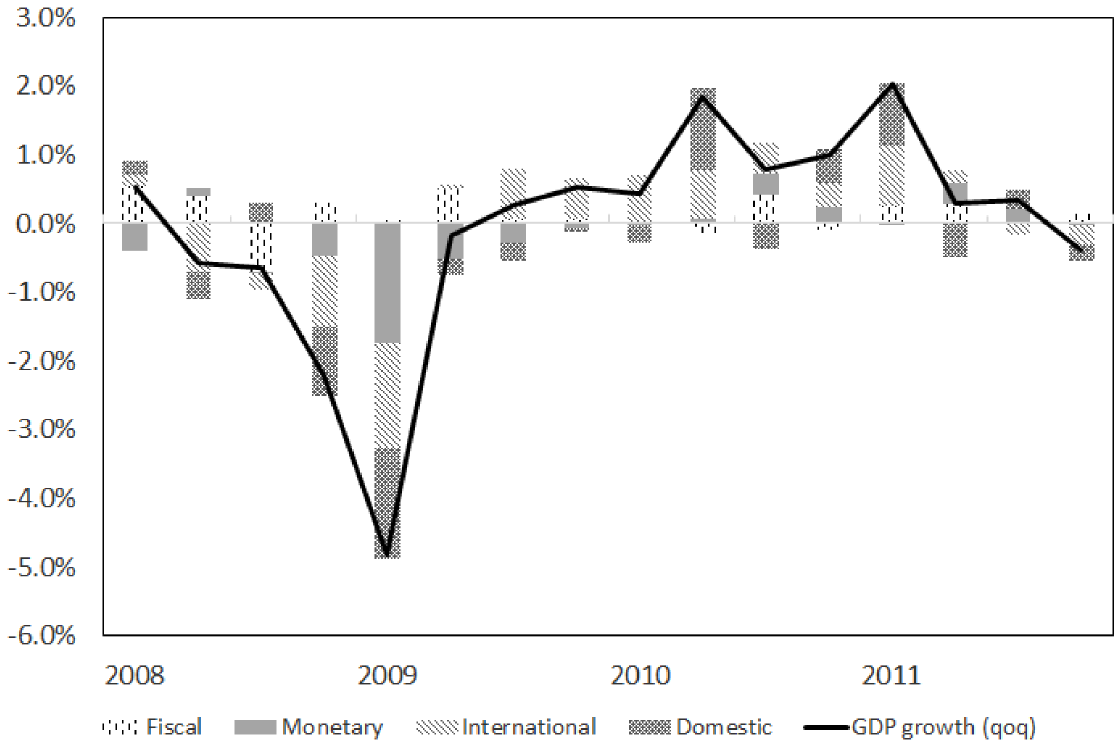

Figure 3: Historical decomposition of (demeaned) quarterly German output growth (solid line): contribution of shocks in percentage points
Contributions of the 18 model shocks. Fiscal shocks contain the six fiscal rule disturbances, monetary shock denotes deviations from the Taylor rule, international shocks consist of the shocks to the rest of the euro area GDP and inflation, export and import price disturbances as well as foreign risk premium shocks, domestic shocks include all remaining disturbances.

2009 (0.3 and 0.5 percentage points), whereas the contraction in the third quarter of 2008 can nearly entirely be attributed to a restrictive fiscal stance. In the the remaining quarters until mid-year 2010 the effects of fiscal policy were negligible. In the third quarter of 2010, fiscal policy again strongly stimulated the expansion of economic activity by 0.4 percentage points. However, at that time the German economy had already been recovering for more than a year, suggesting that the effects of fiscal policy were rather pro-cyclical.

Among the six variables considered in the model, the largest positive impacts can be attributed to government consumption, investment, transfers as well as labor taxes. From the fourth quarter of 2008 until the end of 2009, each of the three spending variables positively contributed to output growth by cumulative 0.3 percentage points (Figure 4). Although the identified positive shocks to government investment were much greater, its low share in the GDP of Germany resulted in a much lower impact in the specific quarters. Government transfers strongly supported the German economy in the first half of 2009, with the largest impact on GDP growth of around 0.2 percentage points in the first quarter of 2009, indicating a positive effect from the car scrapping incentive and several types of allowances. Changes in labor tax rates including social security contributions had a slightly smaller positive impact on output growth compared to the spending variables. For the remaining two tax rates, positive and negative effects are neutralized over the quarters of interest. In total, the fiscal policy instruments under

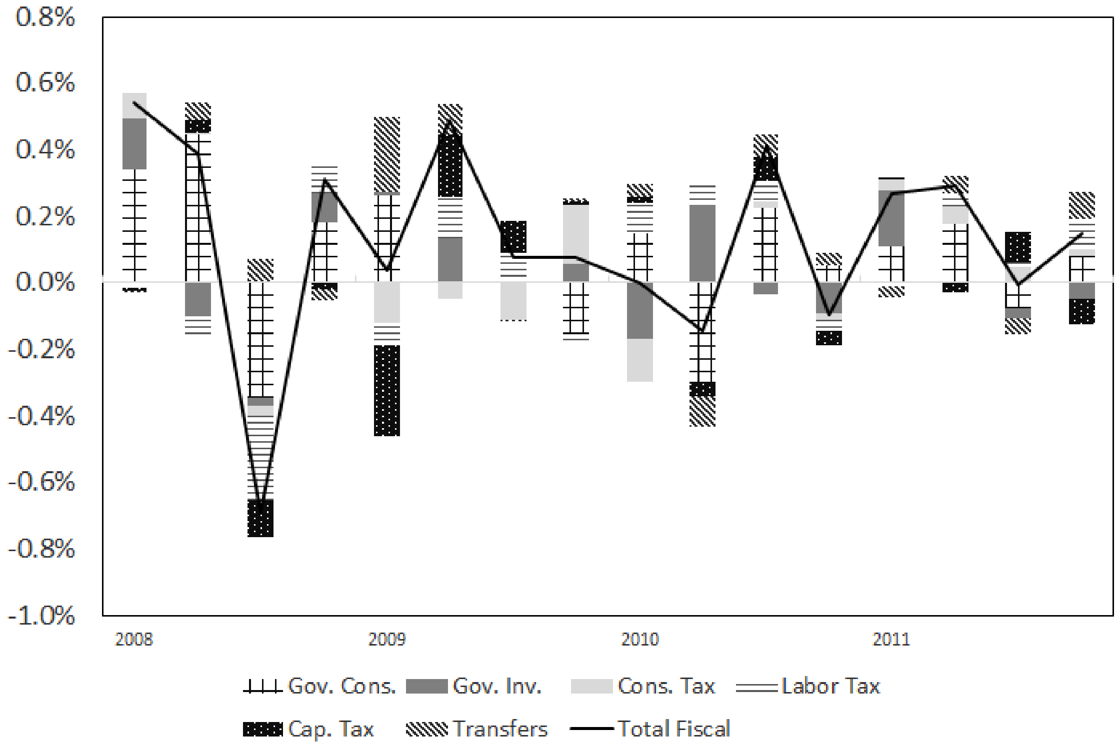

Figure 4: Historical decomposition of (demeaned) quartely German output growth: contribution of fiscal shocks and total fiscal contribution (solid line) in percentage points

consideration contributed slightly positively to German output growth in the period from the implementation of the first stimulus package until the end of 2010. However, policy measures are not estimated to have prevented a larger downturn or to have offset the negative effects of other disturbances during that time. This is in particular true for the sharp contraction in the first quarter of 2009 to which monetary, international and domestic shocks have equally contributed.

As concerns monetary policy, the common euro area interest rate proved to be too restrictive in the wake of lower inflation rates sharply declining output. On the other hand, when from 2010 onwards recovery was already well under way in Germany, however supressed in the rest of the monetary union, the ECB policy supported economic activity in Germany, admittedly to a much lower extent than it curbed it before.

From the international perspective, the slowdown in German economic activity has been primarily caused by the effects of a shock to the UIP condition, interpretable in context of this model as an international risk premium shock. Shocks to foreign output as well as export and import prices, on the other hand, played a negligible role. These findings suggest that the real appreciation of the euro at the beginning of 2009 rather than the worsening global economic conditions reduced the foreign demand for German products that fostered the contraction. In the quarters from mid-year 2009 until the end of 2010, international shocks are estimated to have contributed three-fourths to the economic recovery. Domestic production has been stimulated to almost equal parts by a real depreciation of the euro as well as favorable developments of the terms of trade.

Finally, a number of domestic shocks contributed to the sharp contraction at the beginning of 2009, adding 1.6 percentage points to the total of 4.9 percent. Among these, the by far largest effect can be attributed to risk premium shocks, followed by shocks reducing total productivity as well as the efficiency of newly installed capital. Positive, albeit small, effects have been estimated for labor supply shocks, suggesting that measures that aimed at adjusting labor hours instead of laying off workers proved helpful. In the following recovery, domestic shocks in total played a relatively minor role. Positive contributions can almost solely be attributed to positive risk premium shocks.

6 Sensitivity analysis

As the results of the baseline model specification have been presented, this section now addresses sensitivity analysis. More precisely, we examine the degree to which the results are contingent upon the model setup. In particular, we test whether fiscal foresight as suggested, among others, by Leeper et al. (2013) as well as Schmitt-Grohé and Uribe (2012) is important to control for. To this end, we estimate a different specification of the model in which we do not allow for pre-announcement effects in the fiscal policy rules as proposed by Leeper et al. (2013). The respective equations change to:

$$g_t^c = \rho_{gc} g_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{gc,y} y_t + \varphi_{gc,b} b_{t-1}\right) + \eta_t^{gc}, \quad (37)$$

$$g_t^i = \rho_{gi} g_{t-1}^i + (1-\rho_{\tau c})\left(\varphi_{gi,y} y_t + \varphi_{gi,b} b_{t-1}\right) + \eta_t^{gi}, \quad (38)$$

$$tr_t = \rho_{tr} tr_{t-1} + (1-\rho_{\tau c})\left(\varphi_{tr,l} l_t + \varphi_{tr,b} b_{t-1}\right) + \eta_t^{tr}, \quad (39)$$

$$\tau_t^c = \rho_{\tau c} \tau_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{\tau c,y} y_t + \varphi_{\tau c,b} b_{t-1}\right) + \eta_t^{\tau c}, \quad (40)$$

$$\tau_t^w = \rho_{\tau w} \tau_{t-1}^w + (1-\rho_{\tau w})\left(\varphi_{\tau w,l} l_t + \varphi_{\tau w,b} b_{t-1}\right) + \eta_t^{\tau w}, \quad (41)$$

$$\tau_t^k = \rho_{\tau k} \tau_{t-1}^k + (1-\rho_{\tau k})\left(\varphi_{\tau k,i} i_t + \varphi_{\tau k,b} b_{t-1}\right) + \eta_t^{\tau k}. \quad (42)$$

In that sense, we can relate the alternative setup to the baseline specification by setting the parameter ψ to zero for all fiscal rules in the alternative case. Calibrations and prior choices for all remaining parameters and standard deviations of shocks as well as other estimation options are the same as in the baseline specification. This enables us to directly assess the performance of both models via the comparison of marginal data densities.

Table 5 shows the posterior means of the parameters in the fiscal rules under both model specifications as well as their log data densities. For all six policy rules, the smoothing parameters are larger in the setup not allowing for pre-announcement effects. This finding is not surprising given that the pre-announcement parameter ψ smooths the shock component of the respective fiscal variable to some extent. As concerns the reaction coefficients to business cycle variables, there are no qualitatively different estimates under the different model specifications, when abstracting from the marginal difference in the government investment rule. Government consumption expenditures are, however, estimated to be significantly more pro-cyclical in the presence of fiscal foresight, while the opposite is true for the labor tax rate. As concerns the reaction parameters to debt, fiscal policy is estimated to act even less stabilizing in the absence of pre-announcement effects regarding its consumption and investment expenditures as well as tax rates on factor incomes. The two fiscal variables that stabilize public debt in the baseline setup, however, do so to a larger extent when abstaining from fiscal foresight.

Figure 5 compares the contribution of fiscal shocks to output growth under the different model specifications. The extent to which policy measures have affected economic activity during the recession is comparable under the two setups. The largest differences lie in the contributions in the last quarter of 2008 and the first quarter of 2009. Allowing for pre-announcement effects, fiscal policy strongly stimulated output growth already at the end of 2008, being almost neutral in the period thereafter. Without pre-announcement effects, the quarterly contributions are virtually the opposite. This result stems from a different attribution of the effects of changes in labor taxes, transfers and to a minor extent in consumption taxes. With a high estimated value for the parameter $\psi_{\tau l}$ in the respective fiscal rule, the contribution of the identified shock is "shifted" by one period when allowing for anticipation. The same holds true for the effects of government transfers in the following period. In the third quarter of 2009, the contribution of fiscal shocks to output growth is larger in the baseline specification. This finding reflects the absence of newly anticipated shocks and the attribution of "lagged" shocks at the same time. In the remaining quarters the estimated effects of fiscal policy are similar under both specifications. This holds true for the almost negligible contributions in most of the periods as well as the procyclical stimulus in the third quarter of 2010.

	Baseline	without pre-ann.
AR coefficients		
Government consumption	0.8833	0.8997
Government investment	0.7814	0.8300
Government transfers	0.7409	0.7979
Consumption tax rate	0.6754	0.6620
Labor tax rate	0.7625	0.8475
Capital tax rate	0.7534	0.7726
Coefficients business cycle		
Government consumption	-0.0683	0.0615
Government investment	0.0199	0.0335
Government transfers	-0.6800	-0.7261
Consumption tax rate	0.1775	0.1462
Labor tax rate	0.0574	0.1065
Capital tax rate	0.1886	0.1881
Coefficients debt		
Government consumption	0.3106	0.3460
Government investment	0.0865	0.1195
Government transfers	-0.0528	-0.1006
Consumption tax rate	-0.0178	0.0059
Labor tax rate	-0.0831	-0.1395
Capital tax rate	-0.1216	-0.0879
Lump-sum taxes	0.4753	0.5052
Pre-announcement coefficients		
Government consumption	0.1112	na
Government investment	0.8896	na
Government transfers	0.7888	na
Consumption tax rate	0.8963	na
Labor tax rate	0.8739	na
Capital tax rate	0.0937	na
Log data density	3157.81	3180.80

Table 5: Parameter estimates at the posterior mode and log data densities.
Log data densities were computed using the modified harmonic mean.

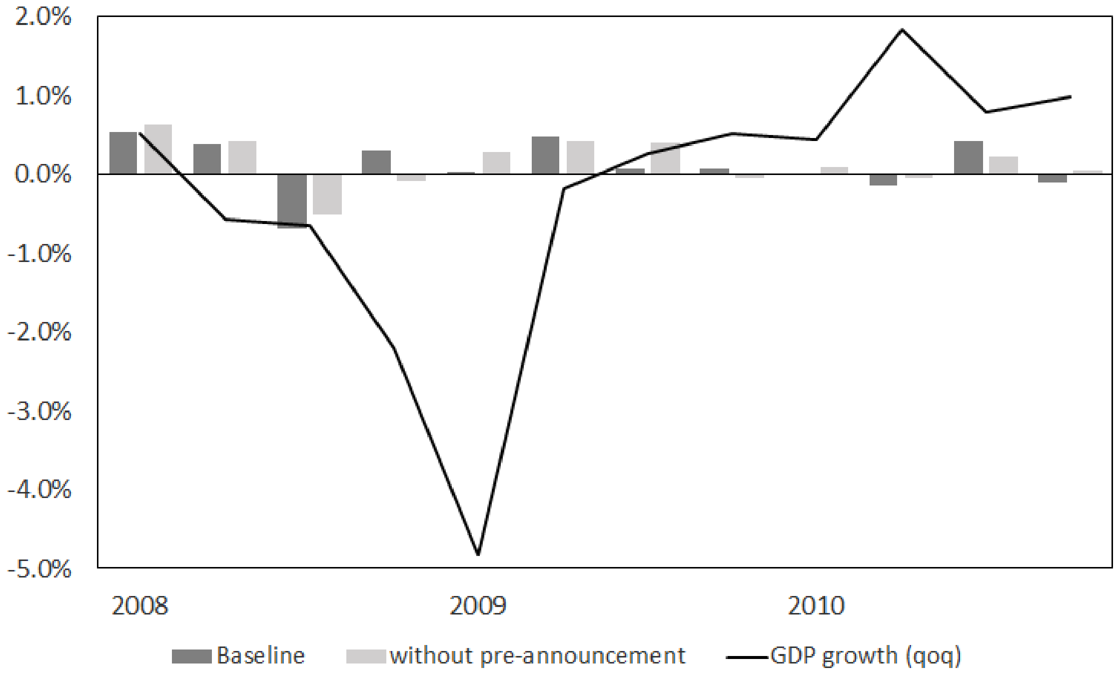

Figure 5: Contribution of fiscal shocks to (demeaned) quarterly GDP growth (solid line) under different model specifications (bars) in percentage points

Taking into account the log data densities, we conclude that the alternative specification is slightly preferred by the data. All in all, the results of our preferred model setup are, however, not sensitive with respect to the exclusion of pre-announcement effects. The cumulative contributions to output growth are exactly the same for the period from the last quarter of 2008 until the end of 2009 (0.98 percentage points) and only slightly different when also accounting for the year 2010: 1.15 percentage points in the baseline setup compared to 1.29 in the alternative case. Allowing for anticipation, however, affects the timing of the contribution of a specific shock. We find that this holds particularly true for tax rates on consumption and labor as well as government transfers and thus variables for which high values for the parameter ψ have been estimated in the respective policy rule.

7 Conclusion

Similar to most other developed countries, the German government adopted several policy measures to mitigate the impact of the Great Recession on the domestic economy. In this paper, we assess the effects of fiscal stimulus packages in the framework of an estimated DSGE model. To account for the cyclical behavior of fiscal variables, in particular the characteristics of automatic stabilizers, we specify six equations for the dynamics of spending and revenue variables as feedback rules. Based on these equations, we identify the actual fiscal shocks in contrast to the total changes in spending and revenue variables. Our estimates hint at the overall positive effects of fiscal policy on German output in the years 2009 and 2010, most of which can be attributed to government consumption, investment, transfers and changes in labor tax rates including social security contributions. Their total impact is, however, moderate compared to other domestic and especially international shocks. Nonetheless, fiscal policy is estimated to have prevented a sharper and prolonged decline in output at the beginning of the global recession and to have contributed to its subsequent recovery, suggesting a timely fiscal response. Large stimulating effects can, however, also be identified for a period in which the economy was already expanding for more than one year, hinting at some unintentional procyclicality. Our overall results are not sensitive to the allowance of fiscal foresight.

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A First order conditions

FOC of optimizing households wrt. consumption:

$$\epsilon_t^c \left(C_t^o - hC_{t-1}^o\right)^{-\sigma} = (1+\tau_t^c)\,\lambda_t^o \tag{A.1}$$

FOC of optimizing households wrt. investment:

$$\begin{aligned} Q_t^o \epsilon_t^i S'\left(\tfrac{I_t^o}{I_{t-1}^o}\right)\tfrac{I_t^o}{I_{t-1}^o} - \quad & \beta E_t \left[Q_{t+1}^o \epsilon_{t+1}^i \tfrac{\lambda_{t+1}^o}{\lambda_t^o} S'\left(\tfrac{I_{t+1}^o}{I_t^o}\right)\left(\tfrac{I_{t+1}^o}{I_t^o}\right)\tfrac{I_{t+1}^o}{I_t^o}\right] + 1 = \\ & Q_t^o \epsilon_t^i \left(1 - S\left(\tfrac{I_t^o}{I_{t-1}^o}\right)\right) \end{aligned} \tag{A.2}$$

FOC of optimizing households wrt. labor

$$(1-\tau_t^w)\frac{W_t}{P_t} = \psi_l \frac{\epsilon_t^l (L_t^o)^\varphi}{\lambda_t^o} \tag{A.3}$$

FOC of optimizing households wrt. bond holdings:

$$\lambda_t^o P_t = \beta E_t \left(\lambda_{t+1}^o P_{t+1}\right) \epsilon_t^{rp} R_t \tag{A.4}$$

FOC of optimizing households wrt. foreign bond holdings:

$$\lambda_t^o P_t = \beta E_t \left(\lambda_{t+1}^o P_{t+1}\right) e_t R_t \phi\left(NFA_t\right) \tag{A.5}$$

FOC of optimizing households wrt. next period's capital stock:

$$Q_t^o = \beta E_t \left[\frac{\lambda_{t+1}^o}{\lambda_t^o}\left(\left(1-\tau_t^k\right)\left[r_t^k u_t - a\left(u_{t+1}\right)\right] + \tau_t^k \delta + (1-\delta)\,Q_{t+1}^o\right)\right] \tag{A.6}$$

FOC of optimizing households wrt. the capital utilization rate:

$$a'\left(u_t\right) = r_t^k \tag{A.7}$$

B Log linearized equations

B.1 Households

Consumption Euler equation of optimizing households:

$$c_t^o = \frac{1}{1+h}\left(E_t c_{t+1}^o + h c_{t-1}^o\right) - \frac{1}{\sigma}\frac{1-h}{1+h} E_t \left(r_t - \pi_{t+1} + \epsilon_t^{rp} + \epsilon_{t+1}^c - \epsilon_t^c + \frac{1}{1+\tau^c}\left(\tau_t^c - \tau_{t+1}^c\right)\right) \tag{A.8}$$

Consumption of rule-of-thumb households:

$$\left(1+\tau^{c}\right)\frac{C^{nr}}{Y}c_t^{nr}=\frac{WL}{Y}\left(\tau_t^{w}+\left(1-\tau^{w}\right)\left(w_t+l_t\right)\right)+\frac{TR^{nr}}{Y}tr_t^{nr}-\frac{C^{nr}}{Y}\tau_t^{c} \tag{A.9}$$

Aggregate consumption:

$$c_t=\left(1-\mu\right)\frac{C^{o}}{C}c_t^{o}+\mu\frac{C^{nr}}{C}c_t^{nr} \tag{A.10}$$

Aggregate transfers:

$$tr_t=\left(\xi\left(1-\mu\right)+\mu\right)\frac{TR^{nr}}{TR}tr_t^{nr} \tag{A.11}$$

Wage dynamics:

$$\begin{aligned} w_t= \; & \tfrac{1}{1+\beta}\left(\beta E_t w_{t+1}+w_{t-1}\right)+\tfrac{\beta}{1+\beta}E_t\pi_{t+1}-\tfrac{1+\beta\chi^{w}}{1+\beta}\pi_t+\tfrac{\chi^{w}}{1+\beta}\pi_{t-1} \\ & -\tfrac{1}{1+\beta}\tfrac{\left(1-\beta\,\theta^{w}\right)\left(1-\theta^{w}\right)}{\theta^{w}\left(1+\frac{\varphi\left(1+\lambda^{w}\right)}{\lambda^{w}}\right)}\left(w_t-mrs_t^{o}-\tfrac{1}{1+\tau^{w}}\tau_t^{w}\right) \end{aligned} \tag{A.12}$$

Marginal rate of substitution (between consumption and labor):

$$mrs_t^{o}=\epsilon_t^{l}+\varphi l_t+\frac{\sigma}{1-h}\left(c_t^{o}-h\,c_{t-1}^{o}\right)+\frac{1}{1+\tau^{c}}\tau_t^{c}-\epsilon_t^{b} \tag{A.13}$$

Private investment Euler equation:

$$i_t=\frac{1}{1+\beta}\left(\beta E_t i_{t+1}+i_{t-1}\right)+\frac{\beta}{\varkappa\left(1+\beta\right)}\left(q_t+\epsilon_t^{i}\right) \tag{A.14}$$

where $\varkappa=S$"

Shadow cost of private capital:

$$q_t=\;\beta E_t\left(\left(1-\delta\right)q_{t+1}+\left(1-\tau^{k}\right)r_{t+1}^{k}-r^{k}\tau_{t+1}^{k}+\delta\tau_{t+1}^{k}\right)-r_t-E_t\pi_{t+1}-\epsilon_t^{rp} \tag{A.15}$$

Capital utilization:

$$u_t=\sigma_u r_t^{k} \tag{A.16}$$

where: $\sigma_u=a''$.

Privat capital law of motion:

$$k_t=\left(1-\delta\right)\,k_{t-1}+\delta\left(i_t+\epsilon_t^{i}\right) \tag{A.17}$$

B.2 Firms

Labor demand:

$$l_t=k_{t-1}+u_t+r_t^{k}-w_t \tag{A.18}$$

Marginal cost (domestic):

$$mc_t = (1-\alpha)\ w_t + \alpha\, r_t^k - z_t - \zeta\, k_{t-1}^g \tag{A.19}$$

Marginal cost (exporters):

$$mc_t^x = mc_t - s_t - t_t^x \tag{A.20}$$

Marginal cost (import retailers):

$$mc_t^m = s_t - t_t^m \tag{A.21}$$

Phillips curve (domestic):

$$\pi_t^h = \frac{\beta}{1+\beta\,\chi^h} E_t \pi_{t+1}^h + \frac{\chi^h}{1+\beta\,\chi^h}\,\pi_{t-1}^h + \frac{\left(1-\beta\,\theta^h\right)\,\left(1-\theta^h\right)}{\left(1+\beta\,\chi^h\right)\,\theta^h}\,\left(mc_t + \epsilon_t^{cp,h}\right) \tag{A.22}$$

Phillips curve (exporters):

$$\pi_t^x = \frac{\beta}{1+\beta\,\chi^x} E_t \pi_{t+1}^x + \frac{\chi^x}{1+\beta\,\chi^x}\,\pi_{t-1}^x + \frac{\left(1-\beta\,\theta^x\right)\,\left(1-\theta^x\right)}{\left(1+\beta\,\chi^x\right)\,\theta^x}\,\left(mc_t^x + \epsilon_t^{cp,x}\right) \tag{A.23}$$

Phillips curve (importers):

$$\pi_t^m = \frac{\beta}{1+\beta\,\chi^m} E_t \pi_{t+1}^m + \frac{\chi^m}{1+\beta\,\chi^m}\,\pi_{t-1}^m + \frac{\left(1-\beta\,\theta^m\right)\,\left(1-\theta^m\right)}{\left(1+\beta\,\chi^m\right)\,\theta^m}\,\left(mc_t^m + \epsilon_t^{cp,m}\right) \tag{A.24}$$

B.3 Fiscal authority

Government consumption:

$$g_t^c = \rho_{gc} g_{t-1}^c + (1-\rho_{gc})\left(\varphi_{gc,y} y_t + \varphi_{gc,b} b_{t-1}\right) + (1-\psi_{gc})\,\eta_t^{gc} + \psi_{gc}\eta_{t-1}^{gc} \tag{A.25}$$

Government investment:

$$g_t^i = \rho_{gi} g_{t-1}^i + (1-\rho_{gi})\left(\varphi_{gi,y} y_t + \varphi_{gi,b} b_{t-1}\right) + (1-\psi_{gi})\,\eta_t^{gi} + \psi_{gi}\eta_{t-1}^{gi} \tag{A.26}$$

Government transfers:

$$tr_t = \rho_{tr} tr_{t-1} + (1-\rho_{tr})\left(\varphi_{tr,l} l_t + \varphi_{tr,b} b_{t-1}\right) + (1-\psi_{tr})\,\eta_t^{tr} + \psi_{tr}\eta_{t-1}^{tr} \tag{A.27}$$

Consumption tax rate:

$$\tau_t^c = \rho_{\tau c}\tau_{t-1}^c + (1-\rho_{\tau c})\left(\varphi_{\tau c,y}y_t + \varphi_{\tau c,b}b_{t-1}\right) + (1-\psi_{\tau c})\,\eta_t^{\tau c} + \psi_{\tau c}\eta_{t-1}^{\tau c} \tag{A.28}$$

Labor tax rate:

$$\tau_t^w = \rho_{\tau w}\tau_{t-1}^w + (1-\rho_{\tau w})\left(\varphi_{\tau w,y}l_t + \varphi_{\tau w,b}b_{t-1}\right) + (1-\psi_{\tau w})\,\eta_t^{\tau w} + \psi_{\tau w}\eta_{t-1}^{\tau w} \tag{A.29}$$

Capital tax rate:

$$\tau_t^k = \rho_{\tau k}\tau_{t-1}^k + (1-\rho_{\tau k})\left(\varphi_{\tau k,y}i_t + \varphi_{\tau k,b}b_{t-1}\right) + (1-\psi_{\tau k})\,\eta_t^{\tau k} + \psi_{\tau k}\eta_{t-1}^{\tau k}, \tag{A.30}$$

Lump-sum taxes:

$$ls_t = \varphi_{ls,b}b_{t-1} \tag{A.31}$$

Public capital law of motion:

$$k_t^g = (1-\delta^g)\,k_{t-1}^g + \delta^g g_t^i \tag{A.32}$$

Government budget constraint:

$$\begin{aligned} \tfrac{B}{Y}b_t = \; & \tfrac{TR}{Y}tr_t + \tfrac{B}{Y}\tfrac{1}{\beta}\left(r_{t-1} - \pi_t + b_{t-1}\right) + \tfrac{G^c}{Y}g_t^c + \tfrac{G^i}{Y}g_t^i - \tfrac{C}{Y}\left(\tau_t^c + \tau^c c_t\right) \\ & -\tfrac{WL}{Y}\left(\tau_t^w + \tau^w\left(l_t + w_t\right)\right) - r^k\tfrac{K}{Y}\left(\tau_t^k + \tau^k\left(u_t + r_t^k + k_{t-1}\right)\right) \\ & +\tfrac{K}{Y}\left(\delta\tau_t^k + \tau^k r^k u_t + \tau^k\delta k_{t-1}\right) - \tfrac{LS}{Y}ls_t \end{aligned} \tag{A.33}$$

where $\frac{LS}{Y} = \frac{1}{\beta}\frac{B}{Y} - \frac{B}{Y} + \frac{G^c}{Y} + \frac{G^i}{Y} + \frac{TR}{Y} - \tau^c\frac{C}{Y} - \tau^w\frac{WL}{Y} - \tau^k r^k\frac{K}{Y} + \tau^k\delta\frac{K}{Y}$.

B.4 Monetary authority and euro area aggregates

Taylor Rule:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left(\rho_\pi\pi_{EA,t} + \rho_y y_{EA,t}\right) + \eta_t^r \tag{A.34}$$

Euro area inflation:

$$\pi_{EA,t} = n\pi_t + (1-n)\,\pi_t^{REA} \tag{A.35}$$

Euro area output gap:

$$y_{EA,t} = ny_t + (1-n)\,y_t^{REA} \tag{A.36}$$

B.5 Aggregation, market clearing and relative prices

Production function:

$$y_t = \phi \left(\zeta \, k_{t-1}^g + z_t + \alpha \, u_t k_{t-1} + (1-\alpha) \; l_t \right) \tag{A.37}$$

where $\phi = (1+\Phi)/Y$.
Goods market clearing:

$$y_t = \; \tfrac{C}{Y} c_t + \tfrac{I}{Y} i_t + \tfrac{G^c}{Y} \left(t_t^h + g_t^c \right) + \tfrac{G^i}{Y} \left(t_t^h + g_t^i \right) + r^k \tfrac{K}{Y} u_t + \tfrac{X}{Y} x_t - \tfrac{M}{Y} m_t \tag{A.38}$$

with exports

$$x_t = -\eta^x t_t^x + y_t^{REA} \tag{A.39}$$

and imports

$$m_t = -\eta t_t^m + \frac{C}{C+I} c_t + \frac{I}{C+I} i_t \tag{A.40}$$

Net foreign assets:

$$nfa_t = \frac{1}{\beta} nfa_{t-1} + \frac{X}{Y} \left(t_t^x + s_t + x_t \right) - \frac{M}{Y} \left(t_t^m + m_t \right) \tag{A.41}$$

Domestic prices (relative to consumer prices)

$$t_t^h = -\frac{1-\omega}{\omega} t_t^m \tag{A.42}$$

Export prices (relative to foreign prices)

$$t_t^x = t_{t-1}^x + \pi_t^x - \pi_t^{REA} \tag{A.43}$$

Import prices (relative to consumer prices)

$$t_t^m = t_{t-1}^m + \pi_t^m - \pi_t \tag{A.44}$$

Real exchange rate (UIP condition, from optimal choice of domestic and foreign bonds)

$$E_t s_{t+1} = s_t + E_t \left(\pi_{t+1}^{REA} - \pi_{t+1} \right) + \kappa nfa_t + \epsilon_t^{uip} + \epsilon_t^{rp} \tag{A.45}$$

B.6 Shocks and AR(1) processes

Technology shock:

$$z_t = \rho_z \, z_{t-1} + \eta_t^z \tag{A.46}$$

Risk-premium shock:

$$\epsilon_t^{rp} = \rho_{\epsilon,rp}\, \epsilon_{t-1}^{rp} + \eta_t^{rp} \tag{A.47}$$

Investment shock:

$$\epsilon_t^{i} = \rho_{\epsilon,i}\, \epsilon_{t-1}^{i} + \eta_t^{i} \tag{A.48}$$

Preference shock:

$$\epsilon_t^{c} = \rho_{\epsilon,c}\, \epsilon_{t-1}^{c} + \eta_t^{c} \tag{A.49}$$

Labor supply shock:

$$\epsilon_t^{l} = \rho_{\epsilon,l}\, \epsilon_{t-1}^{l} + \eta_t^{l} \tag{A.50}$$

Domestic cost-push shock:

$$\epsilon_t^{cph} = \rho_{\epsilon,cph}\, \epsilon_{t-1}^{cph} + \eta_t^{cph} \tag{A.51}$$

Exporters cost-push shock:

$$\epsilon_t^{cpx} = \rho_{\epsilon,cpx}\, \epsilon_{t-1}^{cpx} + \eta_t^{cpx} \tag{A.52}$$

Importers cost-push shock:

$$\epsilon_t^{cpm} = \rho_{\epsilon,cpm}\, \epsilon_{t-1}^{cpm} + \eta_t^{cpm} \tag{A.53}$$

UIP shock :

$$\epsilon_t^{uip} = \rho_{\epsilon,uip}\, \epsilon_{t-1}^{uip} + \eta_t^{uip} \tag{A.54}$$

C Steady state

We fix the steady-state shares of public consumption, public investment, transfers and the three tax rates at their relative sample means. The steady-state ratio of public debt to (quarterly) GDP is set to 2.4 in line with the respective Maastricht criterium.

Assuming that elasticities of substition are identical for intermediate goods, it holds for relative prices:

$$T^h = T^x = T^m = 1 \tag{A.55}$$

(Gross) inflation rates are given by:

$$\Pi = \Pi^h = \Pi^x = \Pi^m = 1 \tag{A.56}$$

From the FOC wrt to investment it follows:

$$Q = 1 \tag{A.57}$$

Given the assumption that:

$$u = 1 \tag{A.58}$$

and:

$$a\left(u\right) = 1 \tag{A.59}$$

it follows from the FOC wrt to the capital stock:

$$r^k = \frac{\beta^{-1} + \delta - 1 - \tau^k \delta}{1 - \tau^k} \tag{A.60}$$

From the FOC wrt to bond holdings it follows that:

$$\frac{1}{\beta} = R \tag{A.61}$$

From the price-setting of firms it follows:

$$MC = \frac{1}{\lambda^p} \tag{A.62}$$

From (11) and recalling that $WL/Y = (1-\alpha)$ and $K^g = \left(G^i/\delta^g Y\right) Y$it follows that:

$$W = \left(\lambda^p \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(r^k\right)^{\alpha}\right)^{\frac{1}{\zeta-(1-\alpha)}} \left(\frac{\delta^g \left(1-\alpha\right)}{\left(G^i/Y\right) L}\right)^{\frac{\zeta}{\zeta-(1-\alpha)}} \tag{A.63}$$

Optimal input factor ratio of firms:

$$K = \frac{\alpha}{1-\alpha}\frac{W}{r^k}L \tag{A.64}$$

From the law of motion for private capital:

$$I = \delta K \tag{A.65}$$

From (11):

$$K^g = \left(\lambda^p \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(r^k\right)^{\alpha} W^{(1-\alpha)}\right)^{\frac{1}{\zeta}} \tag{A.66}$$

The zero profit condition for firms leads to:

$$Y = MCK^{\alpha}L^{1-\alpha}\left(K^g\right)^{\zeta} \tag{A.67}$$

From the production function of firms:

$$\Phi = Y - K^{\alpha}L^{1-\alpha}\left(K^g\right)^{\zeta} \tag{A.68}$$

Making use of the fixed ratios of public expenditures and debt to output:

$$G^c = \frac{G^c}{Y}Y \tag{A.69}$$

$$G^i = \frac{G^i}{Y}Y \tag{A.70}$$

$$TR = \frac{TR}{Y}Y \tag{A.71}$$

$$B = \frac{B}{Y}Y \tag{A.72}$$

Total consumption expenditures equal total income net of taxes, savings and investment expenditures:

$$\left(1+\tau^c\right)C = \left(1-\tau^w\right)WL + TR + \left(1-\tau^k\right)r^kK + \tau^k\delta K - \left(1-\beta^{-1}\right)B - I - LS \tag{A.73}$$

with:

$$LS = \left(\beta^{-1}-1\right)B + G^c + G^i + TR - \tau^cC - \tau^wWL - \tau^kr^kK + \tau^k\delta K \tag{A.74}$$

From the budget constraint of non-Ricardian households and recalling that $TR^{nr} = \frac{TR^o}{\xi} =$

$\frac{TR}{(1-\mu)\xi+\mu}$:

$$(1+\tau^c)\,C^{nr} = (1-\tau^w)\,WL + \frac{TR}{(1-\mu)\,\xi+\mu} \tag{A.75}$$

Consumption of optimizing households is then given by:

$$C^o = \frac{C-\mu C^{nr}}{1-\mu} \tag{A.76}$$

For the scaling parameter it follows from the labor-market equilibrium:

$$\psi_l = (1-\tau^w)\,Kr^k \frac{1-\alpha}{\alpha}\frac{L^{\varphi+1}}{\lambda^w}\frac{((1-h)\,C^o)^{-\sigma}}{1+\tau^c} \tag{A.77}$$

Finally, exports and imports are given by:

$$EX = \frac{1-n}{n}\,(1-\omega^*)\left(\frac{C^{REA}+I^{REA}}{Y^{REA}}\right)Y^{REA}, \tag{A.78}$$

assuming symmetry between home and abroad: $Y^{REA}=Y$ and $\left(C^{REA}+I^{REA}\right)/Y^{REA} = (C+I)\,/Y$, and

$$IM = (1-\omega)\,(C+I) \tag{A.79}$$

D Data and sources

We use a total of 17 time series for estimation. These include domestic series for GDP, private consumption, government consumption, private investment, government investment, transfer payments, wages, hours worked, consumer price inflation, export and import price as well as effective rates on consumption, labor and capital taxes.

Data on real GDP aggregates are taken from the Federal Statistical Office (Destatis). We use quartely, seasonally and working day adjusted series published in the series "Fachserie 18 Reihe 1.3". All series are scaled by the working age population (15-64 years) obtained from Eurostat.

The data series for transfer payments is constructed from quarterly sectoral accounts data on subsidies (D.31 and D.39), social benefits other than social transfers in kind (D. 62), other current transfers (D.75) and capital transfers (D.9) paid to households and NPISH (S.14 and S.15). The series is seasonally adjusted by means of the X-12-ARIMA method, deflated by the GDP deflator obtained from Destatis and scaled by the working age population.

The time series for wages is constructed using seasonally adjusted hourly compensation of employees data from Destatis "Fachserie 18 Reihe 1.3" and deflated by the GDP deflator obtained from Destatis.

We use seasonally adjusted data from Destatis "Fachserie 18 Reihe 1.3" on total hours worked, scaled by the working age population to obtain a series for hours worked.

The time series for consumer, export and import price inflation are obtained by first differencing the logarithm of the respective seasonally and calendar adjusted price index time series by Destatis.

Effective tax rates are constructed following Mendoza et al. (1994). For the consumption tax rate we use data from quarterly sectoral accounts for income from taxes on products (D.21) and divide the series by total consumption expenditures.

For the remaining tax rate we first calculate an effective income tax rate τ_t^i according to the following formula:

$$\tau_t^i = \frac{CTI}{CE - ESSC + PI + NOSMI} \tag{A.80}$$

where we use data from quarterly sectoral accounts of households and NPISH on current taxes on income paid (CTI, D.5), compensation of employees received (CE, D.1), employers social security contributions (ESC, D.12), property income received (PI, D.4) and net operating surplus and mixed income received ($NOSMI$, B.2/3n).

We then calculate the effective labor tax rate according to the following forumla:

$$\tau_t^w = \frac{\tau_t^i(CE - ESSC) + SC}{CE} \tag{A.81}$$

where we use data from quarterly sectoral accounts of the general government on total social contribution received (SC, D.61).

The effective capital tax rate is calculated according to the following formula:

$$\tau_t^k = \frac{(PI + NOSMI - CFC)\tau_t^i + (CTI^g - CTI) + OT^g}{NOSMI^{tot}} \tag{A.82}$$

where we use data from quarterly sectoral accounts of households and NPISH consumption of fixed capital (CFC, P.51), current taxes on income (CTI^g, D.54) and other taxes on production (OT^g, D.29) received by the general government and the net operating surplus and mixed income received ($NOSMI^{tot}$, B.2/3n) of the total economy.

All three effective tax rate series are seasonally adjusted by means of the X-12-ARIMA method.

For the REA variables we use quartely, seasonally and working day adjusted series for nominal GDP, GDP deflators and consumer price indices of Germany and the Euro area provided by Eurostat. We construct a REA GDP deflator and consumer price index on the basis the German and area-wide indices and the German GDP share. We then substract German GDP from the EMU aggregate and deflate nominal REA GDP by the constructed GDP deflator. The series is scaled by working age population in the REA.

For the interest rate we take the 3-month money market rate (EURIBOR), scaled by 400.

All series are linearly detrended prior to estimation.

E Forecast Error Variance Decomposition

	η^{gc}	η^{gi}	η^{tr}	$\eta^{\tau c}$	$\eta^{\tau w}$	$\eta^{\tau k}$	η^{z}	η^{i}	η^{b}	η^{rp}	η^{l}	η^{cph}	η^{cpx}	η^{cpm}	η^{uip}	η^{r}	η^{yrea}	$\eta^{\pi rea}$
y	2.51	0.98	0.35	0.71	0.69	0.43	12.44	5.25	1.41	9.47	15.08	7.81	6.29	10.99	3.01	7.56	12.94	2.09
Δy	4.06	0.54	0.45	0.83	1.30	0.75	4.34	5.15	1.14	23.12	8.26	5.02	4.75	0.79	8.28	9.63	12.41	9.18
c	0.33	1.16	1.20	3.54	0.41	0.17	7.96	8.41	37.61	8.33	5.64	7.20	2.68	8.81	0.51	4.03	1.91	0.10
c^{o}	0.36	1.16	0.03	0.69	0.52	0.09	8.02	9.01	41.92	5.47	8.39	1.99	4.20	8.58	0.68	5.47	3.35	0.06
c^{nr}	0.99	0.23	11.25	11.84	9.46	0.20	3.73	1.64	0.23	5.19	12.42	26.55	1.89	6.76	0.65	0.80	5.18	0.99
i	0.14	0.13	0.03	0.04	0.18	0.08	6.18	51.93	0.08	1.04	5.74	15.02	2.22	11.15	0.86	1.20	3.94	0.04
l	2.50	0.67	0.35	0.71	0.69	0.42	12.66	8.97	1.50	9.20	19.02	4.34	5.94	7.49	3.10	7.79	12.51	2.15
w	0.08	1.23	0.02	0.03	0.02	0.04	8.68	2.05	0.09	1.45	36.18	37.22	0.28	11.75	0.05	0.31	0.49	0.02
tr	0.79	0.27	55.68	0.24	0.24	0.13	3.36	5.22	0.87	2.53	10.25	2.52	2.72	7.15	0.73	3.31	3.78	0.22
π	1.30	0.11	0.35	0.57	1.12	0.82	5.14	0.87	0.80	9.44	12.61	30.23	1.02	26.96	1.11	6.54	0.86	0.15
r	0.27	0.02	0.08	0.12	0.33	0.19	0.41	0.16	0.25	1.59	0.62	2.69	0.28	1.71	0.09	82.24	7.12	1.82

Table A.1: Forecast error variance decomposition at the parameter posterior means (in percent).

Halle Institute for Economic Research –
Member of the Leibniz Association

Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany

Postal Adress: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60
Fax +49 345 7753 820

www.iwh-halle.de

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