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German and the rest of euro area fiscal policy during the crisis

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Non-technical summary

Research Question

Because of the global financial crisis governments around the world have put in place ambitious fiscal stimulus packages more or less starting in 2008. Many of those ambitions, however, forced fiscal authorities to start consolidating shortly after stimulating the economy to ensure stability of public finances. Countries in the European Monetary Union (EMU) suffered noticeably in the crisis in terms of dampened GDP growth. Fiscal policy is said by many to have had a positive effect on GDP growth at the onset of the crisis but a negative contribution to it thereafter. This article quantifies the role of fiscal policy for GDP developments in the EMU.

Contribution

We present the estimated large-scale three-region DSGE model *GEAR* of ***G***ermany, the ***E***uro ***A***rea and the ***R***est of the world. Compared to existing models of this type, *GEAR* incorporates a comprehensive fiscal block, involuntary unemployment and a complex international structure. Employing historical shock decompositions and impulse response functions, we assess the impact of discretionary fiscal policy on GDP growth and the size of potential spillovers between Germany and the rest of the Euro Area during the global financial crisis. We also calculate the size of present-value multipliers for distinct fiscal instruments.

Results

Our analysis suggests that spillovers of fiscal policy shocks in the Euro Area are relatively small. Overall, spending multipliers are higher than revenue-based multipliers and are in line with those found in the literature. We find that, during the global financial crisis, fiscal stimulus packages increased quarter-on-quarter GDP growth substantially, both in Germany and in the rest of the Euro Area. The main drivers of GDP growth in Europe, however, were rest of the world and uncovered interest rate parity shocks, followed by domestic non-fiscal shocks.

Nichttechnische Zusammenfassung

Fragestellung

Im Zuge der Finanzkrise haben Regierungen weltweit, beginnend etwa in 2008, ambitionierte fiskalische Stimulusprogramme auf den Weg gebracht. In der Folge mussten viele Staaten allerdings relativ rasch begleitende Konsolidierungsmaßnahmen einleiten. Die Mitgliedsländer der Europäischen Währungsunion (EWU) haben im Hinblick auf niedriges BIP-Wachstum spürbar unter der Krise gelitten, wobei der expansiven Fiskalpolitik zu Beginn der Krise vielfach ein positiver Effekt zugesprochen wird, im Verlauf allerdings mit deutlich negativen Auswirkungen. Diese Arbeit quantifiziert den Beitrag der Fiskalpolitik in der globalen Finanzkrise auf die BIP-Entwicklungen in Deutschland und der EWU.

Beitrag

Für die Analyse entwickeln und schätzen wir ein großes DSGE-Modell mit drei Regionen – Deutschland, restliches Euro-Gebiet und Rest der Welt (kurz: *GEAR*, ***G***ermany, the ***E***uro ***A***rea and the ***R***est oft he world). Verglichen mit anderen Modellen dieses Typs ist *GEAR* durch einen ausgereiften Fiskalblock, unfreiwillige Arbeitslosigkeit und eine komplexe internationale Struktur gekennzeichnet. Mittels historischer Schockzerlegungen und Impuls-Antwort-Funktionen messen wir den Beitrag diskretionärer Fiskalpolitik während der globalen Finanzkrise, insbesondere auch die Überwälzungseffekte zwischen Deutschland und dem restlichen Euro-Gebiet. Außerdem berechnen wir die Multiplikatoren unterschiedlicher fiskalpolitischer Maßnahmen.

Ergebnisse

Heimische Fiskalschocks übertragen sich nur in relativ begrenztem Umfang auf die jeweils anderen Regionen. Insgesamt sind Multiplikatoren ausgabenseitiger Fiskalschocks (jeweils im In- und Ausland) größer als die einnahmenseitiger Schocks. Alle Multiplikatoren sind im Einklang mit der bestehenden Literatur. Während der globalen Finanzkrise hatten fiskalische Stimulusprogramme einen beträchtlich positiven Effekt auf das BIP-Wachstum in Deutschland und der EWU, gleiches gilt aber auch – mit anderen Vorzeichen – für die Konsolidierungsmaßnahmen. Dennoch wurde das BIP-Wachstum hauptsächlich von nicht-fiskalischen Schocks getrieben, dabei waren Schocks aus dem Rest der Welt und Zinsparitätsschocks, gefolgt von heimischen nicht-fiskalischen Schocks die stärksten Faktoren.

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Abstract

We present the estimated large-scale three-region DSGE model *GEAR* picturing ***G****ermany*, the ***E****uro* ***A****rea* and the ***R****est* of the world. Compared to existing models of this type, *GEAR* incorporates a comprehensive fiscal block, involuntary unemployment and a complex international structure. We use the model to evaluate spillovers of fiscal policy, to calculate various present-value multipliers for distinct fiscal instruments, and to assess how *discretionary* fiscal policy in Germany and the Euro Area affected GDP growth during the global financial crisis. Our analysis suggests that spillovers of fiscal policy shocks in the Euro Area are small. Overall, spending multipliers are higher than revenue-based multipliers and are in line with those found in the literature. We find that, during the crisis, fiscal stimulus packages increased annualized quarter-on-quarter GDP growth substantially, both in Germany and in the rest of the Euro Area. The main drivers of GDP growth in Europe, however, were rest of the world and uncovered interest rate parity shocks, followed by domestic non-fiscal shocks.

Keywords: Fiscal Policy, Unemployment, DSGE modeling, Bayesian estimation

JEL classification: H2, J6, E32, E62.

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1 Introduction

Because of the global financial crisis governments around the world have put in place ambitious fiscal stimulus packages more or less starting in 2008. Many of those ambitions, however, forced fiscal authorities to start consolidating shortly after stimulating the economy to ensure stability of public finances. Countries in the European Monetary Union (henceforth EMU or Euro Area) suffered noticeably in the crisis in terms of dampened GDP growth. Fiscal policy is said by many to have had a positive effect on GDP growth at the onset of the crisis but a negative contribution to it thereafter.[1] To quantify the role of fiscal policy for GDP developments in the EMU, we present a large-scale dynamic stochastic general equilibrium (DSGE) model with three regions in which two of them form a monetary union.

The model we use in this paper is an estimated three-region DSGE model of ***G***ermany, the rest of the ***E***uro ***A***rea and the ***R***est of the world, *GEAR* in short.[2] Employing historical shock decompositions and impulse response functions, we assess the impact of discretionary fiscal policy on GDP growth and the size of potential spillovers between Germany and the rest of the Euro Area during the global financial crisis. We also calculate the size of present-value multipliers for distinct fiscal instruments. The core of our model comprises the well-known DSGE models of Smets and Wouters (2003, 2007) and Christiano et al. (2005), which we extend substantially, however, in three directions: we increase the number of regions to three, all of them linked by trade and asset flows and, for the EMU countries, a common monetary policy; we include involuntary unemployment along the lines of Galí (2010) and Galí et al. (2011); and we introduce an extensive fiscal block that interacts in various ways with the real economy along the lines of Stähler and Thomas (2012). Fiscal authorities can use lump-sum taxes and taxes on consumption, labor income, and returns on physical capital holdings as well as social security contributions on the employer's side to generate revenues. Further, they can issue public debt. Expenditures include interest payments on outstanding debt, public purchases, public investment, transfers and payments for public employees as well as unemployment benefits. The public capital stock and public employment have a positive impact on private sector productivity as in Leeper et al. (2009, 2010) and Pappa (2009).

To estimate the model we construct a large innovative data set for Germany, the rest of the Euro Area (an aggregate of the countries Austria, Belgium, Finland, France, Italy, the Netherlands, Portugal and Spain) and the rest of the world (an aggregate of Brazil, Canada, China, India, Japan, Russia, the United Kingdom, and the United States). The innovation comes in, first, by splitting Euro Area data into two blocks[3] and, second, by constructing a rich set of quarterly fiscal variables (19 out of 40 series are fiscal).

We find that, in terms of *annualized* quarter-on-quarter growth rates, stimulus pro-

[1]For a recent overview of the current debate, including a discussion on fiscal multipliers, see Deutsche Bundesbank (2014) and ECB (2014).

[2]An earlier DSGE model for Germany within the Euro Area can be found in Pytlarczyk (2005). Our model supplements this work by an increased number of regions and trade flows as well as a more complex fiscal and labor market structure; and it is estimated with an up-to-date and innovative data set.

[3]While we focus on Germany as individual country here, one could easily modify our data set to define different composites of Euro Area blocks.

grams positively affected the growth of domestic GDP by 1.2 percentage points (pp) in Germany and 0.12 pp in the rest of the Euro Area during the global financial crisis, while consolidation measures had a negative impact of −0.8 pp in Germany and −1.2 pp in the rest of the Euro Area. The main drivers for the evolution of GDP were rest of the world and uncovered interest rate parity shocks, followed by domestic non-fiscal shocks, amongst them, the technology shock being the most important one. Impulse response functions show negligibly small country spillovers of fiscal shocks from Germany to the rest of the Euro Area and vice versa.

Fiscal policy analysis within DSGE models has become popular recently. Without completeness, Galí and Monacelli (2008) analyze optimal fiscal and monetary policy in a currency union, Coenen et al. (2008) analyze structural tax reforms, Colciago et al. (2008) assess the role of automatic stabilizers, Forni et al. (2009) analyze the importance of fiscal policy shocks for the evolution of macroeconomic aggregates, Christiano et al. (2011) and Cogan et al. (2010) analyze fiscal multipliers, whereas Hebous (2011) provides an overview of the effects of fiscal policy stimulus in structural models. Freedman et al. (2009) and Stähler and Thomas (2012) address short-run costs and long-run benefits of fiscal consolidation and Corsetti et al. (2013) assess the interactions between sovereign risk, fiscal policy and macroeconomic stability.

The studies most closely related to ours are those by Coenen et al. (2012, 2013). They use the fiscal extension of the European Central Bank's New Area-Wide Model (NAWM; see Christoffel et al., 2008) to quantify the impact of fiscal policy on the Euro Area growth rate during the global financial crisis and to calculate the present-value multipliers of distinct fiscal instruments. Our model supplements their analysis in two directions. First, we have a richer fiscal environment, involuntary unemployment and a richer feedback of fiscal policy on the real side through several channels. Second, we are able to disentangle the effects of country-specific fiscal policy and the corresponding spillovers. Thereby, our paper also adds to the literature on fiscal spillovers in the Euro Area. Some papers find empirical evidence or have provided theoretical arguments for noticeable spillovers. Hebous and Zimmermann (2013) use a global vector autoregression (GVAR) model and find evidence for positive spillover effects of fiscal policy. In a two-country real business cycle model, Corsetti et al. (2010) show that a fiscal stimulus with "spending reversals" (ie using future spending cuts to finance the current stimulus) generates positive cross-border fiscal spillovers. Veld (2013) finds that spillovers of fiscal consolidations can be sizeable in the Euro Area based on the traditional structural multi-country QUEST-model used by the European Commission (see Ratto et al., 2009, for a description of the model). On the contrary, Cwik and Wieland (2011) and ECB (2014), both using different traditional structural multi-country models (the ECB uses their New Multi-Country Model based on Dieppe et al., 2011), find that fiscal spillover effects are negligible or even negative. Our analysis supports this latter view.

The rest of the paper is organized as follows. Section 2 describes *GEAR* in detail. Section 3 presents the data, outlines the Bayesian estimation procedure, and explains our calibration and prior choices. Section 4 discusses the main results and illustrates the various transmission mechanisms of *GEAR*. Section 5 concludes.

2 The model

In this section, we will provide an overview of *GEAR* describing preferences, technologies and the behavior of economic agents. Most derivations and first-order conditions are relegated to a detailed equation summary which is available upon request.

From a bird's eye perspective, *GEAR* consists of three regions: **G**ermany, the **E**uro **A**rea (without Germany) and the **R**est of the world. Each region is inhabited by four types of agents: households, firms, a fiscal authority and a monetary authority. Within the Euro Area there is per definition only one common monetary policy.

Households make optimal choices regarding savings in physical capital, which is rented out to private firms, as well as national and international (financial) assets and purchases of consumption goods. Household members also decide whether or not to participate in the labor market. Those who participate may find a job in the private or in the public sector or stay unemployed. Hence, households receive interest and wage payments, unemployment benefits and other fiscal transfers, and they pay taxes. In line with Galí et al. (2007), we also assume that a fraction of households does not participate in asset markets and consumes the entire income each period. Those households have become known as "rule-of-thumb" (RoT) households in the literature; we shall call the other type of households "optimizers".[4] Furthermore, households enjoy some monopoly power on the labor market because different types of labor are needed in production, and these are not perfectly substitutable. Wages are set by a union which takes into account both types of households.

On the production side, monopolistic competitors in each region produce a variety of differentiated products and sell these to the home and foreign market. We assume that there is no price discrimination between markets. Firms use labor and private capital as production inputs. Public employment and the public capital stock can be productivity-enhancing. However, the provision of these inputs is outside the control of firms and conducted by the fiscal authority. Cost minimization determines the amount of labor and capital input demanded by each firm. Because firms enjoy monopolistic power, they are able to set their nominal price. For both, wage and price setting, we assume the existence of Rotemberg adjustment costs (see Ascari et al., 2011, and Ascari and Rossi, 2011, for a discussion).

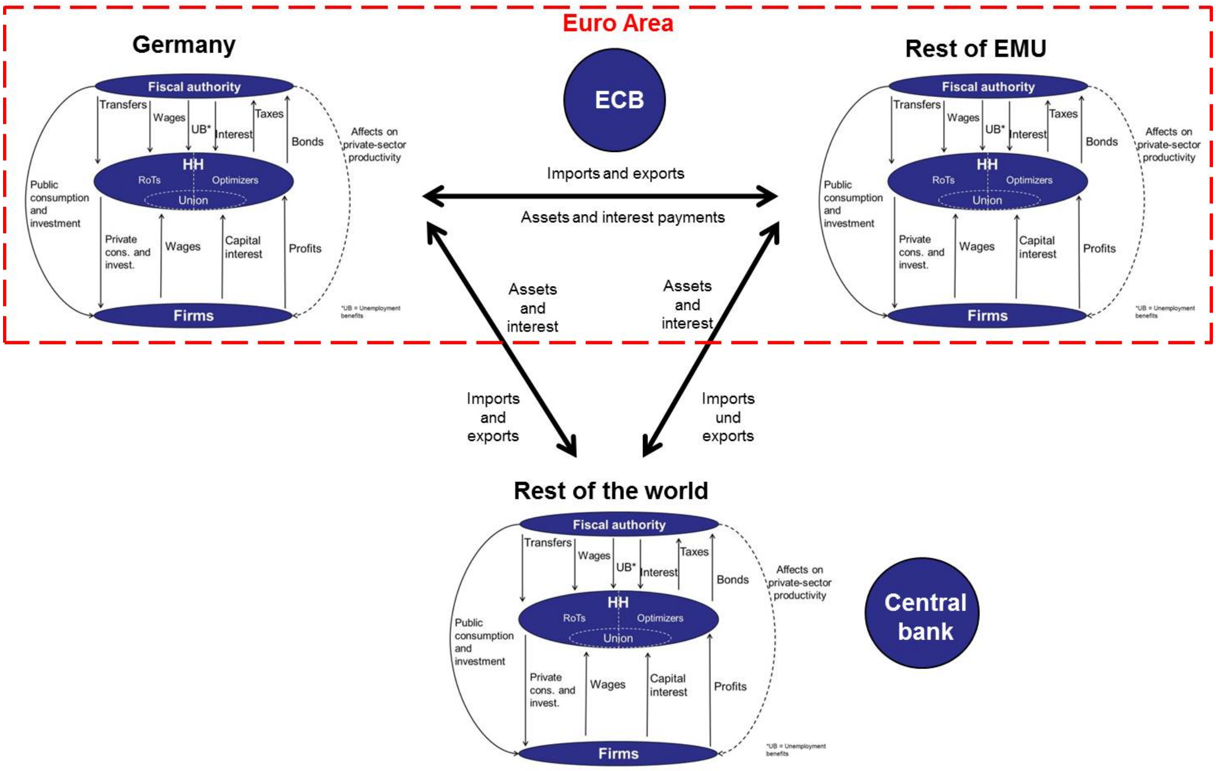
The fiscal authority purchases consumption and investment goods produced in the private sector. The latter increases the public capital stock which may, in turn, improve private-sector productivity (for example, because of better infrastructure). The government also employs public-sector workers for whom it has to pay wages. Services provided by these public-sector workers may also affect private-sector productivity positively (for example, because of better governance). Introducing immediate positive spillovers from the public to the private sector follows the idea of Pappa (2009) and Leeper et al. (2009, 2010); see also D'Auria (2015) for a discussion. Furthermore, the fis-

[4] The empirical literature based on vector-autoregressive (VAR) models has shown that a (persistent) increase in government spending leads to a positive reaction of private consumption, at least on impact (see, among others, Blanchard and Perotti, 2002, Fatás and Mihov, 2001). The standard real business cycle or New Keynesian model does not recover this finding, which has become known as the "consumption puzzle" in the literature. To reconcile these findings, Galí et al. (2007) were the first to include the above mentioned "rule-of-thumb" households into such models.

cal authority pays unemployment benefits and other transfers to private households. It also has to pay interest on outstanding debt. Fiscal authorities finance themselves with distortionary taxes on private consumption, on labor income and on capital returns, lump-sum taxes as well as social security contributions paid by firms. They can also issue new debt. The monetary authority sets the nominal reference interest rates. In the Euro Area, it sets a common rate according to a Taylor-type rule that responds to measured area-wide inflation and the output gap. In this paper, we use a version of the model in which the rest of the world is reduced to a three-equation VAR process (output, inflation and interest rate) as in Christiano et al. (2011) because modeling the third region in detail does not add very much to the current analysis, while it keeps the estimation more tractable.

Figure 1 graphically illustrates the working and the flows of our model. In what follows, we will index each region by $i = a, b, c$. Both EMU regions are assumed to be identical in terms of their economic structure, but they differ in terms of size and parameter values. Without loss of generality, we index country-a agents in the interval $[0, 1]$, country-b agents in $[0, \mathcal{P}^b]$ and country-c agents in $[0, \mathcal{P}^c]$. Hence, $\mathcal{P}^j$, with $j = b, c$, is the size of country j relative to country a.

Figure 1: Model overview



2.1 Firms and production

We will continue by presenting the necessary equations for country a. Those for the region b are analogous and can be found in the equation summary. We assume that, in each country, there is a measure-$\mathcal{P}^i$ continuum of firms in the final goods sector (equal to one for country a). Firms are owned by optimizing households. Each final goods producer purchases a variety of differentiated intermediate goods, bundles these and sells them to the final consumer under perfect competition. The producer price index (PPI) of goods produced in country i and sold in j is defined as $P_t^{i,j}$. We assume that the law of one price holds across regions, so firms in country a set their price $P_t^{a,a}$ for all markets. Multiplying with the nominal exchange rate, then, yields the price of country-a goods charged in the other countries, ie $P_t^{b,a} = S_t^{b,a} P_t^{a,a}$ and $P_t^{c,a} = S_t^{c,a} P_t^{a,a}$, where the nominal exchange rate $S_t^{j,a}$ is defined as country j currency per unit of country-a currency. Clearly, $S_t^{j,a}$ is one within the monetary union (ie, for the Euro Area, $S_t^{b,a} = S_t^{a,b} = 1 \ \forall \ t$). The maximization problem of the representative final goods firm reads

$$\max_{\{\tilde{y}_t^a(z):z\in[0,1]\}} P_t^{a,a} Y_t^a - \int_0^1 P_t^{a,a}(z)\tilde{y}_t^a(z)dz, \tag{1}$$

where $Y_t^a = \left(\int_0^1 \tilde{y}_t^a(z)^{(\theta_{a,t}-1)/\theta_{a,t}}dz\right)^{\theta_{a,t}/(\theta_{a,t}-1)}$ is the production function, $\tilde{y}_t^a(z)$ his demand for each differentiated input good z and $P_t^{a,a}(z)$ the price of each input. $\theta_{a,t}$ is the time-varying elasticity of substitution between differentiated goods and follows a process $\theta_{at}/\left(\theta_{at}-1\right) = \rho_{\theta_a}\theta_{at-1}/\left(\theta_{at-1}-1\right) + \left(1-\rho_{\theta_a}\right)\bar{\theta}_a/\left(\bar{\theta}_a-1\right) + \nu_t^{\theta_a}$, where $\nu_t^{\theta_a}$ is an i.i.d. shock with mean zero and variance σ^{θ_a}. It can be interpreted as a price markup shock. The first-order condition of the maximization problem yields $\tilde{y}_t^a(z) = \left(P_t^{a,a}(z)/P_t^{a,a}\right)^{-\theta_{a,t}} Y_t^a$, which implies that the PPI of country a is given by $P_t^{a,a} = \left(\int_0^1 P_t^{a,a}(z)^{1-\theta_{a,t}}dz\right)^{1/(1-\theta_{a,t})}$.

Private intermediate goods firms on the continuum $z \in [0,1]$ operate as monopolistic competitors in the product market. Each firm produces its intermediate good variety with the following Cobb-Douglas production function

$$y_t^a(z) = e^{\epsilon_t^{A_a}} e^{\epsilon_t^{A_g}} \left(\zeta_a \left(K_t^{G,a}\right)^{\eta^{K^G,a}} \left(N_t^{G,a}\right)^{\eta^{N^G,a}}\right) \left[K_{t-1}^a(z)\right]^{\alpha_a} \left[N_t^{P,a}(z)\right]^{1-\alpha_a} - \Omega_a, \tag{2}$$

where $\epsilon_t^{A_a}$ is an AR(1) productivity shock process, identical across firms in country a, $\epsilon_t^{A_g}$ is an analogous shock on global productivity, identical across firms in all regions, and Ω_a is a fixed cost yielding steady-state profits to be zero. The parameter $0 < \alpha_a < 1$ gives the share of private capital, K_t^a, in production. $N_t^{P,a}$ denotes private-sector employment.

Many DSGE models ignore that government actions directly affect the private sector. However, it is very likely – and probably nobody would abandon this idea entirely – that the public capital stock, $K_t^{G,a}$, and at least the majority of public employees, $N_t^{G,a}$, have an effect on private-sector productivity due to, for example, better infrastructure, efficient governance, education and so on. As we are not able to capture all possible channels through which the government could affect private-sector productivity in a tractable way, we apply the short cut of D'Auria (2015), Leeper et al. (2009, 2010), and Pappa (2009). They assume that public investment and public employment, both provided by the government, affect private-sector productivity as stated in equation (2): $\eta^{K^G,a}$ determines the relevance of public capital in the private-sector productivity function and $\eta^{N^G,a}$ the relevance of public employment (for $\eta^{K^G,a} = \eta^{N^G,a} = 0$, there is no effect), while $\zeta_a > 0$ is a scaling parameter. They are both outside the influence of firms.

With $r^a_{k,t}$ being the consumer price index (CPI)-deflated rental rate of capital and $(1 + \tau^{sc,a}_t)\ w^a_t$ being gross labor costs, including CPI-deflated private-sector wages, w^a_t, and the firms' social security contributions at rate $\tau^{sc,a}_t$, firm z's cost minimization problem yields the following capital-to-labor ratio

$$\frac{r^a_{k,t}}{w^a_t\ (1+\tau^{sc,a}_t)} = \frac{N^{P,a}_t(z)}{K^a_{t-1}(z)} \cdot \frac{\alpha_a}{1-\alpha_a}, \tag{3}$$

which is common to all firms. Real CPI-deflated marginal costs are hence given by

$$mc^a_t = \frac{\left(r^a_{k,t}\right)^{\alpha_a}\ \left(w^a_t\ (1+\tau^{sc,a}_t)\right)^{1-\alpha_a}}{e^{\epsilon^{A_a}_t}\ e^{\epsilon^{A_g}_t}\ \left(\zeta_a\ \left(K^{G,a}_t\right)^{\eta^{K^G,a}}\ \left(N^{G,a}_t\right)^{\eta^{N^G,a}}\right)\ \alpha_a^{\alpha_a}\ (1-\alpha_a)^{1-\alpha_a}} \tag{4}$$

and are also common across firms. We will derive the CPI, P^a_t, in more detail in the next section. Each intermediate goods producer sets its own price $P^{a,a}_t(z)$ to maximize intertemporal profits: the difference between revenues and production as well as Rotemberg price adjustment costs, the latter indicated by a cost parameter γ_a. The maximization problem in CPI-terms can be stated as

$$\begin{aligned} \max_{\{P^{a,a}_{t+s}(z):z\in[0,1]\}} \quad & E_t \sum_{s=0}^{\infty} \beta_a^s \frac{\lambda^a_{o,t+s}}{\lambda^a_{o,t}} \Bigg[\left(\frac{P^{a,a}_{t+s}(z)}{P^a_{t+s}} - mc^a_{t+s}\right) y^a_{t+s}(z) \\ & - \underbrace{\frac{\gamma_a}{2}\left(\frac{P^{a,a}_{t+s}(z)}{(\pi^{a,a}{}_{t+s-1})^{\xi_a}\ (\bar{\pi}^{a,a})^{1-\xi_a}\ P^{a,a}_{t+s-1}(z)} - 1\right)^2 \frac{P^{a,a}_{t+s}}{P^a_{t+s}}\, Y^a_{t+s}}_{=adj^{P,a}_t} \Bigg], \end{aligned} \tag{5}$$

subject to $y^a_t(z) = \tilde{y}^a_t(z) = (P^{a,a}_t(z)/P^{a,a}_t)^{-\theta_a}\ Y^a_t$. The parameter $\xi_a \in [0,1]$ determines the magnitude of price indexation on past inflation, $\pi^{a,a}{}_{t-1}$, or steady-state inflation, $\bar{\pi}^{a,a}$ (see Ascari et al. 2011). Because optimizers own firms the intertemporal discount factor of a firm includes only the marginal utility of optimizing households, $\lambda^a_{o,t}$, determined below.

2.2 Households, consumption, and savings

As already mentioned, we assume that each region is populated by two types of representative households: optimizing and non-Ricardian "rule-of-thumb" (RoT) households, indexed by $x = o, r$ for optimizers and RoTs. They differ in that RoTs do neither save nor borrow but consume all their labor income each period (see Galí et al., 2007). RoT households make up a share $\mu^a \in [0,1)$ of total population, while the remaining share $(1-\mu^a)$ behaves in a Ricardian way. As in Galí et al. (2011), household members are represented by the unit square and indexed by a pair $(\mathfrak{h}_x, \mathfrak{j}_x) \in [0,1] \times [0,1]$. Household members differ in the type of labor service they are specialized in, $\mathfrak{h}_x \in [0,1]$, and by their personal disutility of work, $\mathfrak{j}_x \in [0,1]$. The latter is given by $\kappa_a^w \cdot e^{\epsilon_t^{N_a}} \cdot \mathfrak{j}_x^{\varphi_a}$ if employed and zero otherwise. $\kappa_a^w > 0$ is an exogenous labor disutility scaling parameter and $\epsilon_t^{N_a}$ is an AR(1) labor disutility shock process. $\varphi_a > 0$ determines the shape of the distribution of work disutilities across individual household members. Values not indexed by x are common across household types. Assuming that the utility of household members positively depends on consumption and that there is full risk sharing of consumption within a household as in Merz (1995) or Andolfatto (1996), the utility of household-type x can be written as

$$
\begin{aligned}
& E_t \sum_{s=0}^{\infty} \beta_a^s U\left(C_{x,t+s}^a, N_{x,t+s}^a\left(\mathfrak{h}_x\right)\right) \\
= \quad & E_t \sum_{s=0}^{\infty} \beta_a^s e^{\epsilon_{t+s}^{\beta_a}} \left[\frac{\left(C_{x,t+s}^a - h_a \bar{C}_{x,t+s-1}^a\right)^{1-\sigma_a} - 1}{1-\sigma_a} - \kappa_a^w e^{\epsilon_{t+s}^{N_a}} \int_0^1 \int_0^{N_{x,t+s}^a(\mathfrak{h}_x)} \mathfrak{j}_x^{\varphi_a} d\mathfrak{j} d\mathfrak{h}_x \right] \quad (6) \\
= \quad & E_t \sum_{s=0}^{\infty} \beta_a^s e^{\epsilon_{t+s}^{\beta_a}} \left[\frac{\left(C_{x,t+s}^a - h_a \bar{C}_{x,t+s-1}^a\right)^{1-\sigma_a} - 1}{1-\sigma_a} - \kappa_a^w e^{\epsilon_{t+s}^{N_a}} \int_0^1 \frac{N_{x,t+s}^a\left(\mathfrak{h}_x\right)^{1+\varphi_a}}{1+\varphi_a} d\mathfrak{h}_x \right],
\end{aligned}
$$

where $0 < \beta_a < 1$ is a subjective discount factor, $\epsilon_t^{\beta_a}$ depicts an AR(1) preference shock process, $C_{x,t}^a$ is household type x-specific private consumption, and $h_a \in [0,1]$ is an external habit persistence parameter based on type-specific aggregate consumption of the previous period, $\bar{C}_{x,t-1}^a$. σ_a governs the elasticity of intertemporal substitution. $N_{x,t}^a(\mathfrak{h}_x) \in [0,1]$ denotes the household type x-specific employment rate in period t among workers specialized in labor-type $\mathfrak{h}_x$. Consumption of private goods, $C_{x,t}^a$, is a composite of goods produced at home and abroad. In country a, household type-x consumption aggregator is given by

$$
C_{x,t}^a = \left[\left(n_a^a\right)^{\frac{1}{\eta_a}} \left(C_{x,t}^{a,a}\right)^{\frac{\eta_a-1}{\eta_a}} + \left(n_b^a \cdot e^{\epsilon_t^{b,a}}\right)^{\frac{1}{\eta_a}} \left(C_{x,t}^{a,b}\right)^{\frac{\eta_a-1}{\eta_a}} + \left(n_c^a\right)^{\frac{1}{\eta_a}} \left(C_{x,t}^{a,c}\right)^{\frac{\eta_a-1}{\eta_a}} \right]^{\frac{\eta_a}{\eta_a-1}}, \quad (7)
$$

where n_i^a, with $i = a, b, c$, are the weights of goods in the consumption bundle according to their origin, implying $n_a^a + n_b^a + n_c^a = 1$, and η_a is the elasticity of substitution between these goods (note that η_a is assumed to be the same across countries). $\epsilon_t^{b,a}$ is an

AR(1) trade preference shock process and $C_{x,t}^{i,j}$, with $i, j = a, b, c$, is a good consumed by households of type x in region i which is produced in region j. The weights n_i^a depend on relative country size $\mathcal{P}^i$ and an index of trade openness between country i and j, ϑ_j^i. For country a, we get

$$n_a^a = 1 - \frac{\vartheta_c^a \mathcal{P}^c + \vartheta_b^a \mathcal{P}^b}{1 + \mathcal{P}^b + \mathcal{P}^c},\ n_b^a = \frac{\vartheta_b^a \mathcal{P}^b}{1 + \mathcal{P}^b + \mathcal{P}^c},\ n_c^a = \frac{\vartheta_c^a \mathcal{P}^c}{1 + \mathcal{P}^b + \mathcal{P}^c}.$$

We assume that it holds that $\vartheta_j^i = \vartheta_i^j$ for all $i, j = a, b, c$. For $\vartheta_j^i < 1$, there exists a home bias in consumption such that households prefer goods produced in domestic firms.

To derive the CPI of country a, P_t^a, we note that total spending on consumption goods must obey $P_t^a\, C_{x,t}^a = P_t^{a,a} C_{x,t}^{a,a} + P_t^{a,b} C_{x,t}^{a,b} + P_t^{a,c} C_{x,t}^{a,c}$, where $P_t^{i,j}$ is the PPI described in the previous section.

Nominal consumption expenditures of RoT households amount to $(1 + \tau_t^{c,a})\ P_t^a\, C_{r,t}^a$, where $\tau_t^{c,a}$ is the consumption tax rate. Income of RoTs is given by net wage income from employment in the private and the public sector, $N_t^{P,a}$ and $N_t^{G,a}$, paying nominal gross wages W_t^a and $W_t^{G,a}$ which are both taxed by the rate $\tau_t^{w,a}$. Note that neither employment nor wages are indexed by x as we assume that wage bargaining and employment distribution are undertaken by a union and the government, who both distribute labor and wages uniformly across household types (explained in more detail in the next sections). Unemployed household members receive nominal unemployment benefits $P_t^a \cdot UB^a$. Those members who decided to participate in the labor market, $L_{r,t}^a$, but who did not find a job are unemployed, ie $U_{r,t}^a = L_{r,t}^a - N_t^a$. Here, it is important to note that, while employment rates and wages are independent of the household type, the number of household members participating in the labor market can differ across types. Furthermore, households receive a type-specific lump-sum transfer $P_t^a \cdot TR_{r,t}^a$. Taken together, and noting that RoTs spend their entire income each period, their budget constraint becomes

$$\begin{aligned} & (1 + \tau_t^{c,a})\ P_t^a\, C_{r,t}^a \\ = \ & (1 - \tau_t^{w,a})\ \left(W_t^a\, N_t^{P,a} + W_t^{G,a}\, N_t^{G,a}\right) + P_t^a\, UB^a\ \left(L_{r,t}^a - N_t^a\right) + P_t^a\, TR_{r,t}^a. \end{aligned} \tag{8}$$

When dividing equation (8) by P_t^a, we get the budget constraint in real CPI-terms, where $w_t^a = W_t^a / P_t^a$ and $w_t^{G,a} = W_t^{G,a} / P_t^a$ are real wages. Analogously, the budget constraint for optimizing households – in real terms – is given by

$$
\begin{aligned}
& (1+\tau_t^{c,a})\; C_{o,t}^a + I_{o,t}^a + B_{o,t}^{a,a} + \sum_{j=b,c} S_t^{a,j}\, B_{o,t}^{a,j} + B_{o,t}^{G,a} \\
= \;& (1-\tau_t^{w,a})\; \left(w_t^a\, N_t^{P,a} + w_t^{G,a}\, N_t^{G,a}\right) + UB^a\; \left(L_{o,t}^a - N_t^a\right) \\
+ \;& TR_{o,t}^a + \frac{(1+i_{t-1}^a)\; e^{\epsilon_{t-1}^{RP,EA}}}{\pi_t^a} B_{o,t-1}^{a,a} + \frac{\left(1+i_{t-1}^{a,b}\right)\; e^{\epsilon_{t-1}^{RP,EA}}}{\pi_t^a} B_{o,t-1}^{a,b} \\
+ \;& S_t^{a,c}\, \frac{(1+i_{t-1}^{a,c})\; e^{\epsilon_{t-1}^{RP,RoW}}}{\pi_t^a} B_{o,t-1}^{a,c} \\
+ \;& \frac{\left(1+i_{t-1}^{G,a}\right)}{\pi_t^a} B_{o,t-1}^{G,a} + \left(1-\tau_t^{k,a}\right)\; r_{k,t}^a\, u_t^a\, k_{o,t-1}^a + \tau_t^{k,a}\, \delta_a\, k_{o,t-1}^a + D_{o,t}^a - T_{o,t}^a,
\end{aligned}
\tag{9}
$$

where we have to take into account that optimizers save and borrow. $B_{o,t}^{i,j}$ are private bonds purchased in country i issued by country j, $B_t^{G,a}$ is a government bond issued by the fiscal authority in country a, which is held by domestic households only, and $I_{o,t}^a$ are purchases of investment goods, which is an aggregator analog to private consumption (see equation (7) above). $\pi_t^a = P_t^a / P_{t-1}^a$ is CPI inflation. In addition to the wage and transfer income of RoTs, optimizers also receive interest on their bond holdings, at rates $i_t^{a,j}$ for private and $i_t^{G,a}$ for government bonds. Furthermore, optimizers receive a return, $r_{k,t}^a$, on their capital, $k_{o,t}^a$ and pay lump-sum taxes $T_{o,t}^a$. Capital depreciates at rate δ_a and the government taxes capital gains net of depriciation at rate $\tau_t^{k,a}$. $D_{o,t}^a$ are the profits of firms and $e^{\epsilon_t^{RP,EA}}$ and $e^{\epsilon_t^{RP,RoW}}$ are exogenous "risk premium" shock processes for the Euro Area as a whole and for the rest of the world similar to Christoffel et al. (2008) and Coenen et al. (2013). They can also be interpreted as uncovered interest rate parity (UIP) shocks reflecting the degree of divergence between countries (or regions) in line with Rabanal and Tuesta (2010). The law-of-motion for capital is given by

$$
k_{o,t}^a = (1-\delta_a)\, k_{o,t-1}^a + \left(I_{o,t}^a - I_{o,t}^a \frac{\psi_a^i}{2} \left(\frac{I_{o,t}^a}{I_{o,t-1}^a} - 1 \right)^2 \right) e^{\epsilon_t^{I_a}} \tag{10}
$$

which states that today's capital stock equals yesterday's capital stock net of depreciation plus new investments net of investment adjustment costs, $\psi_a^i/2 \left(I_{o,t}^a / I_{o,t-1}^a - 1\right)^2$, and $\epsilon_t^{I_a}$ is an exogenous AR(1) investment technology shock process. The parameter ψ_a^i determines the costs of investment adjustment.[5]

By maximizing equation (6) subject to (9) and (10), we can now derive the Euler equations of optimizers with respect to private and public bond holdings, physical capital investments as well as their marginal utility of consumption. The first-order conditions for RoT households follow from (6) and (8). We relegate all this to the

[5]Investment adjustment costs have become standard in estimated DSGE models, see Christiano et al. (2005, 2011) for a discussion.

appendix. Note further that any household-type specific variable X_t^x can be aggregated as $X_t = (1-\mu^a)\, X_t^o + \mu^a\, X_t^r$ when concerned with both household types, and as $X_t = (1-\mu^a)\, X_t^o$ when exclusively concerned with optimizing households.

2.3 Labor supply, labor demand, and wage setting

Turning to labor demand, we have to differentiate between private and public sector demand. As in Forni et al. (2009), we assume that labor demand in both sectors gets uniformly allocated among household types and that public sector labor demand, $N_t^{G,a}$, and wages, $w_t^{G,a}$, follow exogenous autoregressive processes described in equations (17) and (18) below. Consistent with OECD data we assume that, in steady state, public sector wages include a markup, mg^a, on private sector wages. In the private sector, a perfectly competitive agency buys the differentiated individual labor services supplied by households, transforms them into a homogenous composite of labor input, $N_t^{P,a}$, and sells that to intermediate goods producers. Hence, labor agencies solve for each variety of labor service, $\mathfrak{h}$,

$$\max_{N_t^{P,a}(\mathfrak{h}):\mathfrak{h}\in[0,1]} N_t^{P,a} = \left(\int_0^1 \left(N_t^{P,a}(\mathfrak{h})\right)^{(\theta_{a,t}^w-1)/\theta_{a,t}^w} d\mathfrak{h}\right)^{\theta_{a,t}^w/(\theta_{a,t}^w-1)}$$

subject to a given level of the wage bill $\int_0^1 W_t^a(\mathfrak{h})\, N_t^{P,a}(\mathfrak{h}) d\mathfrak{h} = \overline{WB}_t^a$. The solution of this problem is the private-sector labor demand for each variety $\mathfrak{h}$,

$$N_t^{P,a}(\mathfrak{h}) = \left(\frac{W_t^a(\mathfrak{h})}{W_t^a}\right)^{-\theta_{a,t}^w} N_t^{P,a}, \tag{11}$$

where W_t^a is the average nominal wage paid in the private sector. Total employment is an aggregate of public and private employment, $N_t^a = N_t^{P,a} + N_t^{G,a}$. $\theta_{a,t}^w$ is the time-varying elasticity of substitution between different types of labor and follows $\theta_{a,t}^w / \left(\theta_{a,t}^w - 1\right) = \rho_{\theta_a^w} \theta_{a,t-1}^w / \left(\theta_{a,t-1}^w - 1\right) + \left(1-\rho_{\theta_a^w}\right) \bar{\theta}_a^w / \left(\bar{\theta}_a^w - 1\right) + \nu_t^{\theta_a^w}$, where $\nu_t^{\theta_a^w}$ is an i.i.d. shock with mean zero and variance $\sigma^{\theta_a^w}$; $\nu_t^{\theta_a^w}$ can be interpreted as a wage markup shock.[6]

In order to derive a labor market equilibrium, we will have to determine labor supply and demand as well as wage setting. Let us, first, turn to the labor supply decision of households. Taking labor market conditions (ie wages and employment) as given, any household member specialized in type $\mathfrak{h}_x$ labor will find it optimal to participate in the labor market if and only if utility from working exceeds his or her disutility. When defining the marginal member for which this condition holds with equality as $L_{x,t}^a$ and noting that $\mathfrak{j}_x \in [0,1]$, $L_{x,t}^a$ can be seen as the labor supply of household-type x; see Galí et al. (2011) for a more detailed discussion. Hence, the labor supply decision

[6] Note that we can identify both labor disutility and wage markup shocks because we include both employment and unemployment as observables (see Galí et al., 2011, for a discussion).

of households can be summarized as

$$\lambda_{x,t}^{a}\left[(1-\tau_{t}^{w,a})\left(w_{t}^{a}\,N_{t}^{P,a}+w_{t}^{G,a}\,N_{t}^{G,a}\right)+UB^{a}\left(L_{r,t}^{a}-N_{t}^{a}\right)\right]=N_{t}^{a}\,\kappa_{a}^{w}\,e^{\epsilon_{t+s}^{N_a}}\left(L_{x,t}^{a}\right)^{\varphi_{a}}, \quad (12)$$

where $\lambda_{x,t}^{a}$ is the marginal utility of consumption.

To determine wages in the private sector, we assume that there are utilitarian unions for each labor type $\mathfrak{h}_x$, representing optimizing and RoT households according to their shares in population. Unions maximize income of its members by optimally choosing nominal wages $W_t^a(\mathfrak{h})$, taking into account the disutility of work and the effects on labor supply and demand. Furthermore, wage setting is due to Rotemberg adjustment costs, indicated by the parameter γ_a^w. Formally, each union maximizes

$$\begin{aligned}
E_t \sum_{s=0}^{\infty} \beta_a^s\, e^{\epsilon_{t+s}^{\beta_a^t}} \Bigg\{ \mu^a \Bigg[\lambda_{t+s}^{r,a} \Bigg((1-\tau_{t+s}^{w,a}) \left(\frac{W_{t+s}^a(\mathfrak{h})}{P_{t+s}^a} N_{t+s}^{P,a}(\mathfrak{h}) + \frac{W_{t+s}^{G,a}(\mathfrak{h})}{P_{t+s}^a} N_{t+s}^{G,a}(\mathfrak{h}) \right) \\
+UB^a \left(L_{t+s}^{r,a}(\mathfrak{h}) - N_{t+s}^a(\mathfrak{h}) \right) - adj_t^{W,a} \Bigg) - \kappa_a^w\, e^{\epsilon_{t+s}^{N^a}} \frac{N_{t+s}^a(\mathfrak{h})^{1+\varphi_a}}{1+\varphi_a} \Bigg] \\
+(1-\mu^a) \Bigg[\lambda_{t+s}^{o,a} \Bigg((1-\tau_{t+s}^{w,a}) \left(\frac{W_{t+s}^a(\mathfrak{h})}{P_{t+s}^a} N_{t+s}^{P,a}(\mathfrak{h}) + \frac{W_{t+s}^{G,a}(\mathfrak{h})}{P_{t+s}^a} N_{t+s}^{G,a}(\mathfrak{h}) \right) \\
+UB^a \left(L_{t+s}^{o,a}(\mathfrak{h}) - N_{t+s}^a(\mathfrak{h}) \right) - adj_t^{W,a} \Bigg) - \kappa_a^w\, e^{\epsilon_{t+s}^{N^a}} \frac{N_{t+s}^a(\mathfrak{h})^{1+\varphi_a}}{1+\varphi_a} \Bigg] \Bigg\},
\end{aligned}$$

with respect to $\left\{W_{t+s}^a(\mathfrak{h}), N_{t+s}^{P,a}(\mathfrak{h}), L_{t+s}^{r,a}(\mathfrak{h}), L_{t+s}^{o,a}(\mathfrak{h}) : \mathfrak{h} \in [0,1]\right\}$ subject to (12) for each household type x, (11) and $N_t^a = N_t^{P,a} + N_t^{G,a}$. The wage adjustment costs, $adj_t^{W,a}$, under Rotemberg are defined as

$$adj_t^{W,a} = \frac{\upsilon_a^w}{2}\left(\frac{W_{t+s}^a(\mathfrak{h})}{\left(\pi_{w,t+s-1}^a\right)^{\xi_a^w} \left(\bar{\pi}^a\right)^{1-\xi_a^w} W_{t+s-1}^a(\mathfrak{h})} - 1 \right)^2 \frac{W_{t+s}^a}{P_{t+s}^a}$$

in the above equation. The solution is symmetric, so that $W_t^a(\mathfrak{h}) = W_t^a$, $L_t^{o,a}(\mathfrak{h}) = L_t^{o,a}$, $L_t^{r,a}(\mathfrak{h}) = L_t^{r,a}$ and $N_t^{P,a}(\mathfrak{h}) = N_t^{P,a}$ for all $\mathfrak{h}$ in equilibrium. Defining $L_t^a = (1-\mu^a)L_t^{o,a} + \mu^a L_t^{r,a}$ as the total labor force, we can then define the unemployment rate as $UR_t^a = \left(L_t^a - N_t^a\right)/L_t^a$. As in the case of price setting of goods, we allow for potential indexation on past wage inflation, $\pi_{w,t-1}^a$, and steady-state wage inflation, indicated by the parameter $\xi_a^w \in [0,1]$. The first-order conditions of this problem then determine wages in the private sector (details can be found in the equation summary upon request).

2.4 Fiscal authority

The real (CPI-deflated) per capita value of end-of-period government debt, $B_t^{G,a} = (1-\mu^a)\, B_{o,t}^{G,a}$, evolves according to a standard debt accumulation equation,

$$B_t^{G,a} = \frac{(1+i_{t-1}^{G,a})}{\pi_t^a}\, B_{t-1}^{G,a} + PD_t^a, \tag{13}$$

where $PD_t^a = G_t^a - Rev_t^a$ denotes the real per capita primary deficit, being defined as total primary expenditures (excluding interest payments on outstanding debt),

$$G_t^a \;=\; R_t^{a,a}\left(C_t^{G,a} + I_t^{G,a}\right) + UB^a\,\left(\mu^a\,(L_t^{r,a} - N_t^a) + (1-\mu^a)\,(L_t^{o,a} - N_t^a)\right) \tag{14}$$

$$+\,(1+\tau_t^{sc,a})\; N_t^{G,a}\, w_t^{G,a} + TR_t^a \tag{15}$$

minus primary revenues,

$$\begin{aligned} Rev_t^a \;=\; & (\tau_t^{w,a} + \tau_t^{sc,a})\left(w_t^a\, N_t^{P,a} + w_t^{G,a}\, N_t^{G,a}\right) + \tau_t^{k,a}\left(r_t^{k,a} - \delta_a\right) K_{t-1}^a \\ & + \tau_t^{c,a}\, C_t^a + T_{o,t}^a. \end{aligned} \tag{16}$$

We assume full home bias in government consumption and investment, $C_t^{G,a}$ and $I_t^{G,a}$, which can be justified by the fact that there is evidence for a strong home bias in government procurement (see, among others, Trionfetti, 2004, and Brulhart and Trionfetti, 2004). $R_t^{a,a} = P_t^{a,a}/P_t^a$ is the relative price between home-country PPI and home-country CPI (an analogous definition holds for $R^{i,j}$). Given public investment, the public sector capital stock evolves according to $K_t^{G,a} = \left(1-\delta_a^G\right) K_{t-1}^{G,a} + I_t^{G,a}$. We abstract from capital adjustment costs here, because, as we will see below, public investment is assumed to be a given by an exogenous stochastic process. Finally, and as in Coenen et al. (2013), transfers are distributed among the two types of households, according to

$$\bar{\mu}^a\left(\frac{TR_{o,t}^a}{\bar{TR}_o^a} - 1\right) = (1-\bar{\mu}^a)\left(\frac{TR_{r,t}^a}{\bar{TR}_r^a} - 1\right).$$

All available fiscal instruments follow a rule governed by the following exogenous processes:

$$\begin{aligned} \log\left(\frac{X_t}{\bar{X}}\right) \;=\; & \rho^{X,a}\log\left(\frac{X_{t-1}}{\bar{X}}\right) - \xi^{X,B^{G,a},a}\log\left(\frac{B_{t-1}^{G,a}}{\bar{B}^{G,a}}\right) - \xi^{X,y,a}\log\left(\frac{Y_{t-1}^a}{\bar{Y}^a}\right) \\ & + \psi^{X,a}\, \nu_t^{X,a} + \left(1-\psi^{X,a}\right)\, \nu_{t-1}^{X,a}, \end{aligned} \tag{17}$$

for instruments $X \in \{C^{G,a}, I^{G,a}, TR^a, w^{G,a}\}$ and

$$X_t - \bar{X} = \rho^{X,a} \left(X_{t-1} - \bar{X}\right) + \xi^{X,B^{G,a},a} \log\left(\frac{B^{G,a}_{t-1}}{\bar{B}^{G,a}}\right) + \xi^{X,y,a} \log\left(\frac{Y^a_{t-1}}{\bar{Y}^a}\right)$$
$$+\psi^{X,a}\, \nu^{X,a}_t + \left(1-\psi^{X,a}\right) \nu^{X,a}_{t-1}, \tag{18}$$

$X \in \{\tau^{w,a}, \tau^{sc,a}, \tau^{k,a}, T^a_o, N^{G,a}\}$.[7] $\nu^{X,a}_t$ is an i.i.d. (discretionary) fiscal policy shock with mean zero and variance $\sigma^{X,a}$, $\rho^{X,a}$ is a persistence parameter and $\xi^{X,B^{G,a},a}$ measures the responsiveness of the corresponding instrument to deviations in the debt ratio from its long-run target. In order to guarantee stability in the debt ratio, for *at least* one instrument the coefficient $\xi^{X,B^{G,a},a}$ must be positive (see, among others, Schmitt-Grohé and Uribe, 2007, and Kirsanova and Wren-Lewis, 2012, for a discussion). $\xi^{X,y,a}$ can be interpreted as an ad-hoc automatic stabilizing component as in Coenen et al. (2013). For an in-depth discussion of the cyclical movements of tax rates, see Kliem and Kriwoluzky (2014). As in Leeper et al. (2009), we allow for anticipation effects of fiscal policy with a weight of $\left(1-\psi^{X,a}\right)$. Following Coenen et al. (2013), we assume that capital taxes are kept constant while consumption taxes follow an AR(1) process including anticipation effects but no reaction on debt or output deviations. The same holds for public employment and public wages.

2.5 Monetary authority

We assume that, in the monetary union, there is only one central bank determining the policy rate i^{EA}_t. Following Stähler and Thomas (2012), it responds to deviations of area-wide CPI inflation, which is a population-share weighted average of inflation in country a and region b, from its long-run target, and to the area-wide output gap, according to a simple Taylor-type rule (see Taylor, 1993),

$$log\left(\frac{1+i^{EA}_t}{1+\bar{i}^{EA}}\right)$$
$$= \rho^a_i log\left(\frac{1+i^{EA}_{t-1}}{1+\bar{i}^{EA}}\right) + (1-\rho^a_i)\,\phi^{EA}_\pi \left(s \cdot log\left(\frac{\pi^a_t}{\bar{\pi}^a}\right) + (1-s)\cdot log\left(\frac{\pi^b_t}{\bar{\pi}^b}\right)\right) \tag{19}$$
$$+ (1-\rho^a_i)\,\phi^{EA}_y \left(s \cdot log\left(\frac{Y^a_t}{\bar{Y}^a}\right) + (1-s)\cdot log\left(\frac{Y^b_t}{\bar{Y}^b}\right)\right) + \nu^{M^{EA}}_t$$

where $s = \frac{\mathcal{P}^a}{\mathcal{P}^a + \mathcal{P}^b}$ is the relative population-weight of country a in the monetary union, ρ^a_i is a smoothing parameter, ϕ^{EA}_π and ϕ^{EA}_y are the monetary policy's stance on inflation and output gap; and $\nu^{M^{EA}}_t$ denotes an i.i.d. monetary policy shock with mean zero and variance $\sigma^{M^{EA}}$.

[7] Note that in the case of lump-sum taxes we consider the deviation from its steady-state value over steady-state output, $\frac{T^a_t - \bar{T}^a}{\bar{Y}^a}$, in order to avoid potential problems with the sign of steady-state lump-sum taxes.

While there is only one policy rate in the monetary union, namely i_t^{EA}, there are two interest rates governing private savings, i_t^a and i_t^b, and, thus, separate foreign asset holding decisions in each country. This could render foreign asset positions to be non-stationary. A common way to guarantee stationarity of foreign asset trade in open-economy DSGE models is the introduction of a risk premium that depends on the relative net foreign asset position of each country (see, among others, Schmitt-Grohé and Uribe, 2003). We will discuss the precise modeling of the risk premium in the section on international linkages, but note that different risk premia can imply differnet interest rates i_t^a and i_t^b. Depending on the net foreign asset position of each country the interest rate prevailing in the corresponding country may be above or below the policy rate. The relation between the two rates is given by

$$log\left(\frac{1+i_t^{EA}}{1+\bar{i}^{EA}}\right) = s \cdot log\left(\frac{1+i_t^a}{1+\bar{i}^a}\right) + (1-s) \cdot log\left(\frac{1+i_t^b}{1+\bar{i}^b}\right). \tag{20}$$

2.6 International linkages and market clearing

Having described the structure of the regions in *GEAR*, it remains to determine the international linkages, ie trading and the respective market clearing. In doing so, we will first describe the trading structure of international bonds and the associated risk premia, second, we derive the conditions for market clearing in the goods sector and the current account, and, last, we set up a VAR for the rest of the world.

2.6.1 International bond structure and risk premia

In order to simplify the trading structure of privately traded bonds, and in order to avoid having to take a stance on the detailed portfolio choice of agents, we assume that residents in country *a* can sell bonds to region *b*, but not the opposite. By allowing residents of region *b* to sell *a*-bonds short, *b* can effectively borrow from *a* as well. The same logic allows bond trade of region *c* with country *a* or region *b* only to take place via bonds issued by region *c*.

To determine interest rates paid to or charged from investors abroad, we assume that the interest rate country-*a* residents have to pay to region-*b* residents depends on the net debt position of *a* vis-à-vis *b* as in Schmitt-Grohé and Uribe (2003), who also provide a discussion of different ways of modeling risk premia. This logic applies to all regions i trading bonds with region j and can, for $i, j = a, b, c$ and $i \neq j$, formally be summarized by

$$1 + i_t^{i,j} = \left(1 + i_t^j\right) \left[1 - \phi\left(exp\left(\frac{rer_t^{i,j}\, B_t^{i,j}}{R_t^{i,i}\, Y_t^i} - \frac{\bar{B}^{i,j}}{\bar{R}^{i,i}\bar{Y}^i}\right) - 1\right)\right], \tag{21}$$

where $R_t^{i,i} = P_t^{i,i}/P_t^i$ and $rer_t^{i,j}$ is the real exchange rate between region i and j, determined in detail in the next subsection.[8] Hence, if the term $\left(rer_t^{i,j}\, B_t^{i,j}\right) / \left(R_t^{i,i}\, Y_t^i\right) -$

[8]Note that due to our simplification mentioned before, we consider only the following ordered pairs

$\left(\bar{B}^{i,j}\right) / \left(\bar{R}^{i,i}\bar{Y}^{i}\right)$ is negative, country i's indebtedness vis-à-vis country j increases above the "normal" steady-state level, $\bar{B}^{i,j} / \left(\bar{R}^{i,i}\bar{Y}^{i}\right)$, which can be zero, and the interest rate $i_t^{i,j}$ will contain a markup on the interest rate that region-j residents would have to pay i_t^j (the reason why home and foreign rates may differ in the buget constraint (9)). The opposite is true for the term being positive.

2.6.2 Market clearing and the current account

Market clearing implies that total supply must equal total demand. Hence, for country a it holds that the entire production of country-a goods is used either domestically or internationally. Hence, taking into account capital utilization costs, it holds that

$$Y_t^a = C_t^{G,a} + I_t^{G,a} + C_t^{a,a} + I_t^{a,a} + \frac{n_b^a}{n_a^b}\left(C_t^{b,a} + I_t^{b,a}\right) + \frac{n_c^a}{n_a^c}\left(C_t^{c,a} + I_t^{c,a}\right) + ADJ_t^a, \tag{22}$$

where $C_t^{G,a} + I_t^{G,a}$ is domestic public and $C_t^{a,a} + I_t^{a,a}$ domestic private consumption and investment demand; $\left(n_j^a / n_a^j\right)\left(C_t^{j,a} + I_t^{j,a}\right)$, for $j = b, c$, is private foreign consumption and investment demand expressed in per-capita terms; and $ADJ_t^a = adj_t^{P,a} / R_t^{a,a} + adj_t^{W,a} / R_t^{a,a}$ are total adjustment costs for price adjustments, $adj_t^{P,a} / R_t^{a,a}$, and wage adjustments, $adj_t^{W,a} / R_t^{a,a}$.

We have to take into account that the cost functions are expressed in CPI-terms, while the rest of equation (22) is expressed in PPI-terms. An analogous equation holds for region b. Note further that, in line with national accounting, where public employment is added to private-sector production at factor costs (including social security contributions) to derive GDP, we define $GDP_t^a = Y_t^a + (1 + \tau_t^{sc,a})\, w_t^{G,a} n_t^{G,a} / R_t^{a,a}$ following Stähler and Thomas (2012). Hence GDP_t^a is an adjunct accounting variable bringing GDP-figures from national accounts closer to those of our model. These differences in accounting are commonly neglected in most DSGE models in which private-sector output, Y_t^a, is generally equalized with GDP.

Given that we assume the third region c to be a VAR process in this paper, we can simplify the rest of the world's consumption and investment demand of country-j products ($j = a, b$) to

$$C_t^{c,j} + I_t^{c,j} = n_j^c\, R_t^{c,j}\left(g^{c,c} + g^{c,i}\right) e^{\epsilon_t^{c,j}}\, Y_t^c, \tag{23}$$

where Y_t^c is the rest of the world output, described below, $g^{c,c}$ and $g^{c,i}$ are consumption and investment shares of this output, respectively, and $\epsilon_t^{c,j}$ is an exogenous AR(1) shock process for import preferences of country-j products. An analogous shock is included for intra-European trade (see equation summary for details).

Given international trade in goods *and* assets, we have to determine the net foreign asset position between all regions. Taking into account the bond trading structure described in the previous section, country a's foreign bond position can be expressed

of (i, j): (b, a), (b, c) and (a, c).

in their respective CPI-terms as

$$\underbrace{rer_t^{a,c}\,B_t^{a,c} + B_t^a}_{=nfa_t^a} = (1+i_{t-1}^{a,c})\,\frac{rer_t^{a,c}\,B_{t-1}^{a,c}}{\pi_t^c} + \left(1+i_{t-1}^{b,a}\right)\frac{B_{t-1}^a}{\pi_t^a} + R_t^{a,a}\,Y_t^a - C_t^a - I_t^a - C_t^{G,a} - I_t^{G,a}, \tag{24}$$

and likewise for country b as

$$\underbrace{rer_t^{b,c}\,B_t^{b,c} + rer_t^{b,a}\,B_t^{b,a}}_{=nfa_t^b} = \left(1+i_{t-1}^{b,c}\right)\frac{rer_t^{b,c}\,B_{t-1}^{b,c}}{\pi_t^c} + \left(1+i_{t-1}^{b,a}\right)\frac{rer_t^{b,a}\,B_{t-1}^{b,a}}{\pi_t^a} + R_t^{b,b}\,Y_t^b - C_t^b - I_t^b - C_t^{G,b} - I_t^{G,b}, \tag{25}$$

where it holds that $B_t^a = -\left(\mathcal{P}^a/\mathcal{P}^a\right)\,B_t^{b,a}$. Equations (24) and (25) state that each country can only consume as much as the sum of its own production and interest payments on outstanding asset holdings, or it will have to take up debt. In other words, the current account of country i, $ca_t^i = nfa_t^i - nfa_{t-1}^i$, is balanced if and only if country i consumes its entire production plus interest payments. Otherwise, the current account will, depending on the country's consumption stance, be positive or negative and country i's net for foreign asset position, nfa_t^i, will naturally increase or decrease. Because bond markets also need to clear in equilibrium, it is straightforward to derive

$$B_t^c = -\left(\frac{\mathcal{P}^a}{\mathcal{P}^c}\,B_t^{a,c} + \frac{\mathcal{P}^b}{\mathcal{P}^c}\,B_t^{b,c}\right), \tag{26}$$

where it holds that $nfa_t^c = B_t^c$. For further reference, we note that, from the perspective of country a, the real exchange rate between regions are related as follows

$$rer_t^{c,a} = \frac{1}{R_t^{a,c}},\quad rer_t^{c,a} = \frac{1}{rer_t^{a,c}} \text{ and } rer_t^{b,c} = \frac{rer_t^{b,a}}{rer_t^{c,a}},$$

And changes in the nominal exchange rate are given by

$$\Delta S_t^{a,c} = \frac{\pi_t^a\,\left(rer_t^{a,c}/rer_{t-1}^{a,c}\right)}{\pi_t^c}$$

in which $\pi_t^{a,c} = \pi_t^c\,\Delta S_t^{a,c}$ holds. Realizing that analogous relations hold between all regions a, b, c and remembering that $\Delta S_t^{a,b} = \Delta S_t^{b,a} = 1$ (because a and b form a monetary union) allows us to derive the remaining relations (see equation summary for a full account) .

2.6.3 The rest of the world

In order to assess the question how much discretionary fiscal policy – also in relation to other shocks – affected German and rest of the Euro Area growth rates, a detailed modeling of the third region is not essential as long as we believe that spillovers from the Euro Area fiscal policy to non-member countries are relatively small, and as long as we allow for the rest of the world to affect the Euro Area. Under these assumptions we can approximate the third-region with a structural vector autoregressive (SVAR) process, similar to Christiano et al. (2011), which greatly reduces the computational burden. Specifically, we assume a three-equation SVAR including rest-of-the-world output, $\hat{Y}_t^c$, inflation, $\hat{\pi}_t^c$, and interest rates, $\hat{i}_t^c$ (all variables in deviation from their steady state).[9] Further, we allow the global technology shock to have an effect on country c as well. Specifically,

$$\begin{pmatrix} \hat{Y}_t^c \\ \hat{\pi}_t^c \\ \hat{i}_t^c \\ \epsilon_t^{A_g} \end{pmatrix} = \underbrace{\begin{pmatrix} a_{1,1} & a_{1,2} & a_{1,3} & 0 \\ a_{2,1} & a_{2,2} & a_{2,3} & a_{2,4} \\ a_{3,1} & a_{3,2} & a_{3,3} & a_{3,4} \\ 0 & 0 & 0 & a_{4,4} \end{pmatrix}}_{=AA} \begin{pmatrix} \hat{Y}_{t-1}^c \\ \hat{\pi}_{t-1}^c \\ \hat{i}_{t-1}^c \\ \epsilon_{t-1}^{A_g} \end{pmatrix} + \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 \\ c_{2,1} & 1 & 0 & c_{2,4} \\ c_{3,1} & c_{3,2} & 1 & c_{3,4} \\ 0 & 0 & 0 & 1 \end{pmatrix}}_{=CC} \begin{pmatrix} \nu_t^{Y,c} \\ \nu_t^{\pi,c} \\ \nu_t^{i,c} \\ \nu_t^{A_g} \end{pmatrix},$$

where $\nu_t^{Y,c}$, $\nu_t^{i,c}$, $\nu_t^{\pi,c}$ and $\nu_t^{A_g}$ are i.i.d. shocks with mean zero and variance $\sigma^{Y,c}$, $\sigma^{i,c}$, $\sigma^{\pi,c}$ and σ^{A_g}. We will estimate these shocks as well as parameter matrices AA and CC.

2.6.4 Shock processes

The model contains 41 structural shocks. Except for the fiscal and monetary policy shocks in (17), (18), and (19), all shocks follow AR(1) processes:

$$\epsilon_t^{X,a} = \rho^X \epsilon_{t-1}^{X,a} + \nu_t^X,$$

in which $i = a, b$ as usual, X denotes the corresponding shock, and ν_t^X is an i.i.d. shock with mean zero and variance σ^X. This completes the model description. We now turn to the estimation of *GEAR*.

3 Bayesian estimation

In this section, we outline how we estimate the model with Bayesian techniques. We start by describing the data and its transformations, continue with calibration and prior choices and conclude by discussing the estimated posterior distributions.

3.1 The data

The specific structure of *GEAR* requires us to construct a novel data set, one which goes beyond the available sources for studies on the Euro Area (see, for example, Fagan et al. 2005). The novelty comes in mainly for two reasons: we need an Euro Area aggregate without Germany and a relatively rich set of quarterly fiscal variables.

[9] In detail, $\hat{Y}_t^c = log\,(Y_t^c/\bar{Y}^c)$, $\hat{\pi}_t^c = \pi_t^c - \bar{\pi}^c$ and $\hat{i}_t^c = i_t^c - \bar{i}^c$.

We focus on data over the sample period from 1999Q1 to 2013Q4 for nine of the initial EMU-11 countries: Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Portugal, and Spain. Measured on the basis of GDP (in PPP-shares) this group of nine covers about 90 percent of the 18 member states of the EMU. The data sources for the various variables are the European System of Accounts (ESA), the ECB Government Statistics (GST), the European Commission for detailed statistics on taxation,[10] the current account statistics of the Bundesbank for bilateral ex- and import flows, and national sources for public employment figures. The Rest of the World is a composite of eight large developed and emerging countries: Brazil, Canada, China, India, Japan, Russia, the United Kingdom, and the United States. As we set up the third country block in a simplified way as a SVAR we need to collect data only on GDP, inflation, and a short-term interest rate. For GDP and inflation we use indexes processed at the Bundesbank based on data from national statistical sources. The U.S. federal fund rate serves as a proxy for the interest rate. Table 1 has the detailed list of variables.[11]

Table 1 also includes details on how we transform the data to match them with the model. In most cases we take GDP-deflated per capita growth rates and subtract the average GDP growth rate (e.g. GDP, consumption, etc.); ratios are simply demeaned (e.g. inflation, tax rates, etc.). While we refer the reader to Table 1 for further details, the construction of quarterly tax rates and public employment, and the region-specific aggregation requires more attention.

To get quarterly consumption and labor tax rates (the latter including social contributions), we take the yearly tax revenue statistics published by the European Commission and convert them into quarterly figures using the method of Chow and Lin (1971). Their method requires at least one related quarterly series which serves as a proxy for the dynamics during the year. Specifically, we use GDP and the respective tax bases – private consumption and total gross wages and salaries – as proxies for quarterly consumption and labor tax revenues and deduct the required rates..[12] In the same vein, we use total employment as a proxy in the Chow-Lin method to derive quarterly public employment figures.

Compiling the Euro Area aggregate without Germany is straightforward for nominal variables or employment figures. To construct the respective price index, however, we need to divide nominal and real GDP, taking care of the chain-index nature of real GDP when summing it up. For the variables in the rest of the world block, we aggregate real GDP and the price indexes by using the log-index method as in Fagan et al. (2005), that is $X = \exp\left(\sum_{i=1}^{n} w_i \log X_i\right)$. The country weights, w_i, denote GDP-shares in PPP units normalized such that $\sum_{i=1}^{n} w_i = 1$. We take the shares w_i from the World Economic Outlook of the International Monetary Fund.

[10] See http://ec.europa.eu/taxation_customs/taxation/gen_info/economic_analysis/tax_structures/index_en.htm.

[11] The dataset is available upon request.

[12] Coenen et al. (2013) and Forni et al. (2009) use the formulas of Mendoza et al. (1994) and apply the Chow-Lin interpolation to the individual components in those formulas. Compared to them, our approach has the advantage that we build on yearly data actually used by institutions to discuss and compare the taxation trends in the European Union.

Table 1: Observables, applied transformations, and classifications

A. Germany and the Rest of the Euro Area ($i = a, b$)	B. Rest of the world
GDP (GDP^i)	GDP (GDP^c, $C^{G,i}$)
Private and public consumption (C^i)	GDP deflator inflation (π^c)
Private and public investment (I^i, $I^{G,i}$)	U.S. Fed funds rate (i^c)
Exports Germany $\rightarrow$ Rest of the Euro Area (EX^i)	
Private and public gross wages and salaries (w^i, $w^{G,i}$)	
Transfers (TR^i)	
Private and public employment share ($N^{P,i}$, $N^{G,i}$)	
Public deficit to GDP ratio (def^i)	
GDP deflator inflation (π^i)	
Euribor, 3-month (i^{EA})	
Unemployment rate (UR^i)	
Labor tax rate ($\tau^{w,i}$)	
Social contribution rate, employer ($\tau^{sc,i}$)	
Consumption tax rate ($\tau^{c,i}$)	

C. Transformations and classifications

In list A all variables from GDP until transfers are in real per capita growth rates (GDP deflator) minus average GDP growth; the remaining variables are demeaned. Private and public employment figures are ratios with respect to population; private employment does not include self-employed persons. Public consumption is net of compensation of employees but accounts for transfers in kind. Transfers TR^i themselves are net of in-kind and rest of the world transfers (in the rest of the Euro Area they also include unemployment benefits). The labor tax rate comprises "direct" taxes on labor and social contributions of employees.

D. Matching identities: observables $\leftrightarrow$ model variables

$GDP^i = Y^i + \frac{N^{G,i} w^{G,i}(1+\tau^{sc,i})}{R^{i,i}}$; $def^i = \frac{\Delta B^{G,i}}{R^{i,i} GDP^i}$; $EX^a = \frac{n_b^a}{n_a^b}\left(C_t^{b,a} + I_t^{b,a}\right)$ and $EX^b = \frac{n_a^b}{n_b^a}\left(C_t^{a,b} + I_t^{a,b}\right)$

3.2 Calibration, prior selection, and estimation results

The model is estimated with Bayesian techniques using the software Dynare (see Adjemian et al., 2011). We calibrate some parameters either by relying on values commonly chosen in the literature or by matching long-run targets in the data. Table 2 displays a summary of calibrated parameters, long-run targets can be found in Table 3. Note that we are able to solve for the (asymmetric) steady state analytically. The complete derivation is available upon request.

3.2.1 Calibration

In the fiscal sector, we mainly target sample averages for tax rates $\tau^{w,i}$, $\tau^{k,i}$, $\tau^{c,i}$, social security contributions, $\tau^{sc,i}$, public employment over total employment, $\frac{N^{G,i}}{N^i}$, and public purchases and investment over GDP, $\frac{C^{G,i}}{GDP^i}$ and $\frac{I^{G,i}}{GDP^i}$. Using unemployment benefits data for Germany, we can determine the sample average of the replacement ratio, $\frac{UB^a}{w^a(1-\tau^{w,a})}$. We use the German estimate also for the rest of the Euro Area due to a lack of reliable data. Further, the markup of public wages over private wages, mg^i, is set to 3% for Germany and the rest of the Euro Area (see Fernàndez de Cordoba et al., 2012, and Afonso and Gomes, 2014). The steady state government debt-to-output ratio is set to 60% on an annual basis, consistent with the Maastricht criteria. Finally, steady state private investment to GDP is set to match the sample average.

Table 2: Calibrated parameters

Parameter	**Value**	
	Germany	Rest of Euro Area
Preferences		
Intertemporal elasticity of substitution , σ	1	1
Discount factor, β	0.9985	0.9985
Parameter influencing Frisch elasticity, φ	10	9
Population size, $\mathcal{P}$	1	2.6
Technology		
Capital share, α	0.33	0.33
Rate of depreciation (private), δ	0.015	0.015
Rate of depreciation (public), δ^G	0.015	0.015
Public sector productivity shifter, ζ	1.22	1.16
Subs. Elasticity: intermediate goods, θ	4	4
Subs. Elasticity: different types of labor, θ^w	5.4	5.1
Fixed costs, Ω	0.35	0.28
International sector		
Risk premium parameter, ϕ	0.01	

Regarding technology parameters, the capital share is set to the standard value of $\alpha_i = 0.33$. The rates of depreciation for private and public capital, δ_i and δ_i^G , are both set to 1.5% as in Coenen et al. (2013). In the steady state, we make sure that

Table 3: Targeted steady-state values

Target variable	**Value** Germany	Rest of Euro Area
Fiscal policy		
Labor income taxes, τ_w	0.304	0.277
Capital taxes, τ_k	0.214	0.316
Consumption taxes, τ_c	0.183	0.196
SSC (employers), τ_{sc}	0.167	0.246
Public purchases ratio, $\frac{C^G}{GDP}$	0.111	0.1006
Public investment ratio, $\frac{I^G}{GDP}$	0.017	0.028
Public employment ratio, $\frac{N^G}{N}$	0.228	0.231
Transfers (incl. UB benefits) ratio, $\frac{TR+(L-N)UB}{GDP}$	0.190	0.183
Replacement ratio, $\frac{UB}{w(1-\tau^w)}$	0.351	0.351
Public markup, mg	0.030	0.030
Government debt ratio (quarterly), $\frac{B^G}{GDP}$	2.4	2.4
Monetary policy		
Inflation rate (quarterly), π	0.0045	
Interest rate (quarterly), i	0.00475	
Labor and goods market		
Unemployment rate, UR	0.082	0.095
Employment rate, N	0.433	0.363
Wage markup	0.263	0.287
Frisch elasticity	0.192	0.218
Price markup	0.333	0.333
International sector		
Relative prices and real exchange rates	1	1
Net foreign assets	0	0
Import share vis-a-vis Ger or RoE, $\frac{C^{i,j}+I^{i,j}}{GDP^i}$	0.130	0.066
Import share vis-a-vis RoW, $\frac{C^{i,c}+I^{I,c}}{GDP^i}$	0.244	0.244

$\zeta^i (N^{G,i})^{\eta^{N^G,i}} (K^{G,i})^{\eta^{K^G,i}} = 1$ through an appropriate choice of the public sector productivity shifter, ζ^i. Finally, we set the elasticity of substitution between intermediate goods, θ_i, to 4 implying a markup of roughly 33%. This value is in line with other studies for the Euro Area (see, for instance, Bayoumi et al., 2004). Finally, the value of fixed costs Ω_i is such that profits are zero in the steady state.

We assume that the utility function is logarithmic in consumption, i.e. $\sigma_i = 1$, which is a common choice in the DSGE literature (see, for instance, Coenen et al., 2013). Further, we set $\beta_i = 0.9985$ which results – together with the assumed target inflation rate of 1.9% (p.a.) – in a steady-state nominal interest rate of 2.5% (p.a.) for the Euro Area as a whole. The parameter influencing the Frisch elasticity of labor supply is set to $\varphi_a = 10$ and $\varphi_b = 9$. These parameter values imply a "true" Frisch elasticity (at the extensive margin) of roughly 0.2% for Germany and the rest of the Euro Area.[13]

[13]Note that φ_i is not simply the inverse of the Frisch elasticity because of the existence of unemploy-

A Frisch elasticity of roughly 0.2% lies in the range of values found in the literature (see Reichling and Whalen, 2012, for a recent survey) and coincides with the estimate of Galí et al. (2011). Their model features a similar structure of the labor market than *GEAR*. Finally, we calibrate relative population sizes based on total population figures.

Regarding the labor market, we target the steady state unemployment and employment rates. The labor disutility scaling parameter, κ_i^w , supports these targets. Given our previous calibration choices, the elasticity of substitution between different types of labor, θ_i^w, as well the wage markup are derived endogenously. $\theta_a^w = 5.4$ and $\theta_b^w = 5.1$ imply a wage markup of roughly 26% for Germany and 29% for the rest of Europe, where the wage markup is given by $w^i\lambda^i / \left(\kappa_a^w (N^a)^{\varphi_a} + UB^i\lambda^i(1-\tau_i^w)\right)$ in our model. This parameterization is in line with other studies for the Euro Area (see, for instance, Bayoumi et al., 2004).

For the international sector, we assume all relative prices and real exchange rates to be equal to one in the steady state. This assumption, while not being unrealistic, proves to be very helpful in calculating the asymmetric steady state. Net foreign asset positions are set to zero and the risk premium parameter ϕ is set to 0.01 as in the NAWM (see Christoffel et al., 2008). Finally the ratio of imports to GDP in Germany and the rest of the Euro Area are matched with their respective sample averages. Note that we assume the import share of the rest of the Euro Area vis-à-vis rest of the world to be equal to the share in Germany due to a lack of reliable data. The targeted shares are supported by appropriate choices for the trade openness parameters.

3.2.2 Prior selection

Tables 4, 5 and 6 summarize our prior choices.[14] In general, we choose rather standard priors. Regarding the shock processes, and fiscal and monetary policy rules we broadly follow the prior assumptions of the New Area-Wide Model (see Christoffel et al., 2008) and its fiscal extension (see Coenen et al., 2013). Concerning debt and output coefficients of fiscal rules, we assume priors means indicating slight debt and output stabilization as in Leeper et al. (2011). For frictions and preference parameters our main source is Forni et al. (2009), because their structure of the labor and goods market is similar to ours. The prior choices for the SVAR describing the rest of the world are in line with Christiano et al. (2011). Regarding the effects of public investment on private production, $\eta^{K^G,i}$, we assume a gamma distribution with a slightly positive mean of 0.1. Thereby, we follow Leeper et al. (2010) who employ the same value of 0.1 in their simulations.[15] We assume the same prior in the case of public employment. This choice is consistent with Pappa (2009) who assumes a range between 0 and 0.25 for $\eta^{N^G,i}$.

ment, public employment and unemployment benefits.

[14]Tables provide information on the prior and posterior distributions. For each prior distribution we state mean and variance, except for inverse gamma distributions where we state mode and variance. Mean, 5% and 95% percentiles of the (marginal) posterior distributions are based on two Markov chains, each with 1,000,000 draws where 300,000 are discarded in a burn-in phase. The average acceptance rates were 27.9% and 27.6%, respectively. We suppress the country index in the tables.

[15]For a discussion, see also Aschauer (1989), Nadiri and Mamuneas (1994), Holtz-Eakin (1994), Kamps (2004), and D'Auria (2015).

Table 4: Priors and posteriors for Germany

Parameter	**Prior distribution**	**Posterior distribution**			
		Mode	Mean	5%	95%
Preferences					
Share of RoT households, μ	B(0.5,0.1)	0.283	0.290	0.196	0.381
Distribution of transfers, $\overline{\mu}$	B(0.5,0.1)	0.476	0.485	0.315	0.650
Habit formation, h	B(0.7,0.1)	0.494	0.498	0.359	0.637
Subs. elasticity: home and foreign goods, η	G(1,0.25)	0.979	0.965	0.653	1.265
Frictions					
Investment adj. costs, v	G(5,0.25)	4.951	4.990	4.579	5.398
Price adj. costs, v^p	G(100,$\sqrt{1000}$)	69.811	66.366	29.878	100.645
Wage adj. costs, v^w	G(100,$\sqrt{1000}$)	61.801	85.298	43.782	127.390
Price indexation, ξ	B(0.75,0.1)	0.351	0.400	0.234	0.566
Wage indexation, ξ^w	B(0.75,0.1)	0.507	0.543	0.344	0.742
Elasticity of pub. inv. w.r.t. output	G(0.1,0.05)	0.084	0.109	0.027	0.189
Elasticity of pub. emp. w.r.t. output	G(0.1,0.05)	0.074	0.098	0.024	0.169
AR coefficients (fiscal rules)					
Labour taxes, ρ_{τ_w}	B(0.75,0.1)	0.826	0.818	0.734	0.906
Consumption taxes, ρ^{τ_c}	B(0.75,0.1)	0.921	0.916	0.873	0.961
SSC (employer), $\rho_{\tau_{sc}}$	B(0.75,0.1)	0.925	0.918	0.873	0.963
Public consumption, ρ_{C^G}	B(0.75,0.1)	0.822	0.812	0.709	0.916
Public investment, ρ_{I^G}	B(0.75,0.1)	0.783	0.772	0.666	0.879
Public employment, ρ_{N^G}	B(0.75,0.1)	0.951	0.946	0.914	0.979
Transfers, ρ_{TR}	B(0.75,0.1)	0.844	0.836	0.762	0.913
Lump sum taxes, ρ_T	B(0.75,0.1)	0.533	0.546	0.373	0.717
Public wages, ρ_{w^G}	B(0.75,0.1)	0.897	0.890	0.826	0.955
Debt feedback coefficients (fiscal rules)					
Labour taxes, ξ^{b,τ^w}	N(0.2,0.05)	-0.005	-0.005	-0.020	0.011
SSC (employer), $\xi^{b,\tau^{sc}}$	N(0.2,0.05)	-0.007	-0.007	-0.014	0.001
Public consumption, $\xi^{b,g}$	N(0.2,0.05)	0.097	0.108	0.043	0.172
Public investment, ξ^{b,I^G}	N(0.2,0.05)	0.219	0.219	0.137	0.298
Transfers, $\xi^{b,TR}$	N(0.2,0.05)	0.166	0.172	0.113	0.230
Lump sum taxes, $\xi^{b,T}$	N(0.2,0.05)	0.163	0.168	0.098	0.240
Output feedback coefficients (fiscal rules)					
Labour taxes, ξ^{y,τ^w}	N(0.2,0.05)	0.073	0.074	0.049	0.098
SSC (employer), $\xi^{y,\tau^{sc}}$	N(0.2,0.05)	-0.006	-0.006	-0.022	0.011
Public consumption, $\xi^{y,g}$	N(0.2,0.05)	0.167	0.169	0.092	0.246
Public investment, ξ^{y,I^G}	N(0.2,0.05)	0.199	0.200	0.118	0.280
Transfers, $\xi^{y,TR}$	N(0.2,0.05)	0.197	0.199	0.125	0.273
Lump sum taxes, $\xi^{y,T}$	N(0.2,0.05)	0.188	0.187	0.109	0.266
Pre-announcement coefficients (fiscal rules)					
Labour taxes, ψ_{τ_w}	B(0.5,0.1)	0.605	0.610	0.566	0.650
Consumption taxes, ψ^{τ_c}	B(0.5,0.1)	0.561	0.512	0.404	0.602
SSC (employer), $\psi_{\tau_{sc}}$	B(0.5,0.1)	0.681	0.679	0.617	0.741

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Parameter	**Prior distribution**	**Posterior distribution**			
		Mode	Mean	5%	95%
Public consumption, ψ_{C^G}	B(0.5,0.1)	0.777	0.768	0.698	0.836
Public investment, ψ_{I^G}	B(0.5,0.1)	0.786	0.776	0.702	0.851
Public employment, ψ_{N^G}	B(0.5,0.1)	0.519	0.498	0.439	0.560
Transfers, ψ_{TR}	B(0.5,0.1)	0.725	0.723	0.652	0.791
Lump sum taxes, ψ_{T}	B(0.5,0.1)	0.802	0.796	0.726	0.865
Public wages, ψ_{w^G}	B(0.5,0.1)	0.749	0.742	0.673	0.814
Monetary Policy					
Interest rate smoothing, ρ_i	B(0.9,0.05)	0.841	0.842	0.809	0.877
Reaction to inflation, ϕ_π	G(1.7,0.1)	1.796	1.794	1.630	1.954
Reaction to output, ϕ_y	G(0.125,0.05)	0.054	0.061	0.024	0.096
AR coefficients (non-fiscal shocks)					
Technology, ρ_A	B(0.75,0.1)	0.899	0.868	0.797	0.941
Investment-specific technology, ρ_I	B(0.75,0.1)	0.757	0.726	0.615	0.840
Preference, ρ_β	B(0.75,0.1)	0.565	0.595	0.415	0.778
Labour disutility, ρ_N	B(0.75,0.1)	0.971	0.965	0.941	0.988
Risk premium EA, $\rho_{RP,EA}$	B(0.75,0.1)	0.772	0.759	0.673	0.849
Risk premium RoW, $\rho_{RP,RoW}$	B(0.75,0.1)	0.529	0.543	0.395	0.695
Price markup, ρ_θ	B(0.75,0.1)	0.558	0.568	0.385	0.758
Wage markup, ρ_{θ^w}	B(0.75,0.1)	0.709	0.631	0.468	0.798
Export preference RoE, ρ_{RoE}	B(0.75,0.1)	0.937	0.925	0.881	0.973
Export preference RoW, ρ_{RoW}	B(0.75,0.1)	0.861	0.831	0.748	0.919
Standard deviations					
Technology, σ_A	IG(0.01,2)	0.009	0.010	0.008	0.011
Investment-specific technology, σ_I	IG(0.01,2)	0.046	0.050	0.037	0.062
Preference, σ_β	IG(0.01,2)	0.019	0.021	0.014	0.027
Labour disutility, σ_N	IG(0.01,2)	0.026	0.027	0.022	0.031
Risk premium EA, $\sigma_{RP,EA}$	IG(0.01,2)	0.004	0.004	0.004	0.005
Risk premium RoW, σ_{RP}, RoW	IG(0.01,2)	0.006	0.006	0.005	0.008
Price markup, σ_θ	IG(0.01,2)	0.077	0.080	0.036	0.120
Wage markup, σ_{θ^w}	IG(0.01,2)	0.236	0.358	0.163	0.543
Export preference RoE, σ_{RoE}	IG(0.01,2)	0.028	0.029	0.024	0.033
Export preference RoW, σ_{RoW}	IG(0.01,2)	0.028	0.029	0.024	0.033
Interest rate, σ_i	IG(0.001,2)	0.0008	0.0009	0.0007	0.0010
Labour taxes, σ_{τ_w}	IG(0.001,2)	0.002	0.002	0.002	0.003
Consumption taxes, σ^{τ_c}	IG(0.001,2)	0.002	0.002	0.002	0.002
SSC (employer), $\sigma_{\tau_{sc}}$	IG(0.001,2)	0.001	0.002	0.001	0.002
Public consumption, σ_{C^G}	IG(0.01,2)	0.018	0.019	0.015	0.023
Public investment, σ_{I^G}	IG(0.01,2)	0.078	0.082	0.065	0.098
Public employment, σ_{N^G}	IG(0.0001,2)	0.000	0.000	0.000	0.000
Public wages, σ_{w^G}	IG(0.01,2)	0.012	0.012	0.010	0.015
Transfers, σ_{TR}	IG(0.01,2)	0.013	0.014	0.011	0.017
Lump sum tax, σ_T	IG(0.01,2)	0.021	0.023	0.017	0.029

Table 5: Priors and posteriors for rest of the Euro Area

Parameter	Prior distribution	Posterior distribution			
		Mode	Mean	5%	95%
Preferences					
Share of RoT households, μ	B(0.5,0.1)	0.209	0.2176	0.14	0.294
Distribution of transfers, $\overline{\mu}$	B(0.5,0.1)	0.356	0.3628	0.212	0.5097
Habit formation, h	B(0.7,0.1)	0.748	0.7505	0.663	0.8396
Subs. elasticity: home and foreign goods, η	G(1,0.25)	0.893	0.9076	0.627	1.1761
Frictions					
Investment adj. costs, v	G(5,0.25)	4.930	4.961	4.567	5.365
Price adj. costs, v^p	G(100,$\sqrt{1000}$)	67.316	78.681	38.040	118.562
Wage adj. costs, v^w	G(100,$\sqrt{1000}$)	79.885	112.910	63.419	161.094
Price indexation, ξ	B(0.75,0.1)	0.447	0.492	0.295	0.683
Wage indexation, ξ^w	B(0.75,0.1)	0.301	0.329	0.183	0.469
Elasticity of pub. inv. w.r.t. output	G(0.1,0.05)	0.070	0.091	0.021	0.158
Elasticity of pub. emp. w.r.t. output	G(0.1,0.05)	0.092	0.116	0.028	0.201
AR coefficients (fiscal rules)					
Labour taxes, ρ_{τ_w}	B(0.75,0.1)	0.842	0.818	0.727	0.912
Consumption taxes, ρ^{τ_c}	B(0.75,0.1)	0.929	0.920	0.876	0.968
SSC (employer), $\rho_{\tau_{sc}}$	B(0.75,0.1)	0.869	0.850	0.772	0.932
Public consumption, ρ_{C^G}	B(0.75,0.1)	0.920	0.918	0.885	0.952
Public investment, ρ_{I^G}	B(0.75,0.1)	0.857	0.851	0.776	0.929
Public employment, ρ_{N^G}	B(0.75,0.1)	0.983	0.979	0.966	0.993
Transfers, ρ_{TR}	B(0.75,0.1)	0.941	0.934	0.898	0.970
Lump sum taxes, ρ_T	B(0.75,0.1)	0.808	0.760	0.597	0.925
Public wages, ρ_{w^G}	B(0.75,0.1)	0.881	0.864	0.787	0.945
Debt feedback coefficients (fiscal rules)					
Labour taxes, ξ^{b,τ^w}	N(0.2,0.05)	0.022	0.024	0.011	0.038
SSC (employer), $\xi^{b,\tau^{sc}}$	N(0.2,0.05)	0.007	0.009	-0.001	0.018
Public consumption, $\xi^{b,g}$	N(0.2,0.05)	0.161	0.164	0.120	0.206
Public investment, ξ^{b,I^G}	N(0.2,0.05)	0.197	0.200	0.128	0.274
Transfers, $\xi^{b,TR}$	N(0.2,0.05)	0.128	0.130	0.093	0.168
Lump sum taxes, $\xi^{b,T}$	N(0.2,0.05)	0.094	0.104	0.052	0.157
Output feedback coefficients (fiscal rules)					
Labour taxes, ξ^{y,τ^w}	N(0.2,0.05)	0.036	0.038	0.009	0.066
SSC (employer), $\xi^{y,\tau^{sc}}$	N(0.2,0.05)	0.016	0.020	-0.003	0.042
Public consumption, $\xi^{y,g}$	N(0.2,0.05)	0.185	0.188	0.114	0.260
Public investment, ξ^{y,I^G}	N(0.2,0.05)	0.189	0.188	0.107	0.268
Transfers, $\xi^{y,TR}$	N(0.2,0.05)	0.220	0.220	0.150	0.291
Lump sum taxes, $\xi^{y,T}$	N(0.2,0.05)	0.194	0.193	0.118	0.269
Pre-announcement coefficients (fiscal rules)					
Labour taxes, ψ_{τ_w}	B(0.5,0.1)	0.738	0.728	0.658	0.797
Consumption taxes, ψ^{τ_c}	B(0.5,0.1)	0.664	0.667	0.611	0.721
SSC (employer), $\psi_{\tau_{sc}}$	B(0.5,0.1)	0.738	0.727	0.658	0.795

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Parameter	**Prior distribution**	**Posterior distribution**			
		Mode	Mean	5%	95%
Public consumption, ψ_{C^G}	B(0.5,0.1)	0.823	0.813	0.753	0.874
Public investment, ψ_{I^G}	B(0.5,0.1)	0.764	0.758	0.685	0.831
Public employment, ψ_{N^G}	B(0.5,0.1)	0.656	0.660	0.614	0.704
Transfers, ψ_{TR}	B(0.5,0.1)	0.744	0.736	0.666	0.806
Lump sum taxes, ψ_T	B(0.5,0.1)	0.298	0.437	0.217	0.733
Public wages, ψ_{w^G}	B(0.5,0.1)	0.830	0.821	0.758	0.885
Monetary Policy					
Interest rate smoothing, ρ_i	B(0.9,0.05)	0.841	0.842	0.809	0.877
Reaction to inflation, ϕ_π	G(1.7,0.1)	1.796	1.794	1.630	1.954
Reaction to output, ϕ_y	G(0.125,0.05)	0.054	0.061	0.024	0.096
AR coefficients (non-fiscal shocks)					
Technology, ρ_A	B(0.75,0.1)	0.915	0.888	0.814	0.962
Investment-specific technology, ρ_I	B(0.75,0.1)	0.721	0.709	0.601	0.821
Preference, ρ_β	B(0.75,0.1)	0.815	0.796	0.698	0.896
Labour disutility, ρ_N	B(0.75,0.1)	0.971	0.965	0.944	0.987
Risk premium EA, $\rho_{RP,EA}$	B(0.75,0.1)	0.772	0.759	0.673	0.849
Risk premium RoW, $\rho_{RP,RoW}$	B(0.75,0.1)	0.529	0.543	0.395	0.695
Price markup, ρ_θ	B(0.75,0.1)	0.582	0.552	0.367	0.742
Wage markup, ρ_{θ^w}	B(0.75,0.1)	0.512	0.442	0.281	0.599
Export preference GER, ρ_{GER}	B(0.75,0.1)	0.929	0.923	0.890	0.958
Export preference RoW, ρ_{RoW}	B(0.75,0.1)	0.864	0.843	0.779	0.912
Standard deviations					
Technology, σ_A	IG(0.01,2)	0.006	0.006	0.004	0.007
Investment-specific technology, σ_I	IG(0.01,2)	0.031	0.033	0.024	0.041
Preference, σ_β	IG(0.01,2)	0.018	0.020	0.013	0.027
Labour disutility, σ_N	IG(0.01,2)	0.022	0.023	0.019	0.027
Risk premium EA, $\sigma_{RP,EA}$	IG(0.01,2)	0.004	0.004	0.004	0.005
Risk premium RoW, σ_{RP}, RoW	IG(0.01,2)	0.006	0.006	0.005	0.008
Price markup, σ_θ	IG(0.01,2)	0.053	0.065	0.033	0.098
Wage markup, σ_{θ^w}	IG(0.01,2)	0.362	0.545	0.276	0.806
Export preference GER, σ_{GER}	IG(0.01,2)	0.028	0.029	0.024	0.033
Export preference RoW, σ_{RoW}	IG(0.01,2)	0.015	0.016	0.013	0.019
Interest rate, σ_i	IG(0.001,2)	0.0008	0.0009	0.0007	0.0010
Labour taxes, σ_{τ_w}	IG(0.001,2)	0.002	0.002	0.002	0.003
Consumption taxes, σ^{τ_c}	IG(0.001,2)	0.002	0.002	0.002	0.002
SSC (employer), $\sigma_{\tau_{sc}}$	IG(0.001,2)	0.002	0.002	0.001	0.002
Public consumption, σ_{C^G}	IG(0.01,2)	0.012	0.013	0.010	0.016
Public investment, σ_{I^G}	IG(0.01,2)	0.038	0.040	0.031	0.047
Public employment, σ_{N^G}	IG(0.0001,2)	0.0002	0.0002	0.0002	0.0002
Public wages, σ_{w^G}	IG(0.01,2)	0.015	0.016	0.013	0.019
Transfers, σ_{TR}	IG(0.01,2)	0.011	0.012	0.009	0.014
Lump sum tax, σ_T	IG(0.01,2)	0.016	0.017	0.011	0.022

Table 6: Priors and posteriors for rest of the world

Parameter	Prior distribution	Posterior distribution			
		Mode	Mean	5%	95%
a_{11}	B(0.75,0.1)	0.776	0.766	0.663	0.876
a_{12}	N(0,0.5)	0.208	0.220	-0.028	0.462
a_{13}	N(0,0.5)	0.348	0.284	-0.088	0.669
a_{21}	N(0,0.5)	-0.054	-0.074	-0.200	0.049
a_{22}	B(0.75,0.1)	0.515	0.507	0.372	0.643
a_{23}	N(0,0.5)	0.533	0.575	0.312	0.849
a_{24}	N(0,0.5)	-0.134	-0.139	-0.359	0.079
c_{21}	N(0,0.5)	0.467	0.447	0.205	0.690
c_{24}	N(0,0.5)	0.228	0.244	-0.144	0.626
a_{31}	N(0,0.5)	0.025	0.001	-0.077	0.066
a_{32}	N(0,0.5)	-0.003	-0.016	-0.081	0.049
a_{33}	B(0.9,0.05)	0.926	0.903	0.831	0.974
a_{34}	N(0,0.5)	-0.109	-0.032	-0.188	0.199
c_{31}	N(0,0.5)	0.072	0.066	-0.001	0.127
c_{32}	N(0,0.5)	0.002	-0.016	-0.092	0.055
c_{34}	N(0,0.5)	-0.108	-0.049	-0.194	0.107
a_{44}	B(0.75,0.1)	0.792	0.790	0.649	0.932
Technology, σ_A	IG(0.01,2)	0.007	0.007	0.006	0.008
Inflation, σ_π	IG(0.01,2)	0.006	0.006	0.005	0.007
Interest rate, σ_i	IG(0.001,2)	0.001	0.001	0.001	0.001
Global technology, σ_z	IG(0.01,2)	0.005	0.005	0.004	0.007
Subs. elasticity: home and foreign goods, η	G(1,0.25)	0.478	0.497	0.324	0.666

3.2.3 Posterior distributions

The main characteristics of the (marginal) posterior distributions are displayed in the last four columns of Tables 4, 5 and 6. The posterior mode is found by maximizing the posterior kernel. Mean and confidence intervals are taken from the (marginal) posterior distributions which are based on two Markov chains with $1,000,000$ draws ($300,000$ draws are discarded in a burn-in phase).

A detailed discussion of all estimation results seems beyond the scope of this paper. Some results are, however, noteworthy. The positive elasticities of private production and public employment in both countries indicate that increases in public investment and employment lead to private productivity enhancements. Note however that the elasticities are estimated to be close to its prior means, which may indicate that the parameters are not very well identified by the data. Estimates for the share of RoT households and the distribution of transfers are sizeable in both countries, but not large, similar to Coenen et al. (2013). Hence, transfer shocks have an impact in our model although both regions exhibit rather Ricardian behavior in general. Turning to the fiscal rules, debt and output stabilization is – in both countries – mainly guaranteed by spending instruments, i.e public investment, public consumption and transfers, and lump sum taxes. Anticipation effects are non-negligible.

4 Quantitative assessment

We now use the estimated model for a quantitative assessment. We first conduct an impulse response analysis for selected shocks to improve the understanding of how the model and some of its fiscal features work. Based on this analysis, we, then, calculate the size of the resulting fiscal multipliers. Following this analysis, we conduct a historical shock decomposition in order to evaluate how much *discretionary* fiscal policy conducted in Germany and the rest of the Euro Area affected GDP growth and how large the intra-European spillovers of these policy shocks were.

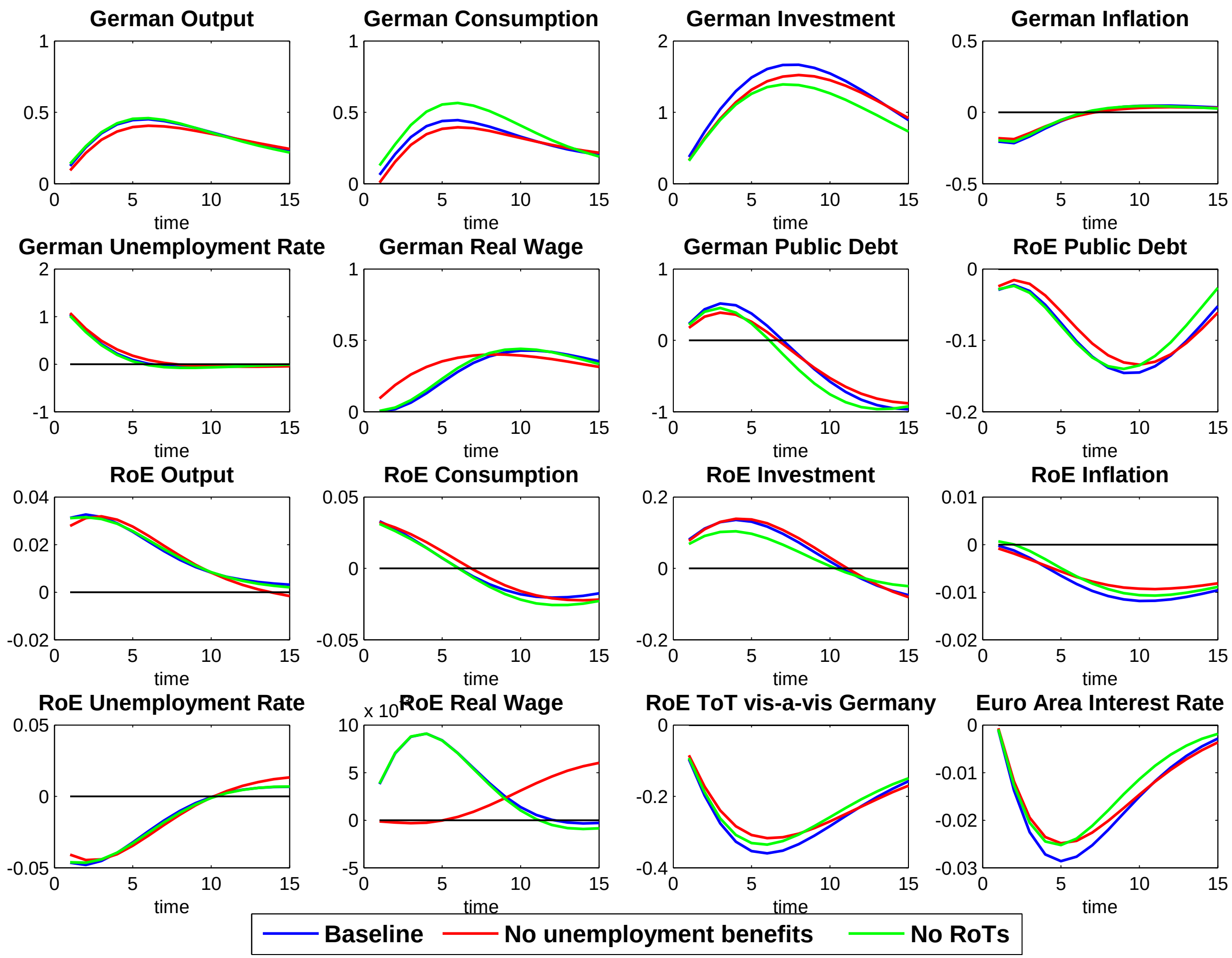
4.1 Impulse response analysis

In this subsection, we first show the effects of two standard shocks – a technology and a monetary policy (Figures 2 and 3). On the fiscal side, we impose shocks to different public revenue and spending components in order to get deeper insights into the mechanisms of *GEAR* (see Figures 4 and 5). All our results are robust to assuming no anticipation of fiscal policy changes. Impact effects with anticipation are, however, somewhat smaller as agents, at least those who are able to behave forward looking, adapt to expected changes in fiscal policy ahead of time.

Figure 2 shows a 1% technology shock in Germany. We observe an increase in GDP, consumption, investment and real wages in Germany; employment falls and unemployment increases; inflation also falls. Hence, the increase in productivity allows firms to decrease employment (to produce the same amount of output ceteris paribus) and producer prices. These effects are standard and are described in more detail in, for example, Galí (2013) who also contrasts the effects of the New Keynesian framework used here to those of the standard neoclassical model. Because of the fall in employment, the labor income tax base deteriorates (which cannot be compensated for by higher wages) and payments for unemployed workers increase. This dampening effect on public finances cannot be overcompensated for by higher consumption revenues, for which the debt-to-GDP ratio increases for a while until it starts falling again. Lower prices improve Germany's terms of trade vis-a-vis the rest of the Euro Area. Still, spillovers of a technology shock in Germany to the rest of the Euro Area are positive due to higher German demand for rest of the Euro area products and a lower policy rate. However, spillovers are relatively small. The effects after such a supply-side shock differ very little when shutting off unemployment benefits or the existence of RoTs. The presence of unemployment benefits, however, tends to slightly dampen the wage reaction after a technology shock, which has a positive effect on GDP, employment and consumption.

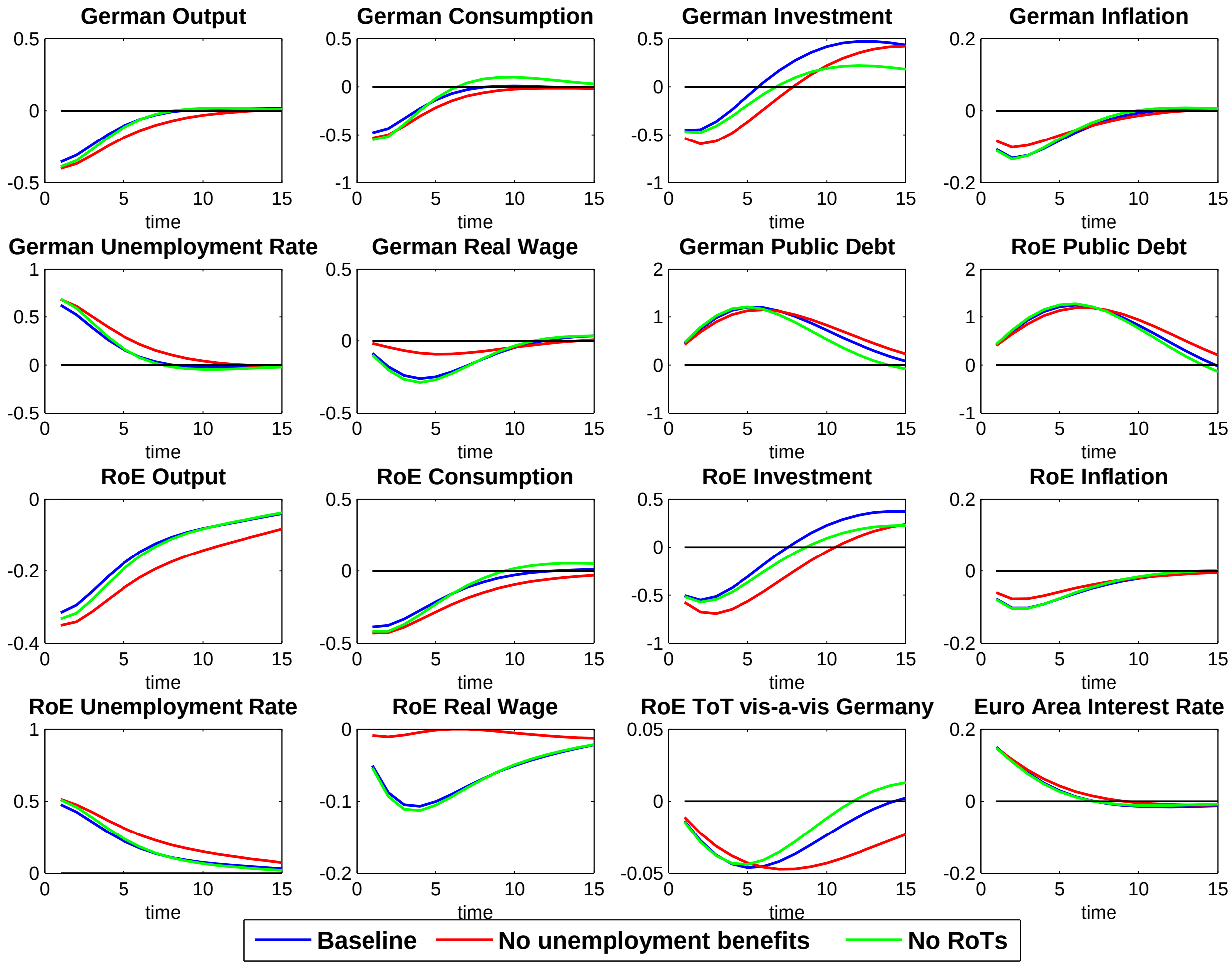
A monetary policy shock reduces private investment and consumption through a temporary increase in the real interest rate (see Figure 3). Following the decline in aggregate demand, output drops and firms cut back their demand for labor and, as a consequence, unemployment increases. The resulting decrease in wages leads firms to cut producer prices because of the impact on marginal costs, which finally feeds through to the consumer price index. Less employment, lower wages, higher unemployment and lower demand deteriorate fiscal balances and the debt-to-GDP ratio increases. Its real value additionally increases due to the fall in prices. These effects hold for Germany and the rest of the Euro Area. According to our estimates, both regions are affected more or less equally. As for the technology shock, we again note that the presence of RoT consumers and unemployment benefits produces only minor differences in the evolution of key macroeconomic variables.

Figure 2: Impulse response functions to a technology shock



Notes: Figure shows impulse response functions of selected variables to a 1% technology shock. All deviations are in percent to steady-state values (percentage point deviations for unemployment, yearly CPI inflation and yearly interest rates as well as yearly debt-to-GDP ratios).

Figure 3: Impulse response functions to a monetary policy shock



Notes: Figure shows impulse response functions of selected variables to a monetary policy shock. All deviations are in percent to steady-state values (percentage point deviations for unemployment, yearly CPI inflation and yearly interest rates as well as yearly debt-to-GDP ratios).

On the fiscal revenue side, we simulate shocks to the labor income and consumption tax rates as well as employer's social security contributions in Germany (Figure 4). All tax rates are raised so as to produce an increase of 1% of the primary-deficit-to-GDP ratio on impact, while thereafter, the fiscal rules are allowed to work as estimated. Hence, all tax rate hikes imply a decrease in the German debt-to-GDP ratio and a drop in private consumption because of lower net income and higher policy-induced consumption costs. Private investment falls because of increases in labor costs (ie higher labor income tax and social security contribution rates), while it increases because of higher consumption taxes. The latter is a direct consequence from optimizing households postponing consumption spending today. Still, this cannot compensate for the consumption loss and, so, aggregate demand falls in all cases. As output deteriorates, the firms' labor demand falls, which implies a fall in real wages after an increase in consumption taxes and social security contribution rates. Because households, at least partly, want to be compensated for the higher labor tax rates – and unions take that into account – they demand higher (gross) wages whenever the labor income tax rate is increased. Given lower demand after an increase in the labor income tax rate and the relatively low wage increase, price changes after a labor income tax hike are small. Whenever the consumption tax rate goes up, firms reduce prices via the marginal costs channel. They increase prices because of the hike in social security contribution rates triggered by higher gross labor costs. These price reactions, of course, feed through to consumer prices. Naturally, this implies an improvement of Germany's terms of trade for increases in the case of the consumption tax rate, while they deteriorate for hikes in social security contributions. Spillovers of tax increases in Germany to the rest of the Euro Area tend to be small but positive. For increases in social security contributions, this is a result of improved terms of trade in the rest of the Euro Area, while for higher consumption tax rates in Germany, this is because of a lower monetary policy rate.

For the government spending side, we simulate a standard shock to public purchases, $C_t^{G,a}$, and contrast this to a shock to public employment and public investment (Figure 5). All shocks are such that public expenditures increase by 1% of GDP on impact, while the fiscal rules are, again, allowed to work as estimated. Higher public demand has to be produced by firms, which increases output. Unemployment falls, generating upward pressure on wages. Higher wages lead to higher prices via the marginal costs channel. Private consumption decreases after a public purchases shock despite the existence of RoT consumers. The reason is that, as optimizers are able to anticipate the shock one period in advance, they adjust (ie reduce) consumption accordingly. Private investment is also crowded-out and the debt-to-GDP ratio increases. Because of higher prices, German terms of trade vis-a-vis the rest of the Euro Area deteriorate and the monetary policy rate goes up. The higher interest rate together with the overall drop in private demand generates slightly negative spillovers to rest of Euro Area.

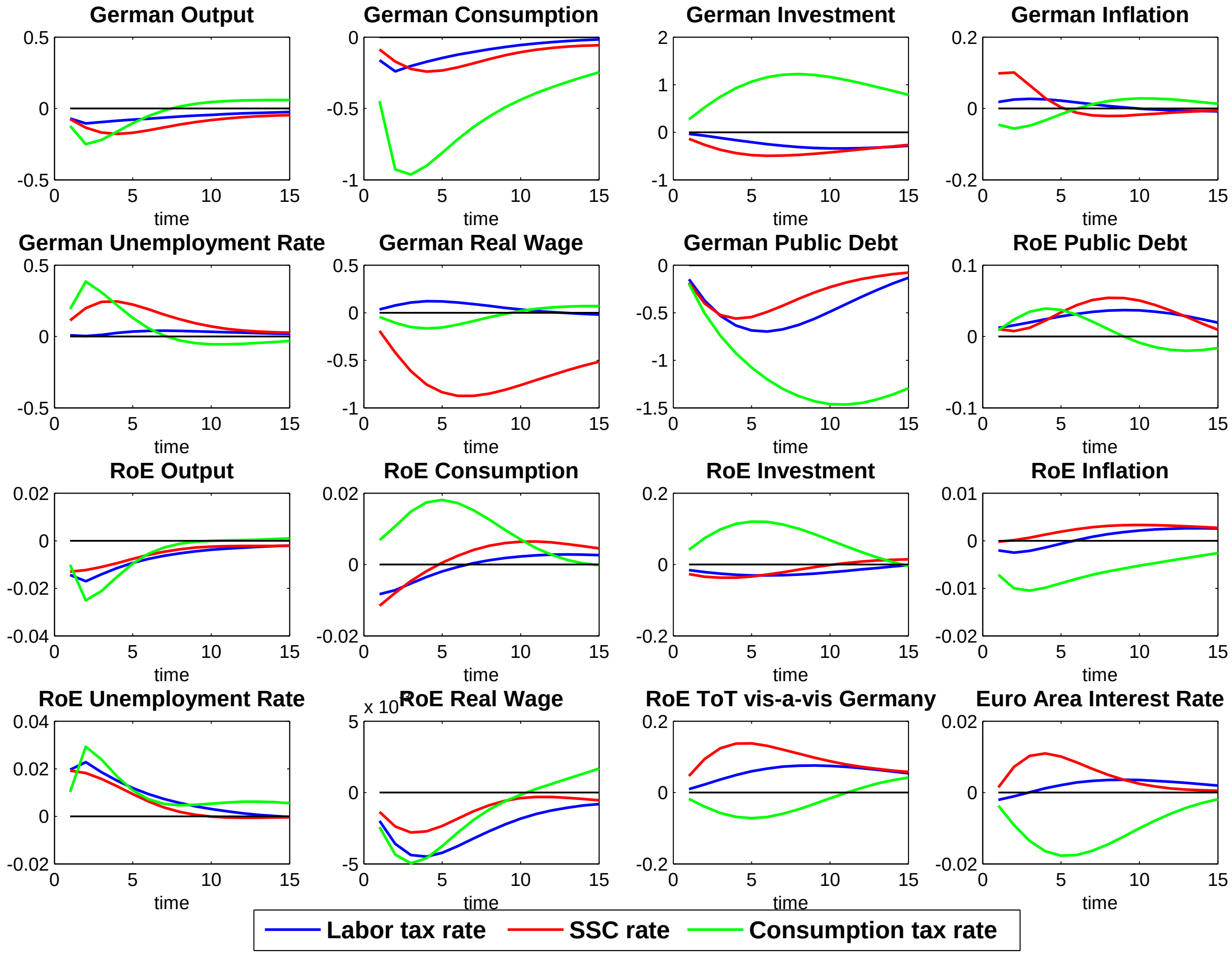
We observe similar effects following a public investment shock. However, given that public investment increases the public capital stock, which affects private-sector productivity positively, private investment demand now increases after four quarters. Private investment after a public investment shock starts exceeding its initial steady-state level after quarter eight. The policy-induced positive "productivity" shock generates effects on employment and prices similar to a pure technology shock. Hence, the increase in prices is less pronounced as it would be after a pure public demand shock and private employment goes up less than in the case of a pure public purchases shock discussed above. Effects of a public investment shock can thus be interpreted as a combination of a pure government purchases shock and a positive productivity shock. This turns spillovers to the rest of the Euro Area to be slightly positive shortly after impact (even though Germany's terms of trade improve in the mid-term).

A shock to public employment in Germany also increases German GDP, private sector-productivity, real wages, public debt and prices, and it reduces unemployment. The shock is more persistent, which can be attributed to the size of the estimated autocorrelation coefficient. In contrast to the public investment shock, however, we observe an initial increase in private consumption and investment in Germany, which can be attributed by initially higher aggregate labor income of households resulting from higher public employment. Because of an increase outside option of workers, wages in the private sector increase, which induces private firms to employ less workers relative to a positive investment shock or a shock to public purchases. While higher public employment overcompensates the relative loss in private-sector employment, the fall in aggregate unemployment is still smaller after a public employment shock.

The relatively high and persistent rise in GDP which we observe is an accounting effect as Figure 6 reveals. Remember that we define GDP in line with national accounting as $GDP_t^a = Y_t^a + (1 + \tau_t^{sc,a})\, w_t^{G,a} n_t^{G,a} / R_t^{a,a}$, which is private-sector output plus public wage bill (including social security contributions). Hence, an increase in public employment increases GDP, but the increase in private-sector output, driven by higher private demand, is only small. The latter is driven by the relatively larger impact on private wages just described. Via the marginal costs channel, firms eventually increase prices. Because higher public employment has to be financed in the medium term, the wealth effect inducing optimizers to decrease private consumption (and investment) dominates the private consumption pattern – and the pattern of private-sector output – eventually.

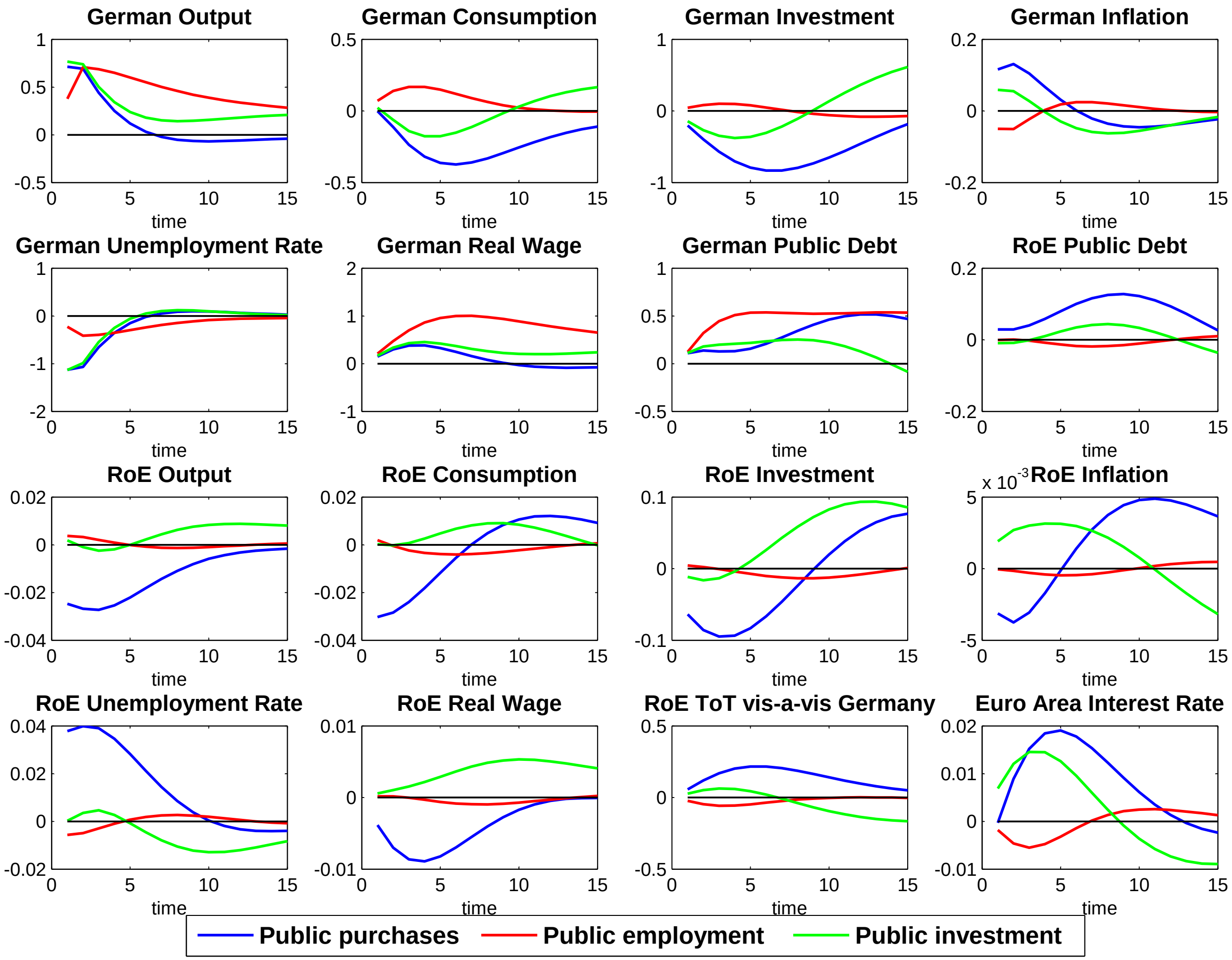
Spillovers to the rest of the Euro Area are mildly positive initially, which is driven by the initial positive demand effects in Germany. However, they become negative when this effect starts dying out, which is further fostered by the the monetary policy reaction in the medium run. This analysis reveals that, when talking about government spending shocks or multipliers, it is crucial to define which spending component one refers to, and whether or not the base of the multiplier is GDP or private sector output (the former being potentially more relevant for empirical analyses).

Figure 4: Impulse response functions to selected fiscal revenue shocks



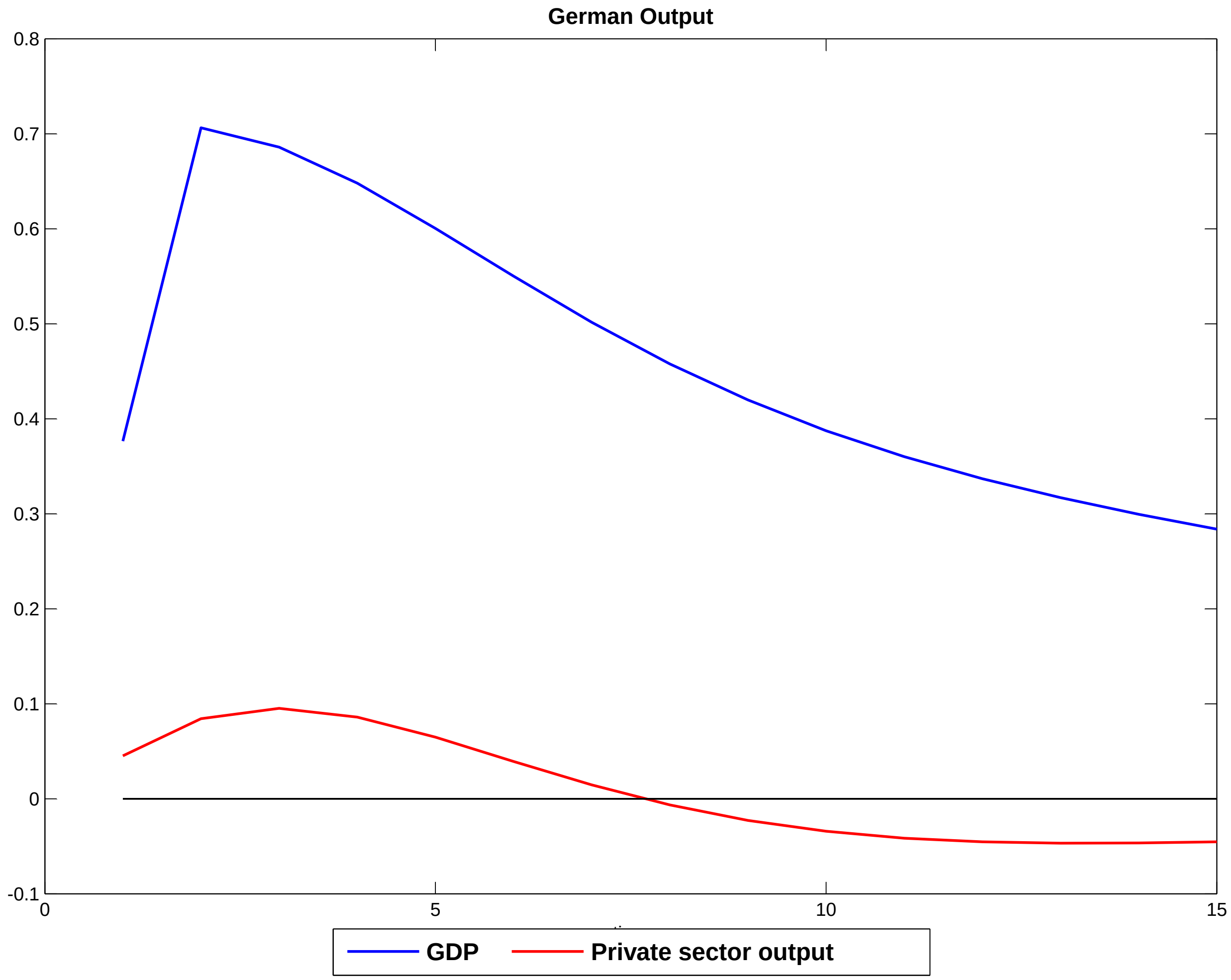
Notes: Figure shows impulse response functions of selected variables to a tax rate shock as indicated decreasing the primary deficit-to-GDP ratio by 1%. All deviations are in percent to steady-state values (percentage point deviations for unemployment, yearly CPI inflation and yearly interest rates as well as yearly debt-to-GDP ratios).

Figure 5: Impulse response functions to selected fiscal spending shocks



Notes: Figure shows impulse response functions of selected variables to a public spending shock as indicated increasing the primary deficit-to-GDP ratio by 1%. All deviations are in percent to steady-state values (percentage point deviations for unemployment, yearly CPI inflation and yearly interest rates as well as yearly debt-to-GDP ratios).

Figure 6: Comparing GDP and private production after a public employment shock



Notes: Figure compares impulse response functions of German GDP and private-sector output after a shock to public employment in Germany. Deviations are in percent to steady-state values, where $GDP_t^a = Y_t^a + (1 + \tau_t^{sc,a})\, w_t^{G,a} n_t^{G,a} / R_t^{a,a}$.

4.2 Fiscal multipliers

Based on the analysis of the previous section, it is now straightforward to derive fiscal multipliers from our model. In doing so, we follow Leeper et al. (2010) and Uhlig (2010) and calculate a present-value multiplier for each fiscal shock. To be precise, the present-value multiplier for government purchases for a horizon k is defined as

$$PV(k) = \frac{\sum_{t=0}^{k}(1+\bar{i}^{i})^{-k}\left(GDP_t^i - G\bar{D}P^i\right)}{\sum_{t=0}^{k}(1+\bar{i}^{i})^{-k}\left(C_t^{g,j} - \bar{C}^{g,j}\right)}$$

and analogously for the other fiscal shocks. Here, $i, j = a, b$ for Germany and the rest of the Euro Area. To capture the spillovers of fiscal policy from Germany to the rest of the Euro Area and vice versa, we present the multipliers of both regions (in that case $i \neq j$). For the domestic multipliers, it holds that $i = j$. The results are summarized in Tables 7 and 8. As already mentioned in the previous section, multipliers are slightly higher without anticipation effects.

Table 7: Present-value multipliers of shocks originating in Germany

	Impact	Year 1	Year 2	Year 3	Year 4	Long run
... in Germany						
Public purchases, $PV\left(dGDP^a \,/ dC^{G,a}\right)$	0.91	0.72	0.50	0.38	0.33	0.24
Public investment, $PV\left(dGDP^a \,/ dI^{G,a}\right)$	0.97	0.85	0.79	0.87	1.02	3.56
Public employment, $PV\left(dGDP^a \,/ dN^{G,a}\right)$	1.13	1.14	1.10	1.05	1.02	0.91
Public employment, $PV\left(dY^a \,/ dN^{G,a}\right)$	0.13	0.14	0.10	0.05	0.02	-0.09
Public transfers, $PV\left(dGDP^a \,/ dTR^{G,a}\right)$	0.31	0.23	0.14	0.08	0.05	-0.29
Labor tax rate, $PV\left(dGDP^a \,/ d\tau^{w,a}\right)$	-0.19	-0.20	-0.23	-0.25	-0.27	-0.27
Social security rate, $PV\left(dGDP^a \,/ d\tau^{sc,a}\right)$	-0.06	-0.19	-0.24	-0.23	-0.22	-0.19
Consumption tax rate, $PV\left(dGDP^a \,/ d\tau^{c,a}\right)$	-0.20	-0.22	-0.14	-0.08	-0.05	0.28
... in rest of the Euro Area						
Public purchases, $PV\left(dGDP^b/dC^{G,a}\right)$	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Public investment, $PV\left(dGDP^b/dI^{G,a}\right)$	0.00	0.00	0.01	0.01	0.02	0.10
Public employment, $PV\left(dGDP^b/dN^{G,a}\right)$	0.10	0.00	0.00	0.00	0.00	0.00
Public transfers, $PV\left(dGDP^b/dTR^{G,a}\right)$	0.03	0.03	0.02	0.02	0.02	0.03
Labor tax rate, $PV\left(dGDP^b/d\tau^{w,a}\right)$	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Social security rate, $PV\left(dGDP^b/d\tau^{sc,a}\right)$	-0.03	-0.02	-0.02	-0.03	-0.01	-0.02
Consumption tax rate, $PV\left(dGDP^b/d\tau^{c,a}\right)$	-0.01	-0.02	-0.01	-0.01	0.00	0.00

Notes: This table shows present-value multipliers based on the estimated impulse response functions computed at the posterior mode estimates of the model parameters for shocks originating in Germany. Note that, for all shocks, it holds that $G\hat{D}P_t^i = \hat{Y}_t^i = 0$ as $t \to \infty$.

Table 7 shows multipliers of fiscal shocks originating in Germany, while Table 8 does the same for shocks originating in the rest of the Euro Area. We see that the domestic output multiplier of a shock to German government purchases is 0.91 on impact and starts falling thereafter. The multiplier is below one because of the fall in private demand described in the previous section. This finding is in line with Forni et al. (2009). The impact multiplier in the rest of the Euro Area is similarly high, also amounting to 0.81 with the same pattern as in Germany (see Table 8). Spillovers between both regions are negative, mainly due to monetary policy reaction (as described in the previous section). But, primarily because the weight of the rest of the Euro Area in the monetary policy function is stronger, spillovers from the rest of the Euro Area to Germany are larger than vice versa. This tends to hold for all fiscal shocks.

A public investment shock generates similar domestic effects on impact. As government investment increases the public capital stock which, in turn, affects private-sector productivity positively, we have a mix between a government purchases shock and a technology shock (as described in the previous section). In Germany, the former effect dominates on impact, and the latter starting in year 4. We observe a steadily increasing multiplier in Germany thereafter which, in the long run, amounts to 3.56. In the rest of the Euro Area, the the pattern is the same in qualitative terms. The long-run multiplier in the rest of the Eur Area is only 2.26, which can be attributed to a smaller impact of the public capital stock on private-sector productivity (see Table 5). The relatively large long-run multipliers in Germany and the rest of the Euro Area are in line with Heppke-Falk et al. (2010), who confirm such high values in an empirical analysis for Germany. Also, Mittnik and Neumann (2001) estimate a VAR model and find that additional public investment leads to a significant increase in GDP equivalent to three times the amount invested; their sample of countries includes France, Germany and The Netherlands. Kamps (2004) finds even higher values in an analysis for 22 OECD countries. Given the positive impact on private consumption and investment in Germany, spillovers to the rest of the Euro Area are positive but still small. Spillovers from the rest of the Euro Area to Germany are negative as a result of the corresponding monetary reaction (see Tables 7 and 8).

As regards the GDP-multiplier of a public employment shock, we see that it is larger than the public purchases multiplier on impact, and it decreases more slowly. Given the discussion about the different effects of a public employment shock to GDP and private-sector output in the previous section (see also Figure 6), it is worthwhile to have a look at the private-sector output multiplier after a public employment shock. We see that it is clearly smaller than the GDP multiplier, becoming negative in the medium to the long run. This finding may be considered interesting, especially for empirical studies.

Transfer shocks generate comparatively modest multipliers given the modest estimates of the fraction of rule of thumb households. The same holds for public revenue-side multipliers and spillovers between regions. These findings are in line with the literature. For example, Coenen et al. (2013), who analyze the Euro Area as a whole, and Leeper et al. (2010) and Uhlig (2010), who calculate multipliers for the US economy, find qualitatively the same and quantitatively similar results. An interesting observation of our analysis is that, while public spending multipliers may differ substantially between regions in the Euro Area, tax and transfer shocks have broadly the same size.

Table 8: Present-value multipliers of shocks originating in the rest of the Euro Area

	Impact	Year 1	Year 2	Year 3	Year 4	Long run
... in Germany						
Public purchases, $PV\left(dGDP^a/dC^{G,b}\right)$	-0.17	-0.15	-0.12	-0.10	-0.09	-0.07
Public investment, $PV\left(dGDP^a/dI^{G,b}\right)$	-0.06	-0.06	-0.05	-0.04	-0.03	0.02
Public employment, $PV\left(dGDP^a/dN^{G,b}\right)$	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Public transfers, $PV\left(dGDP^a/dTR^{G,b}\right)$	0.07	0.05	0.03	0.03	0.03	0.02
Labor tax rate, $PV\left(dGDP^a/d\tau^{w,b}\right)$	-0.09	-0.07	-0.06	-0.06	-0.05	-0.05
Social security rate, $PV\left(dGDP^a/d\tau^{sc,b}\right)$	-0.10	-0.08	-0.06	-0.04	-0.03	-0.02
Consumption tax rate, $PV\left(dGDP^a/d\tau^{c,b}\right)$	-0.04	-0.04	-0.03	-0.02	-0.01	0.01
... in rest of the Euro Area						
Public purchases, $PV\left(dGDP^b/dC^{G,b}\right)$	0.81	0.66	0.47	0.35	0.28	0.08
Public investment, $PV\left(dGDP^b/dI^{G,b}\right)$	0.92	0.79	0.68	0.65	0.69	2.26
Public employment, $PV\left(dGDP^b/dN^{G,b}\right)$	1.07	1.08	1.02	0.95	0.89	0.63
Public employment, $PV\left(dY^b/dN^{G,b}\right)$	0.07	0.07	0.02	-0.05	-0.10	-0.35
Public transfers, $PV\left(dGDP^b/dTR^{G,b}\right)$	0.16	0.12	0.06	0.00	-0.04	-0.27
Labor tax rate, $PV\left(dGDP^b/d\tau^{w,b}\right)$	-0.17	-0.19	-0.20	-0.21	-0.22	-0.25
Social security rate, $PV\left(dGDP^b/d\tau^{sc,b}\right)$	0.02	-0.12	-0.21	-0.21	-0.20	-0.19
Consumption tax rate, $PV\left(dGDP^b/d\tau^{c,b}\right)$	-0.14	-0.16	-0.12	-0.06	-0.01	0.24

Notes: This table shows present-value multipliers based on the estimated impulse response functions computed at the posterior mode estimates of the model parameters for shocks originating in Germany. Note that, for all shocks, it holds that $G\hat{D}P_t^i = \hat{Y}_t^i = 0$ as $t \to \infty$.

To put the results of this section into perspective, it seems important to note that there is *no one size fits all* fiscal multiplier. Multipliers depend on the instrument, the specific country and episode. While our analysis nicely carves out the first two aspects – and additionally puts a focus on spillovers – it abstracts from addressing the latter. The literature has shown that multipliers may differ in recessions and booms (see, among others, Auerbach and Gorodnichenko, 2012, or Ilzetzki et al., 2012), that they depend on the monetary policy stance or whether monetary policy is restricted by, for example, the zero lower bound and on liquidity restrictions in the economy (see, for example, Leeper et al., 2011, or Christiano et al., 2011). Moreover, the state of public finances also plays a role (see Sutherland, 1997). Hence, the multipliers presented here should be interpreted as multipliers in "normal times", ie as a sort of weighted average over different economic episodes (see Parker, 2011, Coenen et al., 2012, and Kilponen et al., 2015, for a discussion).

4.3 Historical shock decomposition

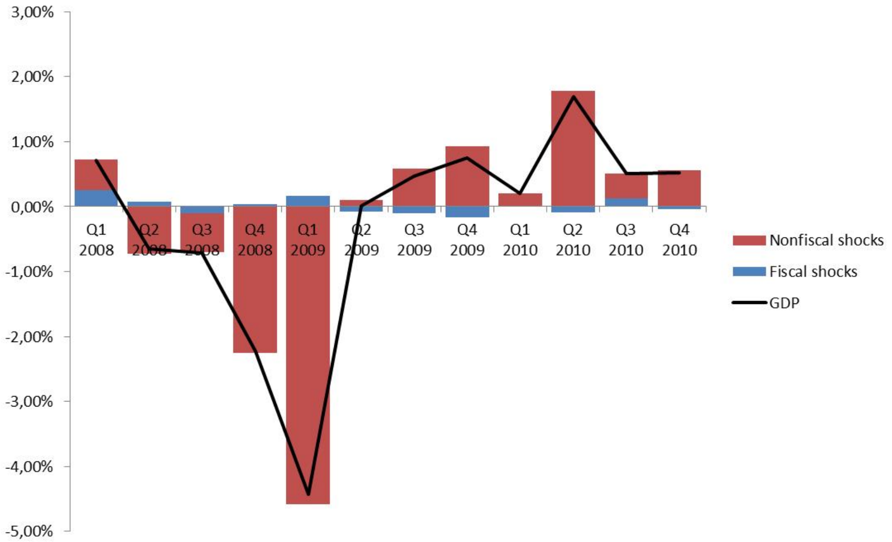
In this section, we present a historical shock decomposition of demeaned real GDP growth to assess the contribution of fiscal policy and other shocks during the global financial crisis. We do this separately for Germany and the rest of the Euro Area. Having identified fiscal policy's role on GDP growth, we will dig a bit deeper and assess which fiscal policy shocks emerged during that period.

Figure 7 depicts the historical shock decomposition showing fiscal and non-fiscal shocks for Germany (Panel 7a) and the rest of the Euro Area (Panel 7b). It suggests that discretionary fiscal measures indeed pushed up quarter-on-quarter GDP growth during the crisis, up to about 0.3 pp in Germany in 2008Q1 and to about 0.04 pp in the rest of the Euro Area in 2008Q2. In terms of annualized quarter-on-quarter growth rates, this implies a contribution of 1.2 pp for Germany and 0.12 pp for the rest of the Euro Area, which is broadly in line with Coenen et al. (2012, 2013). We further see that, in annualized terms, restrictive fiscal measures affected German GDP growth by almost -0.8 pp in 2009Q4, while they dampened GDP growth in the rest of the Euro Area up to about -1.2 pp in 2010Q1. Hence, GDP growth was mainly driven by other than discretionary fiscal policy shocks. Those findings naturally raise two questions: what were the drivers of GDP growth and which fiscal policy instruments contributed to the fiscal impact just described?

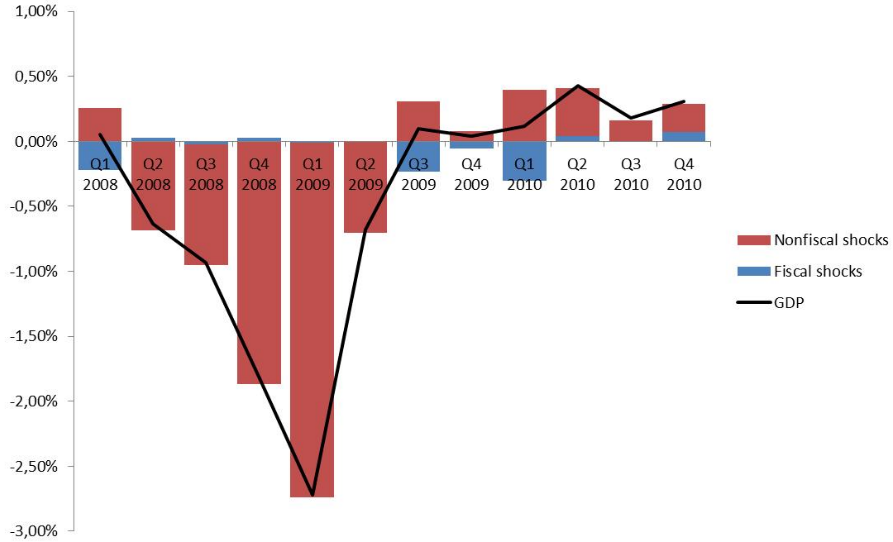
In order to address the first question, Figure 8 depicts the same shock decomposition as before except that, now, we disaggregate the non-fiscal shocks. In particular, we consider shocks from the rest of the world, UIP shocks, monetary policy shocks and domestic and foreign non-fiscal shocks (such as, for example, productivity shocks, preference shocks and so on). We note that discretionary monetary policy, in general, positively contributed to German and rest of Euro Area growth rates given the accommodating stance of monetary policy during that period. Rest of the world shocks were the main driver for the slump in German GDP in 2008, while additionally UIP and non-fiscal shocks from the rest of the Euro Area significantly affected German GDP in 2009, see Panel 8a. Another important driver in Germany were domestic non-fiscal shocks (amongst them, technology shocks seemed most important). The UIP shock can be interpreted as a shock describing cyclical divergence between regions that are not directly explained by the model as it pictures real exchange rate fluctuations which the structural model cannot generate (see Rabanal and Tuesta, 2010).[16] Domestic non-fiscal as well as rest of the world shocks contributed most to German GDP growth in the period after 2010Q1, followed by non-fiscal shocks from the rest of the Euro Area. However, the latter shocks had a smaller impact than at the beginning of the crisis. In line with our multiplier analysis from before, rest of Euro Area fiscal shocks had a virtually negligible impact on German GDP.

[16]Hence, this shock, to some extent, captures the increasing imbalances between Germany, the rest of the Euro Area and the rest of the world which the model cannot explain. During and after the global financial crisis, these imbalances widened, so it does not come as a surprise that this shock becomes important.

Figure 7: Historical decomposition of real GDP growth (demeaned): Fiscal versus non-fiscal shocks



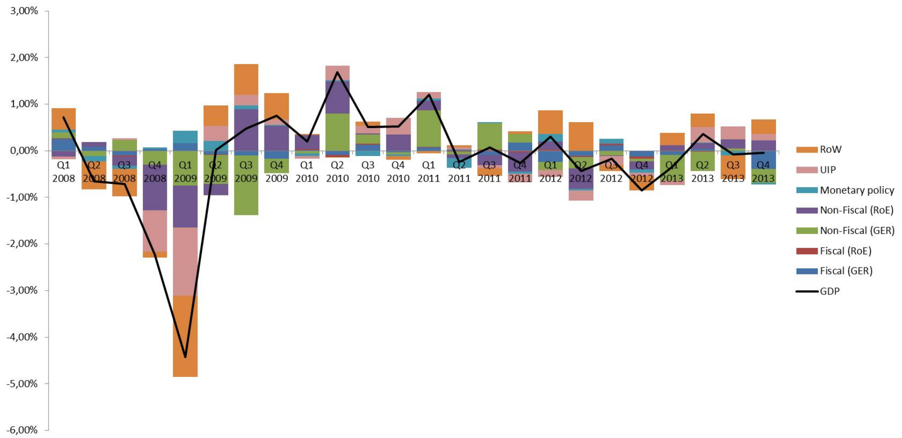
(a) Germany



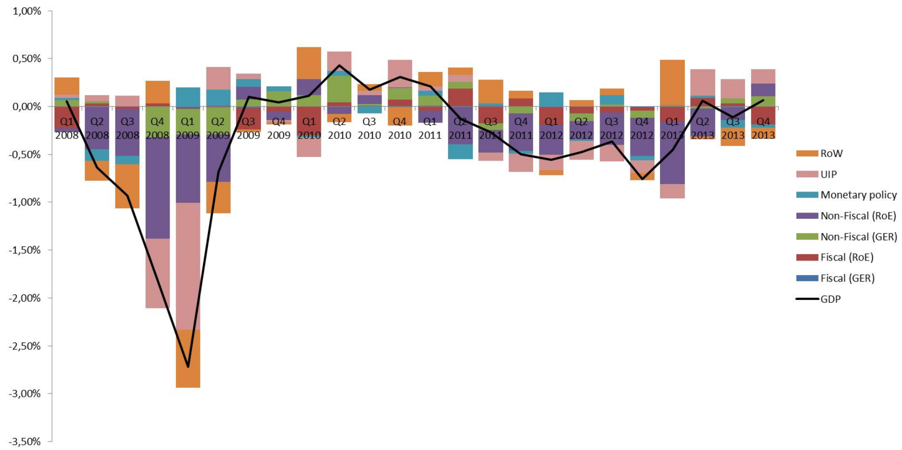
(b) Rest of the Euro Area

Notes: Figure shows quarter-on-quarter GDP growth rates (demeaned) and the contribution of fiscal and non-fiscal shocks to these developments. To annualize, rates have to be multiplied by four. The mean/trend growth rate in our sample period is 0.32% for Germany and 0.14% for the rest of the Euro Area.

Figure 8: Historical decomposition of real GDP growth (demeaned): Disaggregated shocks



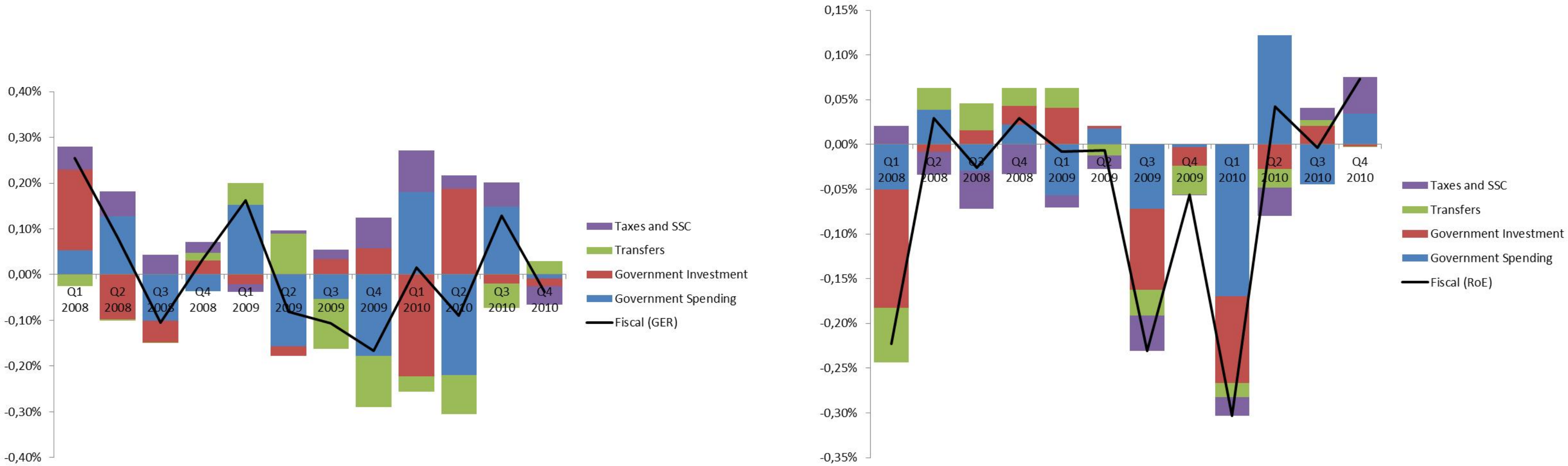
(a) Germany



(b) Rest of the Euro Area

Notes: Figure shows quarter-on-quarter GDP growth rates (demeaned) and the contribution of fiscal and disaggregated non-fiscal shocks to these developments. To annualize, rates have to be multiplied by four. The mean/trend growth rate in our sample period is 0.32% for Germany and 0.14% for the rest of the Euro Area.

Figure 9: Historical decomposition of fiscal policy's contribution to real GDP growth (demeaned)



(a) Germany

(b) Rest of the Euro Area

Notes: Figure shows fiscal policy's contribution to quarter-on-quarter GDP growth rates (demeaned); disaggregated growth contribution by fiscal components. To annualize, rates have to be multiplied by four. The mean/trend growth rate in our sample period is 0.32% for Germany and 0.14% for the rest of the Euro Area.

The picture is somewhat different in the rest of the Euro Area, shown in Panel 8b. Here, the main driver for the GDP slump in 2008 and the beginning of 2009 were domestic non-fiscal shocks, followed by negative growth contributions of UIP (or "divergence") shocks. Also negative German non-fiscal and rest of the world shocks contributed to the decline in Euro Area GDP growth. A noteworthy difference between German and rest of Euro Area growth rates is that, at the end of our sample period, negative domestic non-fiscal and negative UIP shocks in the rest of the Euro Area seem to pick up, while German GDP growth stays rather stable.

The second question, which fiscal shocks contributed to the fiscal impact on GDP growth rates, is addressed in Figure 9. The bold black line represents the contribution fiscal policy had on GDP growth, equivalent to the blue bars in Figure 7. We split this contribution into the components taxes and social security contributions, transfers, public investment and public spending, the latter including public purchases and expenditures for public employment.

We see that, in Germany, the positive fiscal growth impact in 2008 and 2009 was mainly driven by positive shocks to public spending, partly to investment and, to a lesser extent, tax reliefs. In 2009, positive transfers shocks also contributed notably. This corresponds to the time in which the investment and redemption fund was established to foster public investment (2008 and the following years) and in which several public transfer schemes were founded, such as, for example, the car scrap bonus program in 2009, public parental leave subsidies (established in 2007, but mainly started to being used in the years thereafter), an increase in social benefits or the short-time work allowances program. Regarding the positive impact of taxes and social security contributions on GDP growth in Germany during that time, we observed a cut in social security contributions (mainly to the health insurance system), an expansion of tax exemptions as well as an increase in possibilities for tax deductions, all of which are partly still in place today. Around 2010, German fiscal policy started to be somewhat more restrictive, partly to comply with the constitutionalized debt brake. This tighter fiscal stance was mainly expenditure driven. Hence, when contrasting our findings with actual measures conducted, the historical shock decomposition for Germany gives a plausible picture.

For the rest of the Euro Area, it is harder to relate the shock decomposition to concrete policy measures because we observe an aggregate of the rest of the Euro Area and measures were quite different in the corresponding countries. However, we can also note that most of the fiscal stimulus programs had a positive contribution to the GDP growth rates. Stimulus programs contained expenditure hikes and tax cuts. The historical shock decomposition based on our estimates for the rest of the Euro Area suggests that tax cuts had the most positive impact during that time. At the beginning of 2010, the fiscal situation in many of the rest of the Euro Area countries deteriorated and room for fiscal stimulus was narrowed so that some countries started consolidating early. This is reflected in the negative fiscal contribution in 2010Q1. Expenditure cuts were most responsible for the negative impact on GDP growth. Overall, the contribution of discretionary fiscal policy to GDP growth in the Euro Area was not as negative as some may have expected.

5 Conclusions

In this paper, we present the estimated large-scale three-region DSGE model *GEAR*, which pictures ***G***ermany, the ***E***uro ***A***rea and the ***R***est of the world. Relative to existing models of this type, *GEAR* incorporates a comprehensive fiscal block, involuntary unemployment and a complex international structure. We use the model to assess how *discretionary* fiscal policy in Germany and the Euro Area affected GDP growth during the crisis, evaluate spillovers of fiscal policy and calculate various present-value multipliers for distinct fiscal instruments.

We find that, during the crisis, fiscal stimulus packages increased quarterly GDP growth rates up to 1.2 pp and 0.12 pp in Germany and the rest of the Euro Area, while succeeding consolidation measures dampened quarterly GDP growth up to -0.8 pp and -1.2 pp. The main drivers of GDP growth in Europe were rest of the world and uncovered interest rate parity shocks, followed by domestic non-fiscal shocks. Spillovers of fiscal policy shocks to other regions are negligibly small, a finding that is also confirmed by calculating corresponding fiscal multipliers. Overall, spending multipliers are higher than revenue-based multipliers and in line with those found in the literature. A general conclusion from our study for policy makers concerns the need to choose the right mix of instruments for stimulus and consolidation measures, especially when the focus is on GDP growth.

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