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Comparing post-crisis dynamics across Euro Area countries with the Global Multi-country model

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ABSTRACT

Following the global financial crisis, the Euro Area (EA) has experienced a persistent slump and notable trade balance adjustments, but with pronounced differences across EA Member States. We estimate a multi-country structural macroeconomic model to assess and compare the main drivers of GDP growth and trade balance adjustment across Germany, France, Italy, and Spain. We find that the pronounced post-crisis slump in Italy and Spain was mainly driven by positive saving shocks ('deleveraging') and by an increase in investment and intra-euro risk premia. Fiscal austerity in Spain and the productivity slowdown in Italy have been additional sizable contributors to the economic downturn. The results further suggest that euro depreciation, heightened intra-euro risk premia and subdued investment had a sizable impact on the trade balance reversals in Italy and Spain, which has been offset in France by a strong increase in imports and lower exports.

1. Introduction

The macroeconomic situation in the Euro Area (EA) in the aftermath of the global financial crisis has been characterised by two developments: (1) a long-lasting slump in economic activity with a double-dip recession, and (2) a steady rise in the trade balance from (moderate) deficit to surplus (see e.g. Giovannini et al., 2018; Kollmann et al., 2016). However, these aggregate occurrences mask striking differences among the EA Member States. Italy and Spain have experienced protracted double-dip recessions, whereas the recession in Germany and France has been more short-lived. Concerning the trade balance, Italy and Spain have witnessed significant trade balance reversals into positive territory, following years of declining net exports prior to the financial crisis, and Germany's trade balance surplus has further increased, continuing its pre-crisis trend. France's trade balance, to the contrary, deteriorated prior to the financial crisis and has remained almost unchanged since 2009. What are the sources of these different patterns? Is this due to the different nature of the shock hitting these economies? Or is the transmission of the same shock that propagates differently in -say- Spain and Germany?

The existing literature has either focused on the EA aggregate (e.g. Kollmann et al., 2016; Giovannini et al., 2018) or has considered individual EA Member States in isolation (e.g. in't Veld et al. (2014, 2015) for Spain, and Kollmann et al. (2015) for Germany) so far. Even if country-specific studies have used the same class of macroeconomic models, the country-specific structural models all have differed along

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some dimensions. The present paper takes the literature on cross-country comparison a step further by estimating ex ante identical structural models for the four largest EA Member States on the basis of a fully harmonised information set. Differences in the information set may substantially affect structural estimates and model conclusions, as emphasised by Canova et al. (2014), so that estimates proceeding from different data sources cannot easily be compared. Therefore, the existing literature on estimated structural models is of limited use for cross-country comparison.

The contribution of this paper proceeds in two steps. First, we develop the European Commission's Global Multi-country (henceforth, GM) model, which is an estimated dynamic stochastic general equilibrium (DSGE) model that addresses the above-mentioned limits to cross-country analysis by providing a common platform to compare estimates for, at present, the four largest EA Member States (Germany, France, Italy, and Spain) using an ex-ante identical core structure. Second, we use the GM model to identify the main drivers of macroeconomic dynamics in Germany (DE), France (FR), Italy (IT), and Spain (ES) and explain the cross-country differences with respect to the depth and length of the recession starting in 2009 and the post-crisis trade balance adjustment. Using ex ante identical models means that all country-specific models have the same equations, the same prior parameter distributions and the same set of shocks. Moreover, when we bring the EA country-specific models to the data, we use the same information set, i.e. the same time span and an identical selection of observables. This set-up provides a framework for meaningful cross-country comparisons and for a direct measurement of heterogeneity that can be attributed to either the nature (size and persistence) of the shocks, or the associated transmission mechanisms pinned down by the structural parameters.

The GM model that we use for this comparative study builds on the estimated version of the QUEST III model (Ratto et al., 2009), from which it inherits most of its structure. The model has been developed to be flexible in the regional set-up in order to allow for different country configurations. This paper uses the GM model in a three-region configuration designed for the analysis of EA countries, which includes one EA Member State (DE, FR, IT, or ES), the rest of the Euro Area (REA), and the rest of the world (RoW). The model features a large set of supply and demand shocks in labour, goods and financial markets that incorporate nominal and real frictions. The single EA Member State in the model features rich dynamics, whereas the REA and RoW economies are defined in a more stylised form. The three regions are connected by trade and financial linkages and a common monetary policy for the EA. Trade in goods includes commodity (oil) imports from the RoW that are used for the production of domestic total output.

Using the terminology of Blanchard (2018), GM can be classified as a 'policy model' or 'model for policy purposes' that aims at providing quantitative insight into the dynamic effects of specific shocks and alternative policies. Fitting the data reasonably well is an important requirement for policy models and can motivate the introduction of elements, e.g. adjustment frictions and the lag structure, that do not obey to the ideal of maximum theoretical purity. Yet, the optimizing forward-looking behaviour of the agents that populate our model (household and firms) allows us to make meaningful comparison of different monetary or fiscal policy interventions. Moreover, the general equilibrium nature permits a rich set of feedback effects in response to shocks originating from each bit of the economic environment. In all, 'policy models' need to be able to capture actual dynamics, and, at the same time, they need enough theoretical structure to identify shocks, policies, and their effects or transmissions. We view the role of the GM model within this tradition.

Our estimation results suggest that the persistent post-crisis slump in Italy and Spain was mainly driven by domestic demand shocks, in particular positive saving shocks ('deleveraging'), adverse shocks to risk premia on investment, and an increase in intra-EA risk premia ('flight to safety'). Fiscal policy (austerity) in Spain and the productivity slowdown in Italy vis-à-vis the EA aggregate have been additional sizable contributors to the protracted economic downturn in the two countries. Less pronounced negative demand shocks have mitigated the economic slowdown in Germany. Our empirical analysis also suggests that the euro depreciation, the widening of intra-EA risk premia and subdued investments had a significant impact to the trade balance reversals in Italy and Spain. These contributions towards higher net exports have been offset in the case of France by a strong increase in imports and less exports to REA and RoW (negative trade shocks). In addition to the traditionally high saving rate in Germany, the increase in global trade and RoW aggregate demand, the euro depreciation and the decline in oil prices have raised Germany's trade balance surplus after the global financial crisis. The estimated model explains the cross-country differences in economic activity and net trade mostly by heterogeneity in the shocks; the transmission of individual shocks is similar across the four largest EA Member States according to the parameter estimates.

The remainder of this paper is structured as follows: Section 2 presents the theoretical specification of the GM model. The model solution and the econometric approach are discussed in Section 3. Section 4 discusses the estimation results. It evaluates the fitting properties of the estimated country models (Germany, France, Italy, and Spain), their ability to replicate key moments in the data, and analyses differences across countries in the internal transmission dynamics. Moreover, the section provides a quantitative assessment of the relative importance of supply and demand factors, international shocks and discretionary policy for explaining the post-crisis slump and trade balance adjustments in each of the four countries. Section 5 concludes.

2. The model

The GM model lies within the set of medium- and large-scale DSGE models developed and used at policy institutions around the world. Examples include the structural and semi-structural macroeconomic models developed at the ECB or the Eurosystem (see Bokan et al., 2018; Christoffel et al., 2008; Dieppe et al., 2012, 2018; Karadi et al., 2017), the IMF (Helliwell et al., 1990; Hunt and Laxton, 2004), the OECD (Hervé et al., 2011), or the central bank of New Zealand (Kamber et al., 2016). Additionally, most of the national central banks of the Eurosystem have developed DSGE models tailored to capture country-specific business cycles fluctuations, e.g. NONAME for Belgium (Jeanfils and Burggraeve, 2008), FiMOD (Stähler and Thomas, 2012) for Spain, or GEAR for Germany (Gadatsch et al., 2016). Related model comparison exercises can be found, e.g., in Wallis (2004) or in more recent studies by Coenen et al. (2012), Taylor and Wieland (2012), and Wieland et al. (2012, 2016). An overview of institutional applications of the GM model, in particular contributions to the European Commission's economic forecast and policy counterfactuals, can be found in Albonico et al. (2019).

The GM model specification in this paper features three regions: an EMU country, the REA and the RoW. The EMU domestic economy is composed of households, non-financial firms operating either in the domestic market or in the import-export sector, a government and a central bank.

We distinguish between two types of households: Ricardian households are infinitely-lived and have access to financial markets, can smooth their consumption and own the firms; liquidity-constrained households consume their disposable wage and transfer income each period and do not own any financial wealth. Both types of households provide labour services to domestic firms, at the wage set by a labour union with monopoly power.

In the domestic production sector, monopolistically competitive firms produce a variety of differentiated intermediate goods, which are assembled by perfectly competitive firms into a domestic final output

good (value added). In a final step, perfectly competitive firms produce total output by combining value added with energy input.

In the import sector, perfectly competitive firms (import retailers) buy economy-specific goods from the foreign country and assemble them into a final imported good. Final good packagers combine the final imported good with domestic output into final aggregate demand components goods.

The fiscal authority purchases domestic final goods and makes lump-sum transfers to households that are financed by issuing debt and levying distortionary taxes on labour, capital, and consumption, as well as non-distortionary lump-sum taxes. Given the monetary union setting, the European Central Bank (ECB) sets the nominal interest rate following a Taylor rule defined on EA aggregate inflation and the output gap.

The REA and RoW economies are more stylised, featuring a standard three-equation New Keynesian model, consisting of an Euler equation for consumption, a New Keynesian Phillips curve and a Taylor rule. The model is augmented by international trade.

2.1. EMU country households

There is a continuum of households, indexed by $j \in [0,1]$, living in each region k. A share ω_k^s of Ricardian households - savers (s) - owns firms and trades assets in the financial market. The remaining share is liquidity-constrained (c) and consumes its entire disposable wage and transfer income each period. Households preferences are defined over consumption and leisure. Additionally, Ricardian's utility depends on the beginning-of-period financial asset holdings.

2.1.1. Ricardian households

Ricardian preferences are given by the infinite horizon expected lifetime utility:

$$U_{j,k}^s = E_0 \sum_{t=0}^{\infty} (\widetilde{\beta}_{k,t})^t u_{j,k,t}^s(.),$$

where $\widetilde{\beta}_{k,t} = \beta_k \exp(\varepsilon_{k,t-1}^c)$, β_k is the (non-stochastic) discount factor, $\varepsilon_{k,t}^c$ captures a shock to the subjective rate of time preference (saving shock).

Ricardians have full access to financial markets, allowing them to accumulate wealth, $A_{j,k,t}$, which consists of domestic private risk-free bonds, $B_{j,k,t}^{rf}$, domestic government bonds, $B_{j,k,t}^G$, one internationally traded bond, $B_{j,k,t}^W$, and domestic shares, $P_{k,t}^S S_{j,k,t}$:

$$A_{j,k,t} = B_{j,k,t}^{rf} + B_{j,k,t}^G + e_{RoW,k,t} B_{j,k,t}^W + P_{k,t}^S S_{j,k,t},$$

where $P_{k,t}^S$ is the nominal price of shares at time t. Since the international bond is denominated in RoW currency, financial wealth depends on the nominal exchange rate $e_{RoW,k,t}$.

The instantaneous utility function of savers, $u^s(.)$, is defined as:

$$u_{j,k,t}^s(C_{j,k,t}^s, N_{j,k,t}^s, \frac{U_{j,k,t-1}^A}{P_{k,t}^{C,vat}}) = \frac{1}{1-\theta_k}(C_{j,k,t}^s - h_k C_{k,t-1}^s)^{1-\theta_k} - \frac{\omega_k^N \varepsilon_{k,t}^U}{1+\theta_k^N}(C_{k,t})^{1-\theta_k}(N_{j,k,t}^s)^{(1+\theta_k^N)} - (C_{k,t}^s - h_k C_{k,t-1}^s)^{-\theta_k}\frac{U_{j,k,t-1}^A}{P_{k,t}^{C,vat}},$$

where $C_{k,t}^s = \int_0^1 C_{j,k,t}^s dj$, h_k measures the strength of external habits in consumption and ω_k^N the weight of the disutility of labour. $\varepsilon_{k,t}^U$ captures a labour supply shock. The disutility of holding risky financial assets, $U_{j,k,t-1}^A$, takes the following form:

$$U_{j,k,t-1}^A = \left(\alpha_k^{b_0} + \varepsilon_{k,t-1}^B\right) B_{j,k,t-1}^G + \left(\alpha_k^{bw_0} + \varepsilon_{k,t-1}^{bw}\right) e_{RoW,k,t-1} B_{j,k,t-1}^W + \frac{\alpha_k^{bw_1}}{2}\frac{(e_{RoW,k,t-1}B_{k,t-1}^W)^2}{P_{k,t-1}^Y Y_{k,t-1}} + \left(\alpha_k^{S_0} + \varepsilon_{k,t-1}^S\right) P_{k,t-1}^S S_{j,k,t-1}.$$

Internationally traded bonds are subject to transaction costs in form of a function of the net foreign asset position relative to GDP. The asset specific risk premium depends on an asset specific exogenous shock $\varepsilon^x, x \in \{B, S, bw\}$, and an asset specific intercept $\alpha^x, x \in \{b_0, S_0, bw_0\}$. Similar to Krishnamurthy and Vissing-Jorgensen (2012) and Fisher (2015), the approach of modelling the disutility of holding risky assets captures the households preferences for safe assets, i.e. the risk-free short term bonds, which generates endogenously a wedge between the return on risky assets and safe bonds.[1] As in Benigno (2009) and Ratto et al. (2009), we assume that only the RoW bond is traded internationally.[2] It follows that households in the Euro Area can invest in both national and foreign assets, while RoW households can only invest in domestic bonds.

The j^{th} Ricardian household faces the following budget constraint:

$$P_{k,t}^{C,vat} C_{j,k,t}^s + A_{j,k,t} = (1-\tau_k^N) W_{k,t} N_{j,k,t}^s + (1+i_{k,t-1}^{rf}) B_{j,k,t-1}^{rf} + (1+i_{k,t-1}^G) B_{j,k,t-1}^G + (P_{k,t}^S + P_{k,t}^Y \Pi_{k,t}^f) S_{j,k,t-1} + (1+i_{t-1}^W) e_{RoW,k,t} B_{j,k,t-1}^W + T_{j,k,t}^s - tax_{j,k,t}^s, \quad (1)$$

where $P_{k,t}^{C,vat}$ defines the private consumption deflator[3] in terms of input factors, $W_{k,t}$ denotes the nominal wage rate, $N_{j,k,t}^s$ is the employment in hours, $T_{j,k,t}^s$ are government transfers and $tax_{j,k,t}^s$ lump-sum taxes paid by savers. Moreover, $i_{k,t}^{rf}$, $i_{k,t}^G$, and i_t^W are returns on domestic private risk-free bonds, domestic government bonds, and internationally traded bonds, respectively. As Ricardian households own the firms, they receive nominal profits in form of dividends, $P_{k,t}^Y \Pi_{k,t}^f$, that are distributed by differentiated goods producers according to the number of shares held by the households. We define the gross nominal return on shares S_t as:

$$1 + i_{k,t}^S = \frac{P_{k,t}^S + P_{k,t}^Y \Pi_{k,t}^f}{P_{k,t-1}^S}.$$

The Ricardian households maximise the present value of the expected stream of future utility subject to equation (1), by choosing the amount of consumption, $C_{j,k,t}^s$, and next period asset holdings: $B_{j,k,t}^{rf}$, $B_{j,k,t}^G$, $S_{j,k,t}$. The maximisation problem results in the following first-order conditions (FOCs):

$$\lambda_{j,k,t}^s = (C_{k,t}^s - h_k C_{k,t-1}^s)^{-\theta_k}, \quad (2)$$

$$1 = \widetilde{\beta}_t E_t \left[\frac{\lambda_{j,k,t+1}^s}{\lambda_{j,k,t}^s}\frac{(1+i_{k,t}^{rf})}{1+\pi_{k,t+1}^{C,vat}}\right], \quad (3)$$

$$1 = \widetilde{\beta}_t E_t \left[\frac{\lambda_{j,k,t+1}^s}{\lambda_{j,k,t}^s}\frac{(1+i_{k,t}^G) - \left(\varepsilon_{k,t}^B + \alpha_k^{b_0}\right)}{1+\pi_{k,t+1}^{C,vat}}\right], \quad (4)$$

[1] This modification is along the lines of the money-in-utility approach by Sidrauski (1967), in which agents derive utility from their holdings of money. In our model, it reflects the costs of holding risky assets relative to risk-free assets. A similar framework is used by Vitek (2014, 2017).

[2] This assumption is consistent with a reduced form of a global bank in RoW lending domestically and abroad. A similar formulation is adopted also by Kollmann et al. (2013).

[3] $P_{k,t}^{C,vat}$ is the VAT adjusted private consumption deflator, $P_{k,t}^{C,vat} = (1+\tau_k^C) P_{k,t}^C$, where τ^C is the tax rate on consumption (VAT).

$$1 = \widetilde{\beta}_t E_t \left[\frac{\lambda^s_{j,k,t+1}}{\lambda^s_{j,k,t}} \frac{(1 + i^S_{k,t+1}) - \left(\alpha_k^{S_0} + \varepsilon^S_{k,t}\right)}{1 + \pi^{C,vat}_{k,t+1}} \right]. \quad (5)$$

The optimality conditions are similar to standard Euler equations, but incorporate asset-specific risk premia similar to Vitek (2014, 2017), which depend on exogenous shocks ε^B_{kt}, ε^S_{kt}. Combining the Euler equation for the risk-free bond (3) with (4) and (5), we obtain the approximated following expressions:

$$i^G_{k,t} = i^{rf}_{k,t} + rprem^G_{k,t},$$

$$i^S_{k,t} = i^{rf}_{k,t} + rprem^S_{k,t},$$

where $rprem^G_{k,t}$ and $rprem^S_{k,t}$ are risk premia on domestic government bonds and domestic shares, respectively.[4]

Given the monetary union setting, the nominal exchange rate between the k^{th} EMU country and EA is fixed, $e_{EA,k,t} = 1$, implying that $\Delta\ln(e_{RoW,EA,t+1}) = \Delta\ln(e_{RoW,k,t+1})$. We assume that an uncovered interest rate parity condition links the interest rate of the EMU country, $i^{rf}_{k,t}$, to the EA policy rate set by the ECB:

$$(1 + i^{rf}_{k,t}) = (1 + i_{EA,t}) - \left(\alpha_k^{bw1} \frac{e_{RoW,EA,t} B^W_{k,t}}{P^Y_{k,t} Y_{k,t}} + \varepsilon^{FQ}_{k,t} \right),$$

where $\alpha_k^{bw1} \frac{e_{RoW,EA,t} B^W_{k,t}}{P^Y_{k,t} Y_{k,t}}$ captures a debt-dependent country risk premium on net foreign asset holdings as external closure to ensure long-run stability (see Schmitt-Grohe and Uribe, 2003; Adolfson et al., 2008). Following Smets and Wouters (2007) we also introduce an additional risk premium shock, $\varepsilon^{FQ}_{k,t}$ ('flight to safety'), which creates a wedge between the EA policy rate, $i_{EA,t}$, and the return on domestic risk-free assets, $i^{rf}_{k,t}$. Since a positive shock increases the required return on domestic assets and the cost of capital, it reduces current consumption and investment simultaneously and helps explaining the comovement of consumption and investment.

2.1.2. Liquidity-constrained households

Liquidity-constrained households have no access to financial markets. Hence, the instantaneous utility function, $u^c(.)$, is:

$$u^c_{j,k,t}(C^c_{j,k,t} N^c_{j,k,t}) = \frac{1}{1-\theta_k}(C^c_{j,k,t} - h_k C^c_{k,t-1})^{1-\theta_k} - (C_{k,t})^{1-\theta_k} \frac{\omega^N_k \varepsilon^U_{k,t}}{1+\theta^N_k} (N^c_{j,k,t})^{1+\theta^N_k}.$$

In each period, they consume their disposable net income, which consists of labour income and net lump-sum transfers from the government. The budget constraint is described by:

$$(1 + \tau^C_k) P^C_{k,t} C^c_{j,k,t} = (1 - \tau^N_k) W_{k,t} N^c_{j,k,t} + T^c_{j,k,t} - tax^c_{j,k,t}.$$

2.1.3. Wage setting

Households are providing differentiated labour services, $N^r_{j,k,t}$, where $r \in \{s, c\}$ in a monopolistically competitive market. We assume that there is a labour union that bundles working hours provided by both types of domestic households into a homogeneous labour service and resells it to intermediate goods producing firms. We assume that Ricardian and liquidity-constrained households' labour is distributed proportionally to their respective population shares, ω^r_k. Since both households face the same labour demand schedule, each household works the same number of hours, $N^s_{k,t} = N^c_{k,t} = N_{k,t}$. It follows that the individual union's choice variable is a common nominal wage rate for both types of households.

The union maximises the discounted future stream of the weighted average of lifetime utility of its members with respect to the wage and subject to the weighted sum of their budget constraints and the intermediate good producing firms' demand for differentiated labour. Nominal rigidity in wage setting is introduced in the form of adjustment costs for changing wages. Additionally, we allow for real wage rigidity as in Blanchard and Galí (2007) and Coenen and Straub (2005), where the slow adjustment of real wages occurs through distortions rather than workers' preferences. The wage rule is determined by equating the marginal utility of leisure, $U^N_{k,t}$, to the weighted average of the marginal utility of consumption, $\lambda_{k,t}$, times the real wage adjusted for a wage mark-up:

$$\begin{aligned}
&\left[\frac{\mu^w_k U^N_{k,t}}{\lambda_{k,t}} \frac{P^{C,vat}_{k,t}}{P^Y_{k,t}} \right]^{1-\gamma^{wr}_k} \left[(1-\tau^N_k) \frac{W_{k,t-1}}{P^Y_{k,t-1}} \right]^{\gamma^{wr}_k} \\
&= (1-\tau^N_k) \frac{W_{k,t}}{P^Y_{k,t}} + \gamma^w_k \left(\frac{W_{k,t}}{W_{k,t-1}} - 1 - (1 - sfw_k)(\pi^Y_{k,t-1} - \overline{\pi}) - \pi^w \right) \\
&\quad \times \frac{W_{k,t}}{W_{k,t-1}} \frac{W_{k,t}}{P^Y_{k,t}} - \gamma^w_k E_t \left[\widetilde{\beta}_{k,t} \frac{\lambda_{k,t+1}}{\lambda_{k,t}} \frac{P^{C,vat}_{k,t}}{P^{C,vat}_{k,t+1}} \frac{N_{k,t+1}}{N_{k,t}} \right. \\
&\quad \left. \times \left(\frac{W_{k,t+1}}{W_{k,t}} - 1 - (1 - sfw_k)(\pi^Y_{k,t} - \overline{\pi}) - \pi^w \right) \frac{W_{k,t+1}}{W_{k,t}} \frac{W_{k,t}}{P^Y_{k,t}} \right] \\
&\quad + \frac{W_{k,t}}{P^Y_{k,t}} \varepsilon^U_{k,t},
\end{aligned}$$

where μ^w_k is the gross wage mark-up, γ^w_k and γ^{wr}_k represent the degree of nominal and real wage rigidity, respectively, sfw_k is the degree of forward-lookingness in the labour supply equation, and $\varepsilon^U_{k,t}$ captures a shock to the wage mark-up (labour supply shock).[5] The marginal utility of leisure is defined as: $U^N_{k,t} = \omega^N_k (C_{k,t})^{1-\theta_k} (N_{k,t})^{-\theta^N_k}$, and the weighted average of the marginal utility of consumption is given by:

$$\lambda_{k,t} = \omega^s_k (C^s_{k,t} - h_k C^s_{k,t-1})^{-\theta_k} + (1 - \omega^s_k)(C^c_{k,t} - h_k C^c_{k,t-1})^{-\theta_k}.$$

2.2. EMU country production sector

2.2.1. Total output

Total output, $O_{k,t}$, is produced by perfectly competitive firms by combining value added, $Y_{k,t}$, with energy input, $Oil_{k,t}$, using the following CES production function:

[4] Observationally, this approach is equivalent to assuming exogenous risk premia as well as endogenous risk premia derived, e.g., in the spirit of Bernanke et al. (1996).

[5] As the German government implemented an extensive labour market deregulation in 2003–05 ('Hartz' reforms) that included a reduction in unemployment benefits, we capture the effect of the 'Hartz reforms' by treating the benefit replacement rate (ratio of unemployment benefit to wage rate) as an autocorrelated exogenous variable. Following the approach by Kollmann et al. (2015), we observe the historical benefit ratio and estimate the labour market reform as an exogenous permanent reduction in the unemployment benefit ratio. Therefore, real unemployment benefits (paid to unemployed workers of the labour force) enters the budget constraints of the households and the government. The wage setting equation on the left hand side is adjusted by $\left[(1-\tau^N_k) \frac{W_{k,t-1}}{P^Y_{k,t-1}} - BEN_{k,t-1} \right]$, with $BEN_{k,t} = b^U_{k,t} \frac{W_{k,t}}{P^Y_{k,t}}$, where $b^U_{k,t}$ is the replacement rate. A similar adjustment is also done on the right hand side: $\left[(1-\tau^N_k) \frac{W_{k,t}}{P^Y_{k,t}} - BEN_{k,t} \right]$. Since it is only a German-specific labour market shock, we abstract from the inclusion into the general model equations.

$$O_{k,t} = \left[(1 - s_k^{Oil})^{\frac{1}{\sigma_k^o}} (Y_{k,t})^{\frac{\sigma_k^o - 1}{\sigma_k^o}} + (s_k^{Oil})^{\frac{1}{\sigma_k^o}} (Oil_{k,t})^{\frac{\sigma_k^o - 1}{\sigma_k^o}} \right]^{\frac{\sigma_k^o}{\sigma_k^o - 1}}, \quad (6)$$

where s_k^{Oil} is the energy input share[6] and σ_k^o is the elasticity of substitution between factors. Each total domestic output firm maximises its expected profits:

$$\max_{Y_{k,t}, Oil_{k,t}} P_{k,t}^O O_{k,t} - P_{k,t}^Y Y_{k,t} - P_{k,t}^{Oil} Oil_{k,t}$$

subject to the production function (6). The respective first order conditions for the intermediate domestic output and oil are given by:

$$Y_{k,t} = (1 - s_k^{Oil}) \left(\frac{P_{k,t}^Y}{P_{k,t}^O} \right)^{-\sigma_k^o} O_{k,t},$$

$$Oil_{k,t} = s_k^{Oil} \left(\frac{P_{k,t}^{Oil}}{P_{k,t}^O} \right)^{-\sigma_k^o} O_{k,t}.$$

Oil is assumed to be imported from RoW. Hence, the oil price is taken as given:

$$P_{k,t}^{Oil} = e_{RoW,k,t} P_{RoW,t}^{Oil} + \tau^{Oil} P_t^{Y0},$$

where $e_{RoW,k,t}$ is the exchange rate, measured as price of foreign currency in terms of domestic currency, τ^{Oil} and P_t^{Y0} are the excise duty and the (global) GDP deflator trend, respectively. The price index of the composite total output is:

$$P_{k,t}^O = \left[(1 - s_k^{Oil})(P_{k,t}^Y)^{\sigma_k^o - 1} + s_k^{Oil} (P_{k,t}^{Oil})^{\sigma_k^o - 1} \right]^{\frac{1}{1 - \sigma_k^o}}.$$

2.2.2. Value added sector

Value added, $Y_{k,t}$, is produced by perfectly competitive firms by combining a continuum of differentiated goods, $Y_{i,k,t}$, produced by monopolistically competitive firms, according to a Dixit and Stiglitz (1977) production technology:

$$Y_{k,t} = \left[\int_0^1 Y_{i,k,t}^{\frac{\sigma_k^Y - 1}{\sigma_k^Y}} di \right]^{\frac{\sigma_k^Y}{\sigma_k^Y - 1}},$$

where σ_k^Y represents the inverse of the steady state gross price mark-up on differentiated goods. The demand for a differentiated good i is then:

$$Y_{i,k,t} = \left(\frac{P_{i,k,t}}{P_{k,t}^Y} \right)^{-\sigma_k^Y} Y_{k,t}, \quad (7)$$

where $P_{i,k,t}$ is the price of intermediate inputs and the corresponding price index is:

$$P_{k,t}^Y = \left[\int_0^1 (P_{i,k,t})^{1 - \sigma_k^Y} di \right]^{\frac{1}{1 - \sigma_k^Y}}.$$

[6] Note that s_k^{Oil} is perturbed by a trend shock to the degree of country openness, as specified below in equation (15).

2.2.3. Intermediate goods producers

Each firm $i \in [0, 1]$ produces a variety of the domestic good which is an imperfect substitute for varieties produced by other firms. Given imperfect substitutability, firms are monopolistically competitive in the goods market and face a downward-sloping demand function for goods.

Differentiated goods are produced using total capital, $K_{i,k,t-1}^{tot}$, and labour, $N_{i,k,t}$, which are combined in a Cobb-Douglas production function:

$$Y_{i,k,t} = \left[A_{k,t}^Y (N_{i,k,t} - FN_{i,k,t}) \right]^{\alpha_k} (CU_{i,k,t} K_{i,k,t-1}^{tot})^{1 - \alpha_k} - A_{k,t}^Y FC_{i,k}, \quad (8)$$

where α_k is the steady-state labour share, $A_{k,t}^Y$ represents the labour-augmenting productivity common to all firms in the differentiated goods sector, $CU_{i,k,t}$ and $FN_{i,k,t}$ are firm-specific levels of capacity utilisation and labour hoarding, respectively.[7] $FC_{i,k}$ captures fixed costs in production. Total capital is the sum of private installed capital, $K_{i,k,t}$, and public capital, $K_{i,k,t}^G$:

$$K_{i,k,t}^{tot} = K_{i,k,t} + K_{i,k,t}^G.$$

Since total factor productivity (TFP) is not a stationary process, we allow for two types of shocks. They are related to a non stationary process and its autoregressive component:

$$\log(A_{k,t}^Y) - \log(A_{k,t-1}^Y) = g_{k,t}^{\overline{A}^Y} + \varepsilon_{k,t}^{L\overline{AY}},$$

$$g_{k,t}^{\overline{A}^Y} = \rho^{\overline{A}^Y} g_{k,t-1}^{\overline{A}^Y} + (1 - \rho^{\overline{A}^Y}) g^{\overline{A}^{Y0}} + \varepsilon_{k,t}^{g\overline{AY}},$$

where $g_{k,t}^{\overline{A}^Y}$ and $g^{\overline{A}^{Y0}}$ are the time-varying and the long-run growth rates of technology, respectively, and $\varepsilon_{k,t}^{L\overline{AY}}$ is a permanent technological shock.

Monopolistically competitive firms maximise the real value of the firm, $\frac{P_{k,t}^S}{P_{k,t}^Y} S_{k,t}$, which is the discounted stream of expected future profits, subject to the output demand (7), the technology constraint (8), and the law of motion of capital, $K_{i,k,t} = I_{i,k,t} + (1 - \delta_k) K_{i,k,t-1}$.[8] Their problem can be written as:

$$\max_{P_i, N_i, I_i, K_i, CU_i, FN_i} E_t \sum_{s=t}^{\infty} D_{k,s}^S \Pi_{i,k,s}^f,$$

where the stochastic discount factor, $D_{k,s}^S$, is:

$$D_{k,s}^S = \frac{1 + r_{k,t}^S}{\prod_{r=t}^{s} (1 + r_{k,r}^S)}$$

with $1 + r_{k,t}^S = E_t \left[\frac{1 + i_{k,t+1}^S}{1 + \pi_{k,t+1}^Y} \right]$ being the real stock return. The period t profit of an intermediate goods firm i is given by:

$$\Pi_{i,k,t}^f = (1 - \tau_k^K) \left(\frac{P_{i,k,t}^Y}{P_{k,t}^Y} Y_{i,k,t} - \frac{W_{k,t}}{P_{k,t}^Y} N_{i,k,t} \right) + \tau_k^K \delta_k \frac{P_{k,t}^I}{P_{k,t}^Y} K_{i,k,t-1} - \frac{P_{k,t}^I}{P_{k,t}^Y} I_{i,k,t} - adj_{i,k,t},$$

where $I_{i,k,t}$ is the physical investment at price $P_{i,k,t}^I$, τ_k^K is the corporate tax and δ_k the capital depreciation rate.

[7] According to Burnside and Eichenbaum (1996), firms prefer not to layoff workers when the demand is temporarily low, because firing workers may be more costly than hoarding them. Additionally, the inclusion of labor hoarding, $FN_{i,k,t}$, allows to match the observed co-movement between output and working hours.

[8] We assume that the total number of shares $S_{k,t} = 1$.

Following Rotemberg (1982), firms face quadratic adjustment costs, $adj_{i,k,t}$, measured in terms of production input factors. Specifically, the adjustment costs are associated with the output price, $P^Y_{i,k,t}$, labour input, $N_{i,k,t}$, investment, $I_{i,k,t}$, as well as capacity utilisation variation, $CU_{i,k,t}$, and labour hoarding, $FN_{i,k,t}$:

$$adj^{P^Y}_{i,k,t} = \sigma^Y_k \frac{\gamma^P_k}{2} Y_{k,t} \left[\frac{P^Y_{i,k,t}}{P^Y_{i,k,t-1}} - \exp(\overline{\pi}) \right]^2,$$

$$adj^N_{i,k,t} = \frac{\gamma^N_k}{2} Y_{k,t} \left[\frac{N_{i,k,t} - FN_{i,k,t}}{N_{i,k,t-1} - FN_{i,k,t-1}} - \exp(g^{pop}) \right]^2,$$

$$adj^I_{i,k,t} = \frac{P^I_{k,t}}{P^Y_{k,t}} \left[\frac{\gamma^{I,1}_k}{2} K_{k,t-1} \left(\frac{I_{i,k,t}}{K_{k,t-1}} - \delta^K_{k,t} \right)^2 + \frac{\gamma^{I,2}_k}{2} \frac{(I_{i,k,t} - I_{i,k,t-1} \exp(g^Y_k + g^{P^I_k}))^2}{K_{k,t-1}} \right],$$

$$adj^{CU}_{i,k,t} = \frac{P^I_{k,t}}{P^Y_{k,t}} K^{tot}_{i,k,t-1} \left[\gamma^{CU,1}_k (CU_{i,k,t} - 1) + \frac{\gamma^{CU,2}_k}{2} (CU_{i,k,t} - 1)^2 \right],$$

$$adj^{FN}_{i,k,t} = Y_t \left[\gamma^{FN,2}_k \left(\frac{FN_{i,k,t}}{Actr_{k,t} Pop_{k,t}} - \overline{FN} \right) + \frac{\gamma^{FN,2}_k}{2} \left(\frac{FN_{i,k,t}}{Actr_{k,t} Pop_{k,t}} - \overline{FN} \right)^2 \right],$$

where γ's capture the degree of adjustment costs, $\overline{\pi}$, g^{pop}, g^Y_k, $g^{P^I_k}$ are the steady-state growth rates of inflation, population, and country-specific GDP and investment price deflator, respectively. $Actr_{k,t} Pop_{k,t}$ is the active labour force and $\overline{FN}$ is the steady-state labour hoarding. $\delta^K_{k,t} \neq \delta_k$ is a function of the depreciation rate adjusted for the capital trend in order to have zero adjustment costs on the trend-path.[9]

Given the Lagrange multiplier associated with the technology constraint, μ^y, the FOCs with respect to labour, labour hoarding, capital, investment, and capacity utilisation are given by:

$$(1 - \tau^K_k) \frac{W_{k,t}}{P^Y_{k,t}} = \alpha_k \left(\mu^y_{k,t} - \varepsilon^{ND}_{k,t} \right) \frac{Y_{k,t}}{N_{k,t} - FN_{k,t}} - \frac{\partial adj^N_{k,t}}{\partial N_{k,t}} + E_t \left[\frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{\partial adj^N_{k,t+1}}{\partial N_{k,t}} \right], \tag{9}$$

$$\mu^y_{k,t} \alpha_k \frac{Y_{k,t}}{N_{k,t} - FN_{k,t}} = -\frac{Y_{k,t}}{Actr_{k,t} Pop_{k,t}} \times \left(\gamma^{FN,1}_k + \gamma^{FN,2}_k \left(\frac{FN_{k,t}}{Actr_{k,t} Pop_{k,t}} - \overline{FN} \right) \right) + \frac{\partial adj^N_{k,t}}{\partial FN_{k,t}} - E_t \left[\frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{\partial adj^N_{k,t+1}}{\partial FN_{k,t}} \right], \tag{10}$$

$$Q_{k,t} = E_t \left[\frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{P^I_{k,t+1}}{P^Y_{k,t+1}} \frac{P^Y_{k,t}}{P^I_{k,t}} \left(\tau^K_k \delta_k - \frac{\partial adj^{CU}_{k,t}}{\partial K_{k,t-1}} + Q_{k,t+1}(1 - \delta_k) + (1 - \alpha_k) \mu^Y_{k,t+1} \frac{P^Y_{k,t+1}}{P^I_{k,t+1}} \frac{Y_{kt+1}}{K^{tot}_{k,t}} \right) \right], \tag{11}$$

$$Q_{k,t} = \left[1 + \gamma^{I,1}_k \left(\frac{I_{k,t}}{K_{k,t-1}} - \delta^K_{k,t} \right) + \gamma^{I,2}_k \frac{(I_{k,t} - I_{k,t-1} \exp(g^Y_k + g^{P^I_k}))}{K_{k,t-1}} \right] - E_t \left[\frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{P^I_{k,t+1}}{P^Y_{k,t+1}} \frac{P^Y_{k,t}}{P^I_{k,t}} \exp(g^Y_k + g^{P^I_k}) \gamma^{I,2}_k \frac{(I_{k,t+1} - I_{k,t} \exp(g^Y_k + g^{P^I_k}))}{K_{k,t}} \right], \tag{12}$$

$$\mu^y_{k,t}(1 - \alpha_k) \frac{Y_{k,t}}{CU_{k,t}} \frac{P^Y_{k,t}}{P^I_{k,t}} = K^{tot}_{k,t-1} \left[\gamma^{u,1}_k + \gamma^{u,2}_k (CU_{k,t} - 1) \right], \tag{13}$$

where $Q_{k,t} = \mu_{k,t} / \frac{P^I_{k,t}}{P^Y_{k,t}}$ represents Tobin's Q. Equations (9) and (10) characterise the optimal level of labour input, taking into account labour hoarding. While equation (9) equates the marginal cost of labour to its marginal productivity, equation (10) determines the optimal level of labour hoarding at the expense of the loss in the marginal productivity. Equations (11) and (12) define the Tobin's Q, which is equal to the replacement cost of capital (the relative price of capital). Finally, equation (13) describes capacity utilisation, where the left-hand side indicates the additional output produced, while the right-hand side captures the costs of higher utilisation rate.

Given the Rotemberg set-up and imposing the price symmetry condition, $P^Y_{i,k,t} = P^Y_{k,t}$, the FOC with respect to $P^Y_{i,k,t}$ yields the New Keynesian Phillips curve:

$$\mu^y_{k,t} \sigma^Y_k = (1 - \tau^K_k)(\sigma^Y_k - 1) + \sigma^Y_k \gamma^P_k \frac{P^Y_{k,t}}{P^Y_{k,t-1}} \left(\pi^Y_{k,t} - \overline{\pi} \right) - \sigma^Y_k \gamma^P_k \left[\frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{P^Y_{k,t+1}}{P^Y_{k,t}} \frac{Y_{k,t+1}}{Y_{k,t}} \left(\pi^Y_{k,t+1} - \overline{\pi} \right) \right] + \sigma^Y_k \varepsilon^{\mu}_{k,t},$$

where $\varepsilon^{\mu Y}_{k,t}$ is the inverse of the markup shock.

In order to allow firms to be less forward-looking in their price setting, we introduce a backward-looking term $\pi^\star_{k,t} = \rho^{\pi^\star}_k \overline{\pi} + (1 - \rho^{\pi^\star}_k)(\pi^Y_{k,t-1})$. The final New Keynesian Phillips curve takes then the following form:

$$\mu^y_{k,t} \sigma^Y_k = (1 - \tau^K_k)(\sigma^Y_k - 1) + \sigma^Y_k \gamma^P_k \frac{P^Y_{k,t}}{P^Y_{k,t-1}} \left(\pi^Y_{k,t} - \overline{\pi} \right) - \sigma^Y_k \gamma^P_k \frac{1 + \pi^Y_{k,t+1}}{1 + i^s_{k,t+1}} \frac{P^Y_{k,t+1}}{P^Y_{k,t}} \frac{Y_{k,t+1}}{Y_{k,t}} \times \left[sfp_k \left(\pi^Y_{k,t+1} - \overline{\pi} \right) + (1 - sfp_k)(\pi^\star_{k,t} - \overline{\pi}) \right] + \sigma^Y_k \varepsilon^{\mu Y}_{k,t}, \tag{14}$$

where sfp_k is the share of forward-looking price setters.[10]

2.3. Trade

2.3.1. Exchange rates and terms of trade

The nominal effective exchange rate, $e_{k,t}$, measures the trade weighted average price of foreign currency in terms of domestic currency and is defined as:

$$e_{k,t} = \prod_l (e_{l,k,t})^{w^T_{l,k,t}},$$

where $e_{l,k,t}$ is the bilateral exchange rate between domestic country k and foreign country l. Similarly, the real effective exchange rate, $rer_{k,t}$,

[9] We specify $\delta^K_{k,t} = exp(g^{\bar{Y}} + GAPI0) - (1 - \delta_k)$, where $g^{\bar{Y}}$ and $GAPI0$ are the global GDP trend and the investment-specific technology growth, respectively, so that $\frac{I}{K} - \delta^k \neq 0$ along the trend path.

[10] When $\rho^{\pi^\star}_k = 0$, equation (14) nests the standard specification including static expectations. We use and estimate this modified specification for Italy and Spain, as it improves significantly the annual fit of GDP inflation and reduces an over-prediction of inflation at the end of our sample.

measures the trade weighted average price of foreign output in terms of domestic output:

$$rer_{k,t} = \prod_{l} (rer_{l,k,t})^{w^T_{l,k,t}},$$

where $rer_{l,k,t}$ is the bilateral real exchange rate between k and l. $w^T_{l,k,t}$ is the trade weight of the foreign trade partner l in the domestic economy's external trade and is defined as:

$$w^T_{l,k,t} = \frac{1}{2}\left(\frac{P^X_{l,k,t}X_{l,k,t}}{P^X_{k,t}X_{k,t}} + \frac{P^M_{l,k,t}size_{l,k}M_{l,k,t}}{P^{Mtot}_{k,t}M^{tot}_{k,t}}\right),$$

where $X_{l,k,t}$ and $M_{l,k,t}$ stand for domestic exports to and imports from country l, respectively, and $P^X_{l,k,t}$ and $P^M_{l,k,t}$ are the associated price indices. $P^{Mtot}_{k,t}M^{tot}_{k,t} = P^M_{k,t}M_{k,t} + P^{oil}_{k,t}OIL_{k,t}$ are the gross total nominal imports, including oil imports from RoW. $P^X_{k,t}$ and $P^M_{k,t}$ are the respective price aggregates and are defined in the next section.

The terms of trade, $TOT_{k,t}$, are the relative price of export over import goods, that is:$TOT_{k,t} = \frac{P^X_{k,t}}{P^M_{k,t}}$.

2.3.2. Import sector

2.3.2.1. Final good packagers (aggregate import demand). The final aggregate demand component goods $C_{k,t}$ (private consumption good), $I_{k,t}$ (private investment good), $G_{k,t}$ (government consumption good), $I^G_{k,t}$ (government investment good), as well as $X_{k,t}$ (export good) are produced by perfectly competitive firms by combining domestic output, $O^{\mathcal{D}}_{k,t}$, with imported goods, $M^{\mathcal{D}}_{k,t}$, where $\mathcal{D} \in \{C, I, G, I^G, X\}$, using the following CES production function:

$$\mathcal{D}_{k,t} = A^{p^{\mathcal{D}}}_{k,t}\left[(1-u^M_{k,t}s^{M,\mathcal{D}}_k)^{\frac{1}{\sigma^z_k}}(O^{\mathcal{D}}_{k,t})^{\frac{\sigma^z_k-1}{\sigma^z_k}} + (u^M_{k,t}s^{M,\mathcal{D}}_k)^{\frac{1}{\sigma^z_k}}(M^{\mathcal{D}}_{k,t})^{\frac{\sigma^z_k-1}{\sigma^z_k}}\right]^{\frac{\sigma^z_k}{\sigma^z_k-1}},$$

where σ^z_k is the elasticity of substitution of imports, $A^{p^{\mathcal{D}}}_{k,t}$ is a shock to productivity in the sector producing goods, $\mathcal{D}$, and $u^M_{k,t}$ is a shock to the share $s^{M,\mathcal{D}}_k$ of good-specific import demand components. The shock to the country openness is given by:

$$u^M_{k,t} = \exp(\varepsilon^M_{k,t})\left[1 + \tau^{MAY1}_{kk}\varepsilon^{TM}_{kk,t} - \sum_l (1-\tau^{MAY1}_{ll})\varepsilon^{TM}_{ll,t}s^M_{lk}\right]. \quad (15)$$

The shock is partially endogenized and composed of a country-specific shock, $\varepsilon^M_{k,t}$, and a bilateral trend, $\varepsilon^{TM}_{xx,t}$ with $xx \in \{kk, ll\}$, which depends on changes in the technology of trading partners. The latter is defined as:

$$\varepsilon^{TM}_{xx,t} = \rho^{TM}_x\varepsilon^{TM}_{xx,t-1} - (1-\rho^{TM}_x)\left[\tau^{MAY2}_{xx}A^{\bar{Y}}_{x,t-1}\frac{\exp(g^{AY0}_x)}{\bar{Y}}\right],$$

where ρ^{TM}_x captures the persistence of the trade trend, τ^{MAY2}_{xx} measures the relative competitiveness of the domestic country, and τ^{MAY1}_{xx} captures its impact on the openness. More precisely, an increase in relative productivity lowers the domestic degree of openness (proportionally to τ^{MAY1}_{xx}) and increases the degree of openness of trading partners towards domestic exports (proportionally to $(1-\tau^{MAY1}_{xx})$).[11]

From profit maximisation we obtain the following domestic, $O^{\mathcal{D}}$, and import, $M^{\mathcal{D}}$, demand aggregates:

$$O^{\mathcal{D}}_{k,t} = (A^{p^{\mathcal{D}}}_{k,t})^{\sigma^z_k-1}\left(1-u^M_{k,t}s^{M,\mathcal{D}}_k\right)\left(\frac{P^O_{k,t}}{P^{\mathcal{D}}_{k,t}}\right)^{-\sigma^z_k}\mathcal{D}_{k,t},$$

$$M^{\mathcal{D}}_{k,t} = (A^{p^{\mathcal{D}}}_{k,t})^{\sigma^z_k-1}u^M_{k,t}s^{M,\mathcal{D}}_k\left(\frac{P^M_{k,t}}{P^{\mathcal{D}}_{k,t}}\right)^{-\sigma^z_k}\mathcal{D}_{k,t},$$

where $P^{\mathcal{D}}_{k,t}$ is the price deflator associated to the demand components:

$$P^{\mathcal{D}}_{k,t} = (A^{p^{\mathcal{D}}}_{k,t})^{-1}\left[(1-u^M_{k,t}s^{M,\mathcal{D}}_k)(P^O_{k,t})^{1-\sigma^z_k} + u^M_{k,t}s^{M,\mathcal{D}}_k(P^M_{k,t})^{1-\sigma^z_k}\right]^{\frac{1}{1-\sigma^z_k}}.$$

We define total non-oil imports as:

$$M_{k,t} = M^C_{k,t} + M^I_{k,t} + M^G_{k,t} + M^{IG}_{k,t} + M^X_{k,t}.$$

2.3.2.2. Import retailers (economy-specific final import demand). Final imported goods are produced by perfectly competitive firms combining economy-specific final imports. They maximise the following profit function:

$$\max_{M_{l,k,t}} P^M_{k,t}M_{k,t} - \sum_l P^M_{l,k,t}M_{l,k,t}\frac{size_l}{size_k}$$

subject to the following CES production function:

$$M_{k,t} = \left[\sum_l \left(s^M_{l,k}u^M_{l,k,t}\right)^{\frac{1}{\sigma^{FM}_k}}\left(M_{l,k,t}\frac{size_l}{size_k}\right)^{\frac{\sigma^{FM}_k-1}{\sigma^{FM}_k}}\right]^{\frac{\sigma^{FM}_k}{\sigma^{FM}_k-1}},$$

where σ^{FM}_k is the price elasticity of demand for country l's goods and $\sum_l s^M_{lk} = 1$ are the import shares. The demand for goods from country l is given by:

$$M_{l,k,t} = s^M_{l,k}u^M_{l,k,t}\left(\frac{P^M_{l,k,t}}{P^M_{k,t}}\right)^{-\sigma^{FM}_k}M_{k,t}\frac{size_k}{size_l},$$

where $u^M_{l,k,t}$ captures an endogenous bilateral trend component:

$$u^M_{l,k,t} = \frac{1-(1-\tau^{MAY1}_{ll})\varepsilon^{TM}_{ll,t}}{1-\sum_z(1-\tau^{MAY1}_{zz})\varepsilon^{TM}_{zz,t}s^M_{z,k}}. \quad (16)$$

The import price index is:

$$P^M_{k,t} = \left[\sum_l s^M_{l,k}u^M_{l,k,t}(P^M_{l,k,t})^{1-\sigma^{FM}_k}\right]^{\frac{1}{1-\sigma^{FM}_k}}$$

with $P^M_{l,k,t}$ being the economy-specific import goods price. Since all products from country l are initially purchased at export price, $P^X_{l,t}$, the economy-specific import goods price can be also expressed as:

$$P^M_{l,k,t} = e_{l,k,t}P^X_{l,t}.$$

2.3.3. Export sector

The exporting firms are competitive and export a good that is a combination of domestic output and import content. Their profit maximisation problem is defined in Section 2.3.2. The corresponding export price is given by:

$$P^X_{k,t} = \exp(\varepsilon^X_{k,t})\left[(1-u^M_{k,t}s^{M,X}_k)(P^O_{k,t})^{1-\sigma^z_k} + u^M_{k,t}s^{M,X}_k(P^M_{k,t})^{1-\sigma^z_k}\right]^{\frac{1}{1-\sigma^z_k}},$$

where $\varepsilon^X_{k,t}$ is the export-specific price shock.

[11] The endogenous trend tries to capture the trend in import share and is estimated only for Italy and Spain. The baseline specification without this endogenous component is nested in (15) by setting $\tau^{MAY2}_{xx} = 0$. Note that the same trend affects similarly the oil import demand.

Table 1
Selected calibrated structural parameters.

Monetary Policy		EA			
Nominal interest rate in SS	$\bar{i}_{EA}$	0.005			
CPI inflation in SS	$\overline{\pi}^{c,vat}_{EA}$	0.005			
Interest rate persistence	ρ^{i}_{EA}	0.85			
Response to inflation	$\eta^{i,\pi}_{EA}$	1.62			
Response to GDP	$\eta^{i,y}_{EA}$	0.07			
Preferences		**DE**	**FR**	**IT**	**ES**
Intertemporal discount factor	β	0.998	0.998	0.998	0.998
Share of Ricardian households	ω^{s}	0.61	0.66	0.67	0.69
Preference for imports from RoW	s^{M}_{RoW}	0.53	0.41	0.49	0.47
Preference for imports from REA	s^{M}_{REA}	0.47	0.59	0.51	0.53
Import share in consumption	$s^{M,C}$	0.26	0.24	0.21	0.21
Import share in investment	$s^{M,I}, s^{M,IG}$	0.36	0.28	0.28	0.29
Import share in government exp	$s^{M,G}$	0.10	0.09	0.07	0.10
Import share in export	$s^{M,X}$	0.31	0.28	0.27	0.31
Weight of disutility of labour	ω^{N}	1.28	3.38	4.26	4.56
Production					
Cobb-Douglas labour share	α	0.65	0.65	0.65	0.65
Depreciation of private capital stock	δ	0.01	0.02	0.01	0.01
Depreciation of public capital stock	δ^{G}	0.01	0.02	0.01	0.01
Share of oil in total output	s^{Oil}	0.015	0.015	0.015	0.015
Linear capacity utilisation adj. costs	$\gamma^{u,1}$	0.02	0.02	0.01	0.01
Fiscal policy					
Consumption tax	τ^{C}	0.20	0.20	0.20	0.20
Corporate profit tax	τ^{k}	0.30	0.30	0.30	0.30
Labour tax	τ^{N}	0.39	0.53	0.45	0.35
Deficit target	*DEFTAR*	0.02	0.02	0.04	0.02
Debt target	*BTAR*	2.55	2.84	4.46	2.31
Steady state ratios					
Private consumption share	C/Y	0.57	0.55	0.60	0.59
Private investment share	I/Y	0.17	0.19	0.17	0.20
Gov't consumption share	C^{G}/Y	0.19	0.23	0.19	0.18
Gov't investment share	I^{G}/Y	0.02	0.04	0.03	0.04
Transfers share	T/Y	0.17	0.18	0.18	0.14
Others					
Size of the country (% of world)	*size*	4.66	3.57	2.90	1.86
Trend of total factor productivity	g^{AY0}	0.003	0.002	0.003	0.001

2.4. Fiscal policy

The government collects taxes on labour, τ^{N}_{k}, capital, τ^{K}, consumption, τ^{C}, and lump-sum taxes, $tax_{k,t}$, and issues one-period bonds, $B^{G}_{k,t}$, to finance government consumption, $G_{k,t}$, investment, $I^{G}_{k,t}$, transfers, $T_{k,t}$, and the servicing of the outstanding debt. The government budget constraint is:

$$B^{G}_{k,t} = (1 + i^{G}_{k,t-1})B^{G}_{k,t-1} - R^{G}_{k,t} + P^{G}_{k,t}G_{k,t} + P^{IG}_{k,t}I^{G}_{k,t} + T_{k,t}P^{Y}_{k,t},$$

where nominal government revenues, R^{G}, are defined as:

$$R^{G}_{k,t} = \tau^{K}(P^{Y}_{k,t}Y_{k,t} - W_{k,t}N_{k,t} - P^{I}_{k,t}\delta_{k}K_{k,t-1}) + \tau^{N}_{k}W_{k,t}N_{k,t} + \tau^{C}P^{C}_{k,t}C_{k,t} + \tau^{Oil}P^{Y0}_{t}Oil_{t} + tax_{k,t}P^{Y}_{k,t}Y_{k,t}.$$

Excise duties on oil imports from RoW, $\tau^{Oil}P^{Y0}_{t}$, are assumed to be exogenously determined. To close the government budget constraint, lump sum taxes, $tax_{k,t}$, adjust residually as follows:

$$tax_{k,t} = \rho_{\tau}tax_{k,t-1} + \eta^{deft}_{k}\left(\frac{\Delta B^{G}_{k,t-1}}{Y_{k,t-1}P^{Y}_{k,t-1}} - DEFTAR_{k}\right) + \eta^{BT}_{k}\left(\frac{B^{G}_{k,t-1}}{Y_{k,t-1}P^{Y}_{k,t-1}} - BTAR_{k}\right) + \varepsilon^{tax}_{k,t},$$

where $DEFTAR_{k}$ and $BTAR_{k}$ are the targets on government deficit and government debt, respectively, and $\varepsilon^{tax}_{k,t}$ captures a shock. Hence, the government uses lump-sum taxes as budget closure and increases (decreases) taxes when the level of government debt and the government deficit is above (below) the debt and deficit target. The law of motion of government capital is:

$$K^{G}_{k,t} = (1 - \delta^{G}_{k})K^{G}_{k,t-1} + I^{G}_{k,t},$$

where δ^{G}_{k} is the depreciation rate of public capital.

The model uses a measure of discretionary fiscal effort (DFE) as defined by the European Commission (2013):

$$DFE_{k,t} = \frac{R^{G}_{k,t}}{Y_{k,t}} - \frac{\Delta E^{G}_{k,t} - (\Delta Y^{pot}_{k,t} - 1)E^{G}_{k,t-1}}{Y_{k,t}},$$

where $E^{G}_{k,t}$ is the adjusted nominal expenditure aggregate, and $Y^{pot}_{k,t}$ is the medium-term nominal potential output.[12] In order to be consistent with the definition of DFE, which is defined with respect to all primary adjusted government expenditures, we define the aggregate nominal expenditure as:

$$E^{G}_{k,t} = P^{G}_{k,t}G_{k,t} + P^{IG}_{k,t}I^{G}_{k,t} + P^{Y}_{k,t}T_{k,t}.$$

[12] The adjusted nominal expenditure removes interest payments and non-discretionary unemployment expenditures from total nominal expenditure.

Table 2
Prior and posterior distribution of key estimated model parameters.

		Prior distribution		Posterior distribution			
		Distr	Mean St.Dev	DE	FR	IT	ES
Preferences							
Habit persistence	h	**B**	0.5 0.1	0.73 (0.58, 0.76)	0.78 (0.67, 0.83)	0.81 (0.74, 0.86)	0.76 (0.68, 0.83)
Risk aversion	θ	**G**	1.5 0.2	1.41 (1.14, 1.62)	1.38 (1.17, 1.88)	1.42 (1.23, 1.85)	1.51 (1.21, 1.82)
Inverse elasticity of labor supply	θ^N	**G**	2.5 0.5	2.98 (2.14, 3.62)	2.04 (1.58, 2.82)	2.07 (1.65, 2.93)	2.10 (1.64, 2.74)
Import price elasticity	σ^z	**G**	2 0.4	1.30 (1.14, 1.54)	1.38 (1.18, 1.64)	1.13 (1.07, 1.27)	1.27 (1.13, 1.44)
Oil price elasticity	σ^o	**B**	0.5 0.2	0.10 (0.01, 0.25)	0.10 (0.03, 0.31)	0.26 (0.11, 0.54)	0.28 (0.07, 0.46)
Share of forward-looking price setters	sfp	**B**	0.5 0.2	0.98 (0.93, 1.00)	0.99 (0.92, 1.00)	0.36 (0.04, 0.63)	0.74 (0.58, 0.84)
Nominal and real frictions							
Price adj. cost	γ^P	**G**	60 40	20 (14, 34)	36 (26, 51)	11 (10, 14)	18 (16, 26)
Nominal wage adj. cost	γ^w	**G**	5 2	3.43 (2.6, 5.76)	4.07 (2.8, 6.5)	2.69 (0.73, 3.29)	2.24 (1.21, 3.88)
Real wage rigidity	γ^{wr}	**B**	0.5 0.2	0.96 (0.94, 0.98)	0.97 (0.95, 0.98)	0.97 (0.94, 0.98)	0.98 (0.96, 0.99)
Employment adj. cost	γ^N	**G**	60 40	54 (29, 85)	108 (23, 216)	38 (23, 79)	6.4 (3, 11)
Labour hoarding adj. cost	γ^{FN}	**G**	2 0.5	1.58 (1.35, 1.89)	1.24 (1.08, 1.59)	1.62 (1.38, 1.99)	1.57 (1.28, 1.94)
Capacity util. adj. cost	γ^{CU}	**G**	0.003 0.001	0.004 (0.002, 0.006)	0.004 (0.002, 0.006)	0.004 (0.002, 0.006)	0.005 (0.003, 0.007)
Investment adj. cost	γ^I	**G**	60 40	31 (16, 55)	34 (16, 49)	19 (7, 35)	22 (9, 41)
Lump sum taxes							
Taxes persistence	ρ_τ	**B**	0.5 0.2	0.86 (0.80, 0.93)	0.96 (0.94, 0.98)	0.88 (0.80, 0.93)	0.95 (0.89, 0.98)
Taxes response to deficit	η^{deft}	**B**	0.03 0.01	0.02 (0.01, 0.04)	0.02 (0.01, 0.03)	0.03 (0.02, 0.04)	0.02 (0.01, 0.03)
Taxes response to debt	η^{BT}	**B**	0.02 0.01	0.003 (0.001, 0.008)	0.002 (0.001, 0.003)	0.004 (0.001, 0.007)	0.004 (0.001, 0.006)

Notes: Cols. (1)-(2) list model parameters. Cols. (3)-(4) indicate the prior distribution function (B: Beta distribution; G: Gamma distribution). Identical priors are assumed across countries. Cols. (5)-(8) show the mode and the HPD intervals of the posterior distributions of DE, FR, IT, and ES parameters, respectively.

We use the following DFE rules for government consumption, $G_{k,t}$, investment, $I^G_{k,t}$, and transfers, $T_{k,t}$:

$$\frac{\Delta G_{k,t}P^G_{k,t}}{P^Y_{k,t}Y_{k,t}} = \left(\Delta Y^{pot}_{k,t}\exp(\pi^Y_{k,t})-1\right)\frac{G_{k,t-1}P^G_{k,t-1}}{P^Y_{k,t}Y_{k,t}} - \alpha^G_{k,t}\left(\frac{G_{k,t-1}P^G_{k,t-1}}{P^Y_{k,t-1}Y_{k,t-1}}-\overline{G}\right)+\varepsilon^G_{k,t},$$

$$\frac{\Delta I^G_{k,t}P^{IG}_{k,t}}{P^Y_{k,t}Y_{k,t}} = \left(\Delta Y^{pot}_{k,t}\exp(\pi^Y_{k,t})-1\right)\frac{I^G_{k,t-1}P^{IG}_{k,t-1}}{P^Y_{k,t}Y_{k,t}} - \alpha^{IG}_{k,t}\left(\frac{I^G_{k,t-1}P^{IG}_{k,t-1}}{P^Y_{k,t-1}Y_{k,t-1}}-\overline{I}^G\right)+\varepsilon^{IG}_{k,t},$$

$$\frac{\Delta T_{k,t}P^Y_{k,t}}{P^Y_{k,t}Y_{k,t}} = \left(\Delta Y^{pot}_{k,t}\exp(\pi^Y_{k,t})-1\right)\frac{T_{k,t-1}P^Y_{k,t-1}}{P^Y_{k,t}Y_{k,t}} - \alpha^T_{k,t}\left(\frac{T_{k,t-1}P^Y_{k,t-1}}{P^Y_{k,t-1}Y_{k,t-1}}-\overline{T}\right)+\varepsilon^T_{k,t},$$

where $\varepsilon^G_{k,t}$, $\varepsilon^{IG}_{k,t}$, $\varepsilon^T_{k,t}$ are shocks to government consumption, investment and transfers, respectively. The parameters $\alpha^G_{k,t}, \alpha^{IG}_{k,t}, \alpha^T_{k,t} > 0$ are policy feedback parameters to ensure long-run stability of the model.

2.5. Monetary policy

Monetary policy is modeled using a Taylor-type rule where the ECB sets the policy rate, $i_{EA,t}$, in response to the annualised EA-wide inflation and output gaps (Taylor, 1993).[13] The policy rate adjusts sluggishly to deviations of inflation from their respective target level and to the output gap and is subject to a random shock, $\varepsilon^i_{EA,t}$:

$$i_{EA,t}-\overline{i} = \rho^i_{EA}(i_{EA,t-1}-\overline{i}) + (1-\rho^i_{EA})\left[\eta^{i\pi}_{EA}0.25\left(\pi^{C,vat,QA}_{EA,t}-\overline{\pi}^{C,vat,QA}_{EA}\right) + \eta^{iy}_{EA}\left(\log\left(0.25\sum_{r=1}^{4}Y_{EA,t-r}\right)-\log\left(0.25\sum_{r=1}^{4}Y^{pot}_{EA,t-r}\right)\right)\right] + \varepsilon^i_{EA,t},$$

where $\overline{i} = \overline{r} + \overline{\pi}^{Yobs}$ is the steady-state nominal interest rate, equal to the sum of the steady state real interest rate and GDP inflation. Quarterly annualised inflation is defined as:

$$\pi^{C,vat,QA}_{EA,t} = \log\left(\sum_{r=0}^{3}P^{C,vat}_{EA,t-r}\right)-\log\left(\sum_{r=4}^{7}P^{C,vat}_{EA,t-r}\right).$$

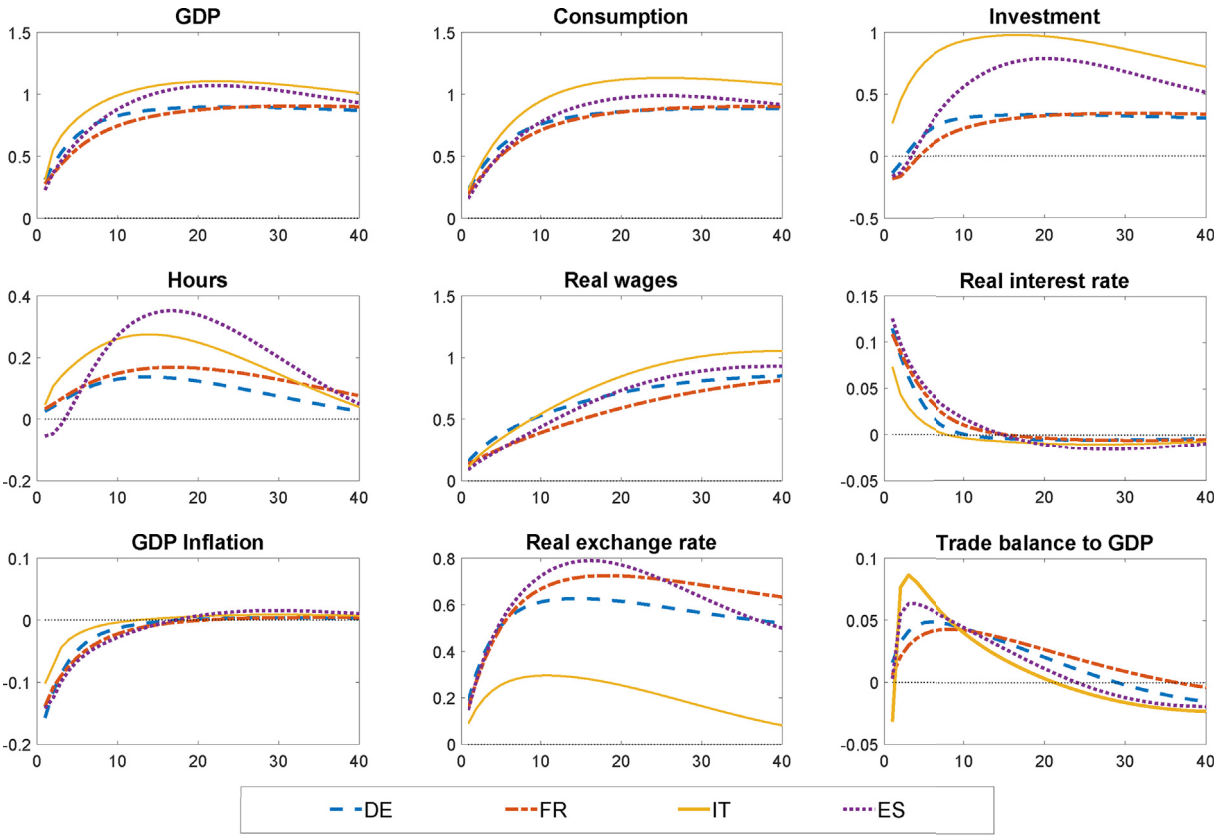
[13] We define potential output, $Y^{pot}_{k,t}$, as the output level that would prevail if labour input equaled steady-state per capita hours worked, capital stock is utilised at full capacity and TFP equaled its trend component.

Table 3
Theoretical moments and model fit.

Variable	Std(%)		AR(1)		Corr (x, GY)		R^2	
	Data	Model	Data	Model	Data	Model	1-y ahead	2-y ahead
Germany								
GDP growth (GY)	0.84	1.25	0.41	0.05	1.00	1.00	0.50	0.01
Consumption growth (GC)	0.58	1.21	−0.24	0.53	0.27	0.24	−2.33	−2.80
std(GC)/std(GY)	0.69	0.97	–	–	–	–	–	–
Investment growth	4.22	4.85	−0.02	0.20	0.49	0.39	0.27	0.07
GDP deflator	0.35	0.69	0.44	0.70	−0.25	−0.10	0.78	−0.24
Hours growth	0.54	0.64	0.28	0.20	0.58	0.76	0.36	−0.04
Δ Trade balance to GDP	0.67	0.90	−0.07	0.01	0.34	0.58	0.80*	0.32*
France								
GDP growth (GY)	0.48	0.94	0.59	0.08	1.00	1.00	0.50	−0.59
Consumption growth (GC)	0.45	0.82	0.18	0.62	0.60	0.32	−0.19	−5.17
std(GC)/std(GY)	0.95	0.87	–	–	–	–	–	–
Investment growth	2.77	3.17	0.16	0.27	0.59	0.50	0.44	0.03
GDP deflator	0.29	0.49	0.70	0.83	0.15	0.13	0.77	0.04
Hours growth	0.39	0.52	0.61	0.15	0.59	0.85	0.45	−0.07
Δ Trade balance to GDP	0.39	0.66	−0.20	0.01	−0.17	0.61	0.85*	0.56*
Italy								
GDP growth (GY)	0.74	1.30	0.68	0.06	1.00	1.00	0.73	0.40
Consumption growth (GC)	0.58	0.85	0.67	0.57	0.74	0.29	0.82	0.64
std(GC)/std(GY)	0.78	0.66	–	–	–	–	–	–
Investment growth	4.12	5.20	0.05	0.25	0.59	0.51	0.09	0.21
GDP deflator	0.54	0.76	−0.24	0.33	−0.11	−0.21	0.24	0.20
Hours growth	0.57	0.71	0.31	0.20	0.59	0.62	0.74	0.33
Δ Trade balance to GDP	0.41	0.81	0.20	−0.01	−0.19	0.47	0.86*	0.65*
Spain								
GDP growth (GY)	0.70	1.43	0.91	0.14	1.00	1.00	0.82	0.44
Consumption growth (GC)	0.88	1.43	0.62	0.48	0.83	0.47	0.88	0.48
std(GC)/std(GY)	1.25	1.00	–	–	–	–	–	–
Investment growth	2.91	3.85	0.33	0.42	0.59	0.42	0.46	0.00
GDP deflator	0.47	0.60	0.75	0.69	0.58	0.05	0.90	0.73
Hours growth	1.13	1.24	0.27	0.31	0.77	0.75	0.90	0.45
Δ Trade balance to GDP	0.63	0.95	0.20	−0.02	−0.44	0.50	0.91*	0.69*

* Note: The R^2 is reported for the absolute nominal trade balance.

Fig. 1. Capacity utilisation in the model and the data.



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 2. Permanent positive TFP shock.

The policy parameters (ρ^i, $\eta^{i\pi}$, η^{iy}) capture interest rate inertia and the response to annualised inflation and output gap, respectively.

2.6. Closing the economy

Market clearing requires that:

$$Y_{k,t}P^Y_{k,t} + \tau^{Oil}Oil_{k,t}P^{Y0}_t = P^C_{k,t}C_{k,t} + P^I_{k,t}I_{k,t} + P^{IG}_{k,t}I^G_{k,t} + P^G_{k,t}G_{k,t} + TB_{k,t},$$

where the trade balance, $TB_{k,t}$, is defined as the difference between exports and imports:

$$TB_{k,t} = P^X_{k,t}X_{k,t} - \sum_l \frac{size_l}{size_k}P^M_{l,k,t}M_{l,k,t} - P^{OIL}_{RoW,k,t}OIL_{RoW,k,t}e_{RoW,k,t}.$$

EMU-country exports are the sum of imports of domestic goods by other countries:

$$X_{k,t} = \sum_l M_{l,k,t},$$

where $M_{l,k,t}$ stands for imports of economy l from EMU country k.

Net foreign assets, $B^W_{k,t}$, evolve according to:

$$e_{RoW,k,t}B^W_{k,t} = (1 + i^{bw}_{t-1})e_{RoW,k,t}B^W_{k,t-1} + TB_{k,t} + ITR_kP^Y_{k,t}Y_{k,t},$$

where ITR_k represents international transfers, which are calibrated to allow a non-zero steady-state of the trade balance.

Finally, net foreign assets of all countries sum to zero:

$$\sum_l NFA_{l,t}size_l = 0.$$

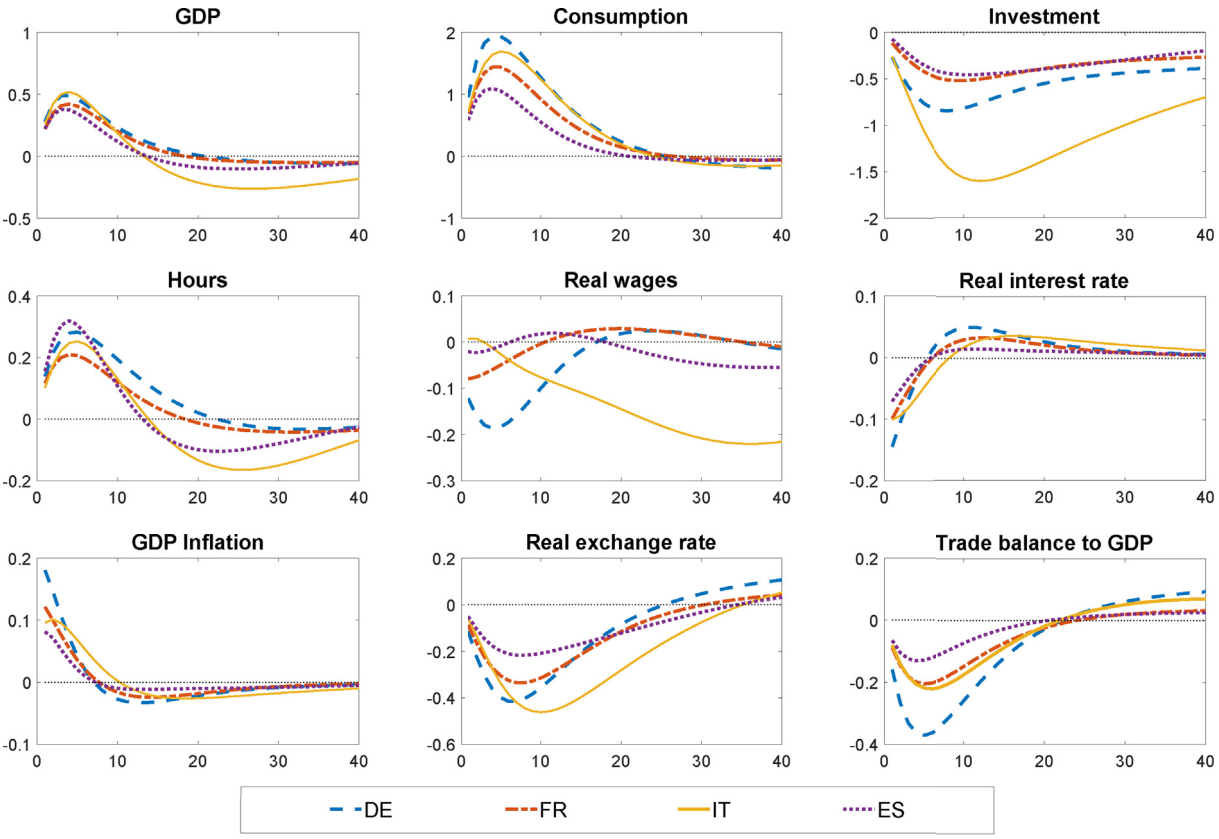
2.7. The REA and RoW block

The model of the REA and RoW blocks is simplified in structure. Specifically, REA and RoW consist of a budget constraint for the representative household (Ricardian), demand functions for domestic and imported goods (derived from CES consumption good aggregators), a production technology that uses only labour as input factor, a New Keynesian Phillips curve, and a Taylor rule. The REA and RoW blocks abstract from capital accumulation. There are shocks to labour productivity, price mark-ups, the subjective discount rate, the relative preference for domestic and imported goods as well as monetary policy shocks. Unless otherwise specified, subscript k corresponds to REA and RoW.

Since RoW is an oil exporter, its resource constraint is:

$$P^Y_{RoW,t}Y_{RoW,t} + P^{Oil}_{RoW,t}OIL_{RoW,t} = P^C_{RoW,t}C_{RoW,t} + P^X_{RoW,t}X_{RoW,t} - \sum_l \frac{size_l}{size_{RoW}}e_{l,RoW,t}P^X_{l,t}M_{l,RoW,t},$$

where $X_{RoW,t}$ are non-oil exports by RoW.



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 3. Negative private saving shock.

The resource constraint for REA, as an oil importer, is:

$$P^{Y}_{REA,t}Y_{REA,t} + \tau^{Oil}P^{Y0}_{t}OIL_{REA,t} = P^{C}_{REA,t}C_{REA,t} + P^{X}_{REA,t}X_{REA,t} - \sum_{l}\frac{size_{l}}{size_{REA}}e_{l,REA,t}P^{X}_{l,t}M_{l,REA,t},$$

where $\tau^{Oil}P^{Y0}_{t}OIL_{REA,t}$ captures the excise duty.

Final aggregate demand $C_{k,t}$ (in the absence of investment and government spending in REA and RoW) is a combination of domestic output, $Y_{k,t}$ and imported goods, $M_{k,t}$, using the following CES function:

$$C_{k,t} = A^{p}_{k,t}\left[(1-u^{M,C}_{k,t}s^{M}_{k})^{\frac{1}{\sigma^{c}_{k}}}(Y^{C}_{k,t})^{\frac{\sigma^{c}_{k}-1}{\sigma^{c}_{k}}} + (u^{M,C}_{k,t}s^{M}_{k})^{\frac{1}{\sigma^{c}_{k}}}(M^{C}_{k,t})^{\frac{\sigma^{c}_{k}-1}{\sigma^{c}_{k}}}\right]^{\frac{\sigma^{c}_{k}}{\sigma^{c}_{k}-1}},$$

where $u^{MC}_{k,t}$ is a shock to input components and s^{M}_{k} the import share. From profit maximisation we obtain the demand for domestic and foreign goods:

$$Y^{C}_{k,t} = (A^{p}_{k,t})^{\sigma^{c}_{k}-1}(1-u^{M,C}_{k,t}s^{M}_{k})\left(\frac{P^{Y}_{k,t}}{P^{C}_{k,t}}\right)^{-\sigma^{c}_{k}}C_{k,t},$$

$$M^{C}_{k,t} = (A^{p}_{k,t})^{\sigma^{c}_{k}-1}u^{M,C}_{k,t}s^{M}_{k}\left(\frac{P^{M}_{k,t}}{P^{C}_{k,t}}\right)^{-\sigma^{c}_{k}}C_{k,t},$$

where the consumer price deflator, $P^{C}_{k,t}$, is given by:

$$P^{C}_{k,t} = \frac{1}{A^{p}_{k,t}}\left[(1-u^{M,C}_{k,t}s^{M}_{k})(P^{Y}_{k,t})^{1-\sigma^{c}_{k}} + u^{M,C}_{k,t}s^{M}_{k}(P^{M}_{k,t})^{1-\sigma^{c}_{k}}\right]^{\frac{1}{1-\sigma^{c}_{k}}}.$$

The intermediate good producers use labour to manufacture domestic goods (non-oil output) according to a linear production function:

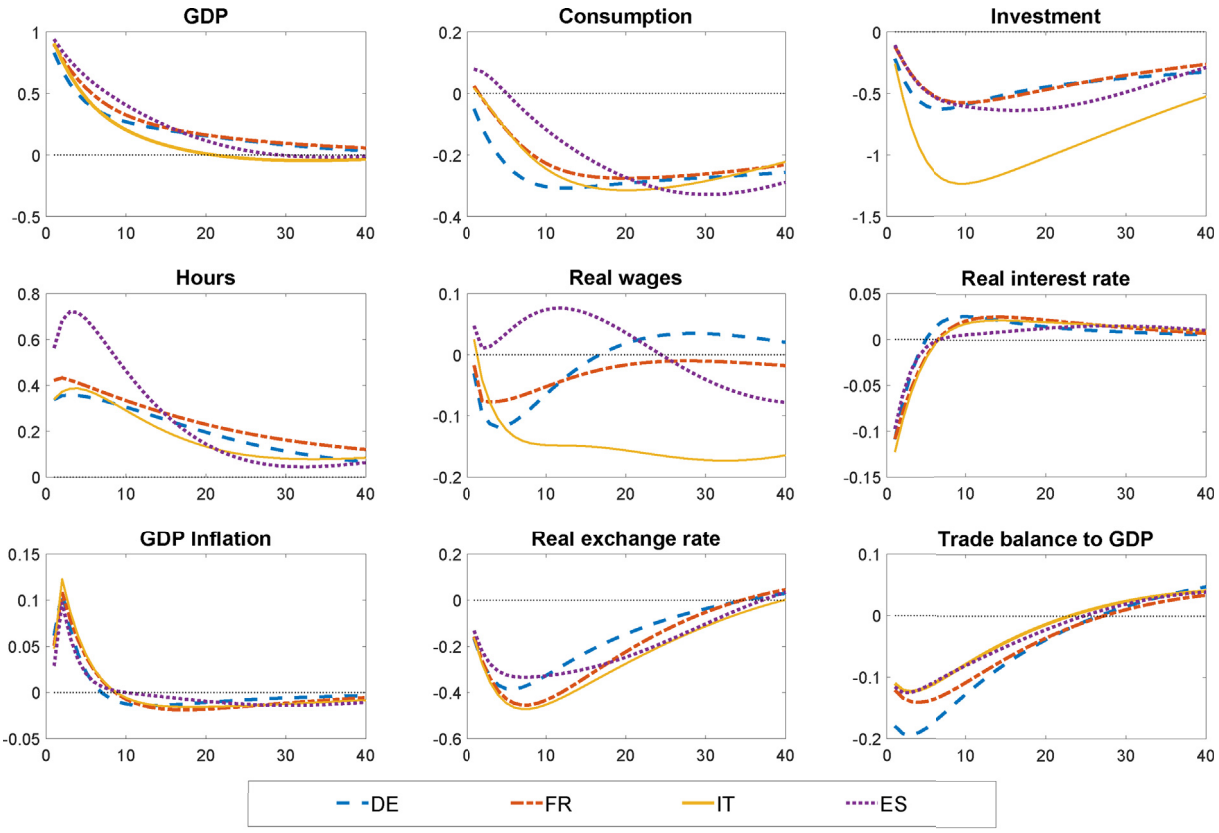
$$Y_{k,t} = A^{Y}_{k,t}N_{k,t},$$

where $A^{Y}_{k,t}$ captures a trend in the productivity and $N_{k,t} = Actr_{k,t}Pop_{k,t}$ is the active population in the economy. Price setting for non-oil output follows a New Keynesian Phillips curve:

$$\pi^{Y}_{k,t} - \overline{\pi} = \widetilde{\beta}_{k,t}\frac{\lambda_{k,t+1}}{\lambda_{k,t}}\left[sfp_{k}(\pi^{Y}_{k,t+1}-\overline{\pi}) + (1-sfp_{k})(\pi^{*}_{k}-\overline{\pi})\right] + \phi^{Y}_{k}\log\frac{Y_{k,t}}{\overline{Y}_{k}} + \varepsilon^{Y}_{k,t},$$

where $\lambda_{k,t} = (C_{k,t} - hC_{k,t-1})^{-\theta_{k}}$ is the marginal utility of consumption, $\varepsilon^{Y}_{k,t}$ is a cost push shock, sfp_{k} is the share of forward-looking price setters, and π^{*}_{k} measures the weight of backward-looking price setters according to $\pi^{\star}_{k,t} = \rho^{\pi^{\star}}_{k}\overline{\pi} + (1-\rho^{\pi^{\star}}_{k})(\pi^{Y}_{k,t-1})$.

Monetary policy in RoW follows a Taylor-type rule:



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 4. Positive government expenditure shock.

$$i_{RoW,t} - \bar{i} = \rho^{i}_{RoW}(i_{RoW,t-1} - \bar{i}) + (1 - \rho^{i}_{RoW}) \left[\eta^{i\pi}_{RoW} 0.25 \left(\pi^{C,QA}_{RoW,t} - \overline{\pi}^{C,QA} \right) + \eta^{iy}_{RoW} \left(\log \left(0.25 \sum_{r=1}^{4} Y_{RoW,t-r} \right) - \log \left(0.25 \sum_{r=1}^{4} Y^{pot}_{RoW,t-r} \right) \right) \right] + \epsilon^{i}_{RoW,t}.$$

Oil is considered to be an unstorable exogenous endowment of RoW and it is supplied inelastically:

$$OIL_{RoW,t} = \sum_{l} \frac{size_{l}}{size_{RoW}} OIL_{l,RoW,t},$$

where net oil exporting firms' revenues in RoW are driven only by its price, $P^{Oil}_{RoW,t}$, which is assumed to be denominated in RoW currency:

$$P^{Oil}_{RoW,t} = \frac{P^{Y0}_{t}}{A^{P^{Oil}}_{RoW,t}}.$$

Total nominal exports for REA and RoW are defined as:

$$P^{X}_{k,t} X_{k,t} = \sum_{l} P^{X}_{l,k,t} M_{l,k,t},$$

with the bilateral export price being defined as the domestic price subject to a bilateral price shock:

$$P^{X}_{l,k,t} = \exp(\epsilon^{X}_{l,k,t}) P^{Y}_{k,t}.$$

We combine the FOCs with respect to international bonds of REA and RoW to obtain the uncovered interest parity (UIP) condition:

$$E_t \left[\frac{e_{RoW,EA,t+1}}{e_{RoW,EA,t}} \right] (1 + i^{bw}_{RoW,t}) = (1 + i_{EA,t}) + \epsilon^{bw}_{EA,t} + \alpha^{bw0}_{EA} + \alpha^{bw1}_{EA} \frac{e_{RoW,EA,t} B^{W}_{EA,t}}{P^{Y}_{EA,t} Y_{EA,t}},$$

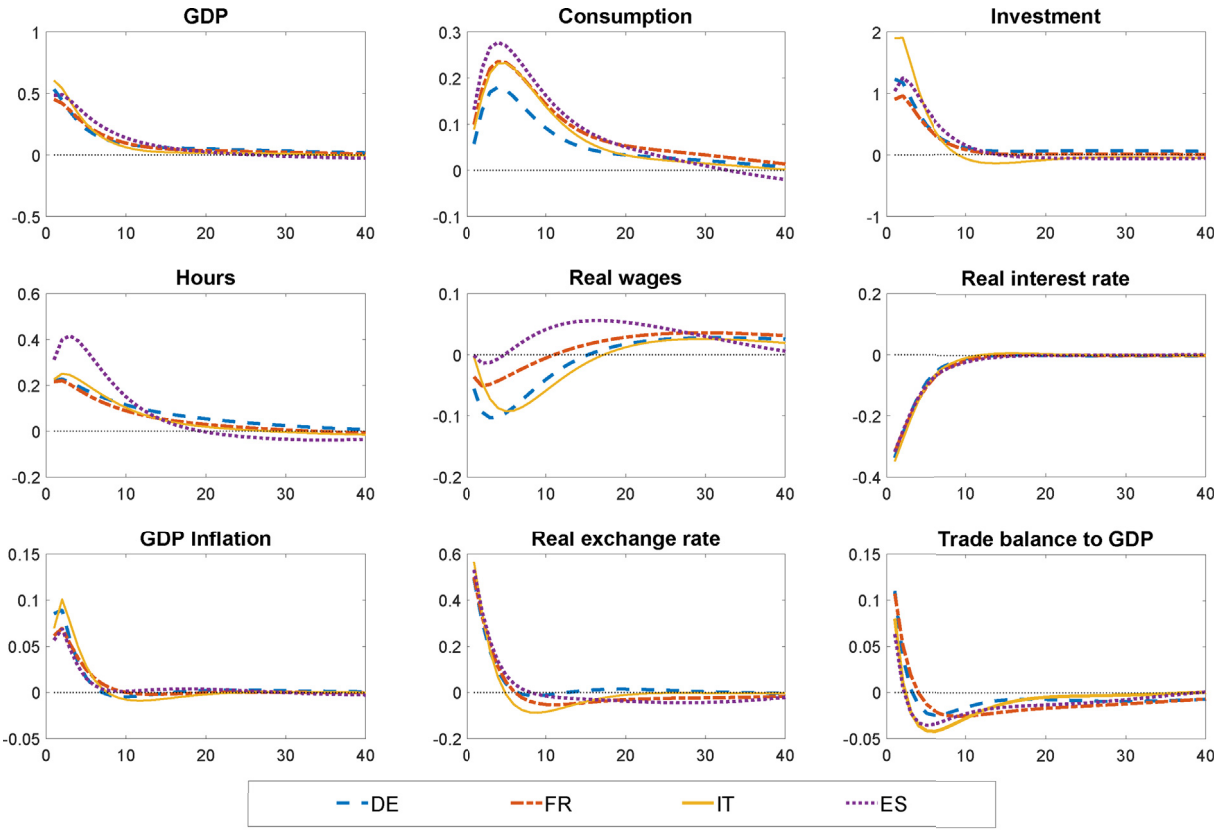
where $\epsilon^{bw}_{EA,t}$ captures a bond premium shock between EA and RoW (exchange rate shock), and α^{bw1}_{EA} is a debt-dependent country risk premium on net foreign asset holdings to ensure long-run stability (Schmitt-Grohe and Uribe, 2003; Adolfson et al., 2008).

3. Model solution and econometric approach

The model is solved by linearising it around its deterministic steady-state. A subset of parameters is calibrated at quarterly frequency to match long-run properties, the remaining parameters are estimated using Bayesian methods.[14]

As in Bayesian practice, the likelihood function (evaluated by implementing the Kalman Filter) and the prior distribution of the parameters

[14] We use the Dynare software 4.5 to solve the linearised model and to perform the estimation (see Adjemian et al., 2011).



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 5. EA monetary policy shock.

are combined to calculate the posterior distribution. The posterior Kernel is then simulated numerically using the slice sampler algorithm as proposed by Planas et al. (2015).[15]

The estimation uses quarterly and annual data for the period 1999q1 to 2017q2.[16] Data for EMU countries and the Euro Area are taken from Eurostat (in particular, from the European System of National Accounts ESA2010), while the Rest of the World series are constructed using the IMF International Financial Statistics (IFS) and World Economic Outlook (WEO) databases.[17] The estimated model uses 38 observed series and assumes 39 exogenous shocks.[18] On the one hand, the large number of shocks is dictated by the fact that we use a large number of observables for estimation. On the other hand, many shocks are needed to capture key dynamic properties of macroeconomic and financial data (see Kollmann et al., 2015).

Along the deterministic steady-state all real variables (deflated by the GDP deflator) are assumed to grow at a rate of 1.3% per year (the average growth rate of EA output over the sample period). Prices grow at an EA inflation rate of 2% per year, adjusted by country-specific average productivities for the demand components (private and public consumption and investment). Population is detrended by the EA average rate of population growth (0.4% per year). The steady-state ratios of main economic aggregates to GDP are calibrated to match historical ratios for each country over the sample period.

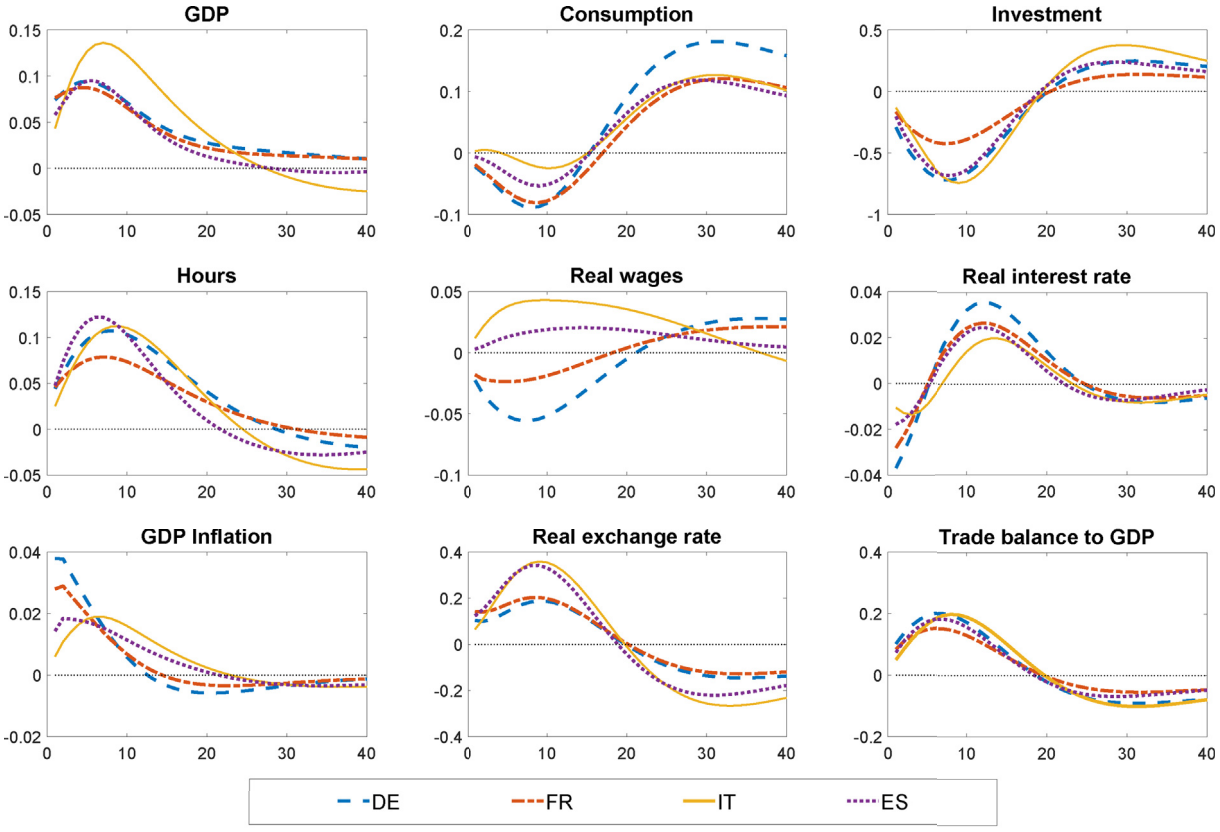
Table 1 provides an overview of the calibrated parameters. The discount factor at quarterly frequency is set to 0.9983 for all countries to match an annual real interest rate of 1%. Given the monetary union setting, we calibrate the EA monetary policy parameters according to their estimated values based on a two-region configuration of the GM model (EA-RoW): the interest rate persistence is set to 0.845, and the coefficients for the response to the EA inflation gap and the EA output gap are 1.625 and 0.07, respectively. Trade related parameters such as the degree of openness or preferences for imports are calibrated to match the average shares of import content in the demand components as computed by Bussière et al. (2013). The steady-state shares of Ricardian households are calibrated following the survey in Dolls et al. (2012). The debt targets are set to match the average values of the debt-to-GDP ratios over the sample.

[15] The slice sampler algorithm was introduced by Neal (2003). Planas et al. (2015) reconsider the slices along the major axis of the ellipse to better fit the distribution than any of Euclidean slices. The slice sampler has been shown to be more efficient and offer better mixing properties than the Metropolis-Hastings sampler (Calés et al., 2017).

[16] The model is estimated at quarterly frequency, interpolating annual data for the series that are not available at higher frequency.

[17] Appendix A provides a detailed description of data sources, definitions and transformations.

[18] The list of observables can be found in Appendix B.1. Note that we additionally observe the historical replacement rate in Germany to capture the effect of the 'Hartz reforms'.



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 6. Positive foreign demand shock.

4. Estimation results

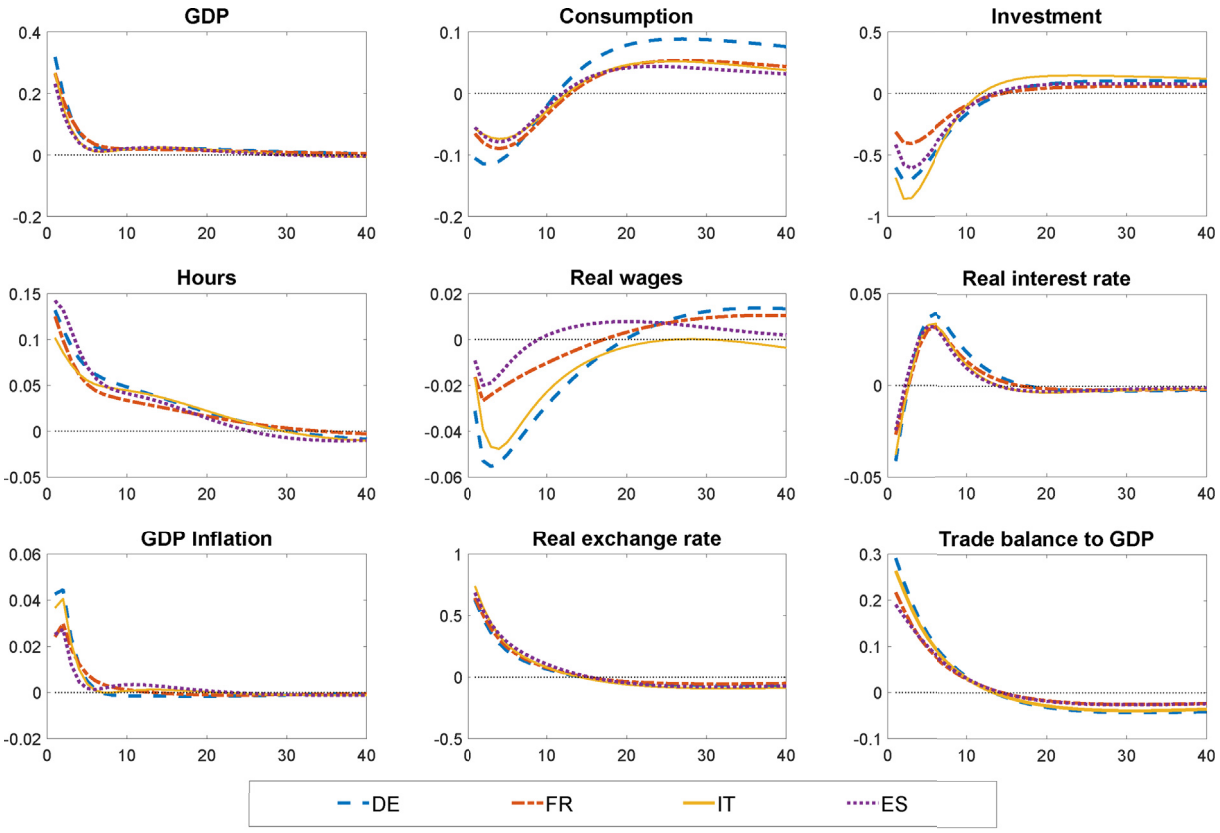
In this section, we present the posterior estimates of key model parameters, the ability of the model to fit the data and impulse response functions. We discuss the drivers of the post-crisis slump and trade balance adjustments in each country by analysing the historical shock decomposition of real GDP growth and the trade balance-to-GDP ratio.

4.1. Posterior estimates

The posterior estimates, with Highest Posterior Density intervals, of key model parameters are reported in Table 2. The estimated habit persistence is relatively high in Italy, which implies a slow adjustment of consumption to changes in income. Risk aversion coefficients are similar for all countries and range between 1.38 and 1.51. The inverse of the labour supply elasticity is relatively high in Germany (2.98) compared to the other countries. The import price elasticity coefficient in Italy is lower (1.13) than in the other countries (1.27–1.38). Since we use the modified Phillips curve equation (14) for Italy and Spain, the estimated share of forward-looking price setters is significantly lower in Italy (0.36) and Spain (0.74) compared to Germany and France. Price and nominal wage adjustment costs are higher in France (36 and 4.07, respectively) and rather low in Italy and Spain. Real wage rigidity is high for all countries. Employment adjustment costs vary significantly among the countries. The labour market rigidity is linked to the two adjustment cost parameters in labour demand and labour hoarding. The former appears to be relatively rigid in France (108) compared to Spain (6.4) and Italy (38). The latter features similar levels in Germany (1.58), Italy (1.62) and Spain (1.57), with a somewhat lower level in France (1.24). Capacity utilisation adjustment costs are similar across the four countries, whereas Italy (19) and Spain (22) face lower investment adjustment costs compared to Germany (31) and France (34). The fiscal feedback rule on lump-sum taxes exhibits relatively high persistence for France (0.96) and Spain (0.95), implying a more drawn-out response to debt and deficit levels. The estimated responses of taxes to deficit and debt targets are in the same order of magnitude across countries. The posterior estimates of key model innovations can be found in Appendix B.2.

4.2. Model fit

In order to evaluate the capability of the model to fit the data, Table 3 compares sample and model-implied moments for a subset of key statistics. In particular, we focus on volatilities and persistence of real GDP, consumption, investment, employment, the trade balance-to-GDP ratio and the GDP deflator as well as the cross-correlation of GDP with its main components. We use first differences for the trade balance-to-GDP ratio and quarter-on-quarter growth rates for all other variables. The estimated models tend to overestimate the volatility of real variables. However, the relative magnitudes seem to be preserved, e.g. std(GC)/std(GY). Of particular note is the high volatility of investment, which is in line with the data patterns. Most of the correlations between GDP growth and its components are fairly well captured. More precisely, all country models replicate well the correlation of consumption, investment and employment with output. In our model the trade balance is positively correlated with output, but matches the data pattern only for Germany. Moreover, our estimated models are able to replicate both negative (for Germany and Italy)



Note: Real variables are presented as percentage deviation, GDP inflation and the trade balance-to-GDP ratio are expressed in percentage-point deviations from the steady-state. Real interest rates are shown in annualised percentage-point deviations from the steady-state. An increase in the real exchange rate represents a real depreciation. The dynamic responses of DE, FR, IT and ES variables are represented by dashed, dash-dotted, continuous and dotted lines, respectively.

Fig. 7. Positive shock to preferences for international bond (euro depreciation).

and positive (for France and Spain) correlations between GDP inflation and GDP growth. First-order autocorrelations are particularly well seized in Spain, whereas the other countries show a more differentiated picture.

The last two columns in Table 3 report the R^2 of the 1-year and 2-year ahead forecast. We define the R^2 as follows:

$$R^2 = 1 - \frac{e_j' e_j}{y_j' y_j},$$

where $y_j = [y_{1,j}, \dots, y_{T,j}]'$ is the country-specific j^{th} time series in deviation from the model-implied steady-state and $e_j = [e_{1,j}, \dots, e_{T,j}]'$ is the associated k-step ahead forecast error obtained from the Kalman filter recursions. The definition implies that R^2 has an upper bound located at 1 and is unbounded from below. This means that in the perfect case where the model generates no forecast error, the R^2 is one and it declines monotonically as the forecast error increases. Since the volatility of the forecast error can be larger than the volatility of the observed time series, the R^2 can be negative. In that case, a constant forecast centered on the sample mean would do a better job since its R^2 coincides with zero. The graphical representation of the k-step ahead forecast, i.e. the 1-year and 2-year ahead forecast at each point in time, can be found in Figs. B.1–B.4 in Appendix B.3.

The 1-year ahead R^2 is mostly positive for all analysed countries, indicating that the model forecast errors are not very large. Even the 2-year ahead forecast provides a relatively good fit, especially for IT and ES. A different picture arises for Germany and France, for which the estimated model delivers a poor (in-sample) forecast accuracy particularly for consumption.[19]

An additional way to assess the fit of the model is to compare the estimates of endogenous variables with their observable counterparts. For example, capacity utilisation is an endogenous variable defined in the GM model and it is treated as a latent variable, endogenously determined by the firm's decision rules. As a consequence, the Kalman filter allows us to retrieve a model-consistent estimate of capacity utilisation over the business cycles. While capacity utilisation is not directly measurable in national account statistics, we use a 'model-free' or reduced-form proxy that has been constructed to compare the model-based and model-free estimates of capacity utilisation.[20] Fig. 1 plots the times series of capacity utilisation implied by the reduced form proxy and the GM implied one computed via the Kalman filter.

As the differences are minimal and the two measures coincide, it gives additional credit to the plausibility of the estimated structural models to replicate key features of EA Member State business cycles. It is useful to underline that this match has been improved for France, Italy and Spain by the introduction of labour hoarding as choice variable.

4.3. Dynamic transmission of shocks

Figs. 2–7 show the dynamic responses of the main variables to

[19] Similar issues in fitting consumption behaviour in Germany are reported in Kollmann et al. (2015).

[20] For details on the construction of the capacity utilisation series, see Havik et al. (2014).

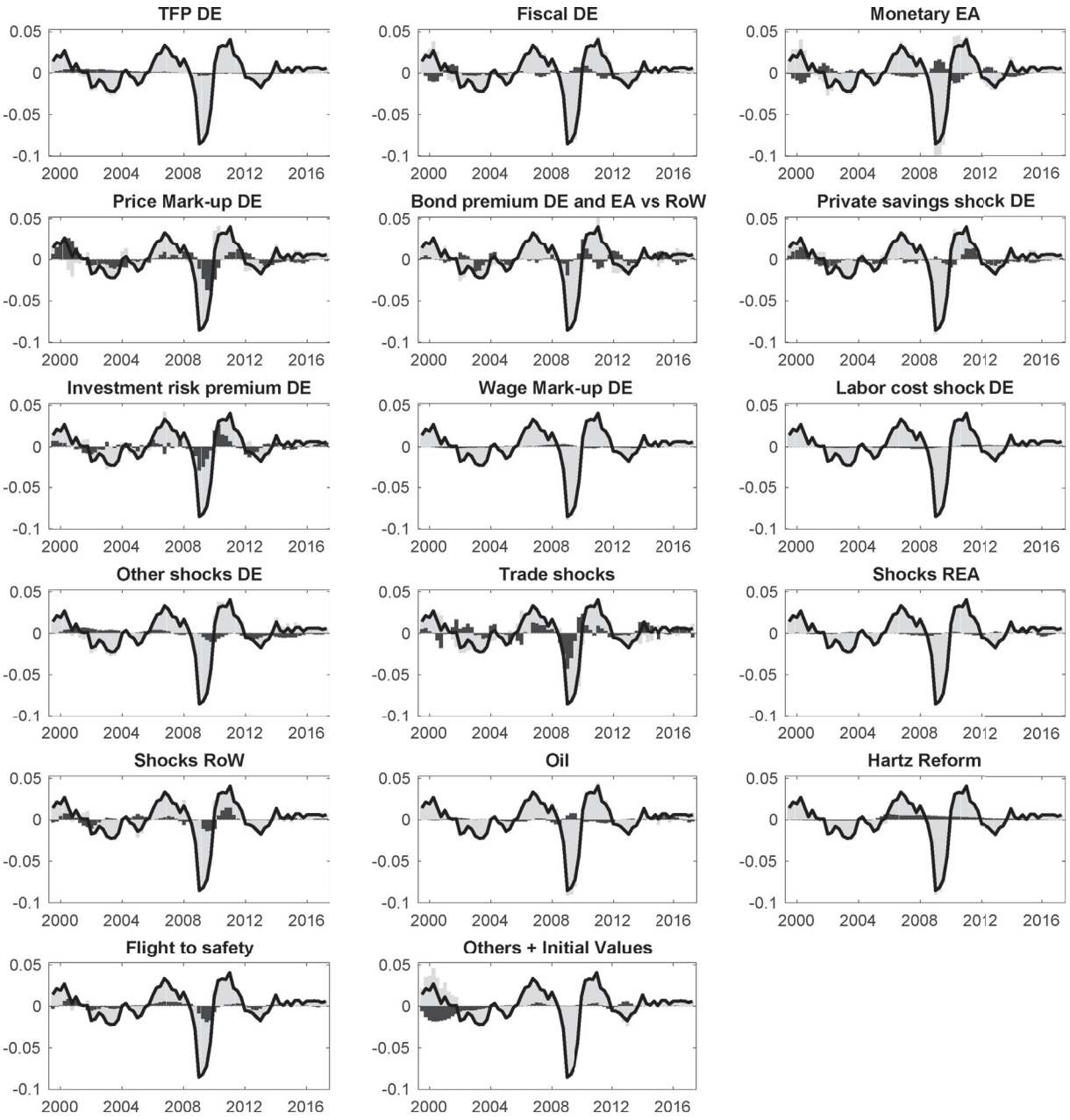


Fig. 8. Historical decomposition of real GDP growth in Germany.

domestic supply (TFP), domestic demand (private saving and government spending), EA monetary policy and foreign demand shocks as well as an exchange rate shock to the euro. All figures report the response of a temporary shock of 1% except for TFP, where it is a temporary shock to the growth rate (i.e. permanent to the level). In all cases we report expansionary shocks. Each panel shows, for the four countries, the dynamic response of the following endogenous variables: real GDP, private consumption, private investment, total hours worked, real wages, real interest rate, GDP inflation, real effective exchange rate, and the trade balance-to-GDP ratio.

4.3.1. Permanent positive TFP shock

A one-time permanent increase in the level of TFP lowers the marginal costs of production (Fig. 2). As a result, firms lower prices, GDP inflation goes down and real wages and income increase. The delayed increase in consumption is due to habit persistence in preferences. Expected higher returns increase the investment in Italy. Higher investment adjustment costs in Germany, France and Spain prevent the increase of investment on impact. Employment temporarily decreases in Spain, but reacts positively in Germany, France and Italy, where labour demand adjustment costs are much more elevated. The exchange rate depreciates and the trade balance improves temporarily due to substitution of imports by domestic demand. However, on impact, the relatively slow adjustment in prices and increased demand induce a negative trade balance in Italy.

4.3.2. Negative private saving shock (positive shock to consumption demand)

A negative shock to the saving rate, which is modeled as a persistent increase in the subjective rate of time preference of households, boosts domestic consumption with a concomitant increase in domestic output and prices (Fig. 3). The shock triggers a rise in the policy rate and an increase in the real interest rate in the medium term, leading to a decline in investment. The trade balance deteriorates

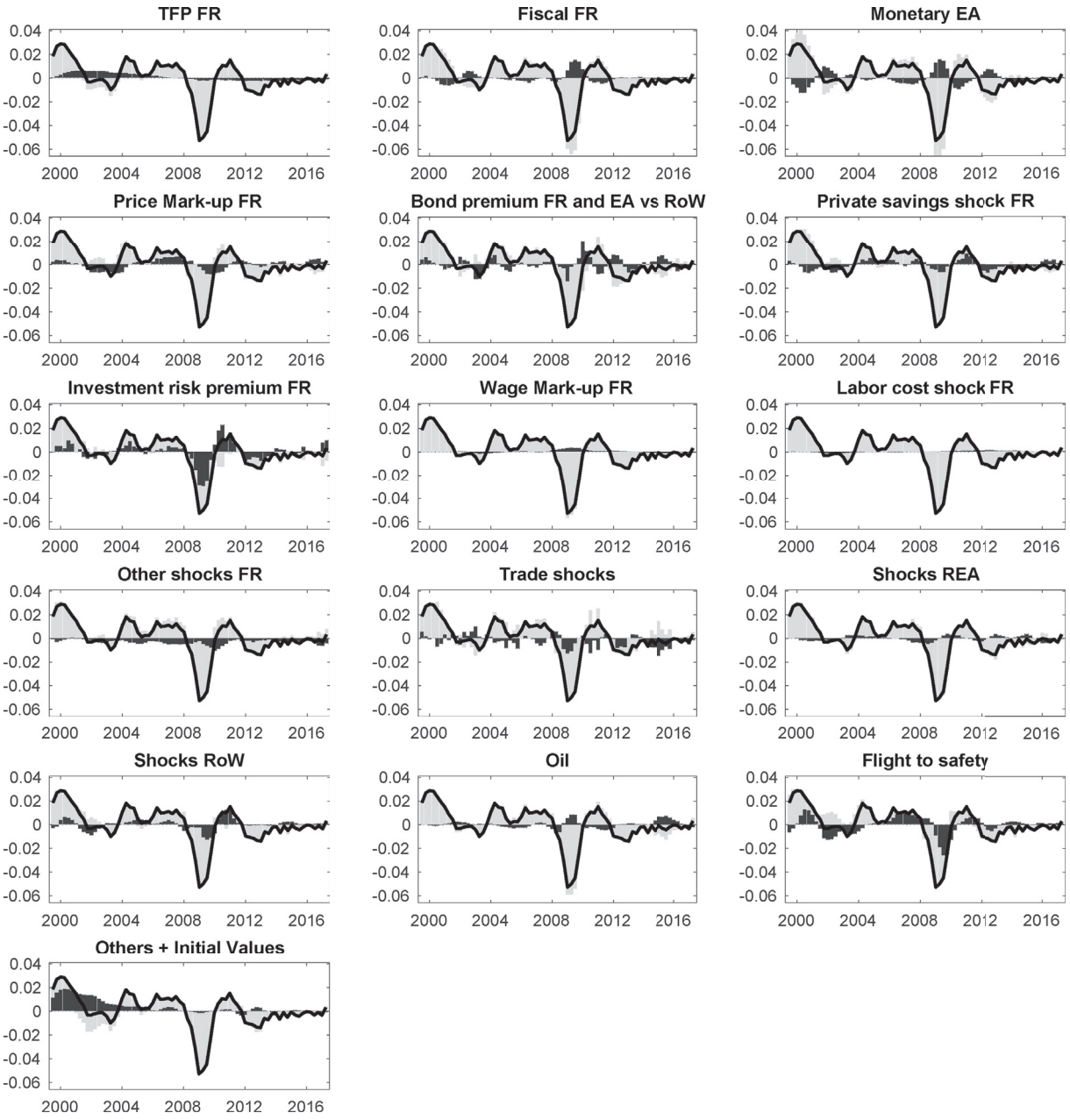


Fig. 9. Historical decomposition of real GDP growth in France.

on impact due to a combination of higher import (domestic demand expansion) and lower export demand (real exchange rate appreciation). Fig. 3 also shows that due to low investment adjustment costs in Italy the positive shock to domestic consumption has particularly negative consequences on investment. Additionally, lower price and labour market frictions (labour hoarding and wage stickiness) lead to a more persistent decrease of real wages in Italy compared to the other countries.[21]

4.3.3. *Government expenditure shock*

An increase in government expenditure raises domestic output and crowds out private consumption and investment in the medium term (Fig. 4). Upward pressure on prices leads to a real exchange rate appreciation and a deterioration of the trade balance. The fiscal multiplier is close to one on impact and similar in size across the four countries. While consumption in Germany is negative on impact, we can see some crowding-in of consumption in the other countries, particularly in Spain. Furthermore, the lower estimated labour market frictions in Spain lead to a more pronounced positive effect on employment and real wages.

4.3.4. *EA monetary policy shock*

An expansionary monetary policy (lowering the annualised interest rate by 1pp) implies an increase in aggregate demand components (Fig. 5). Investment raises substantially due to a decline in real interest rates. Higher domestic demand induces firms to increase labour demand which results in higher employment. The real exchange rate depreciates due to a strong initial depreciation of the euro. The gain in competitiveness improves the trade balance-to-GDP ratio.

[21] The dynamic response of real wages in Italy is also influenced by the modified formulation of the hybrid Phillips curve (see equation (14)), which we use for better fitting GDP inflation in Italy.

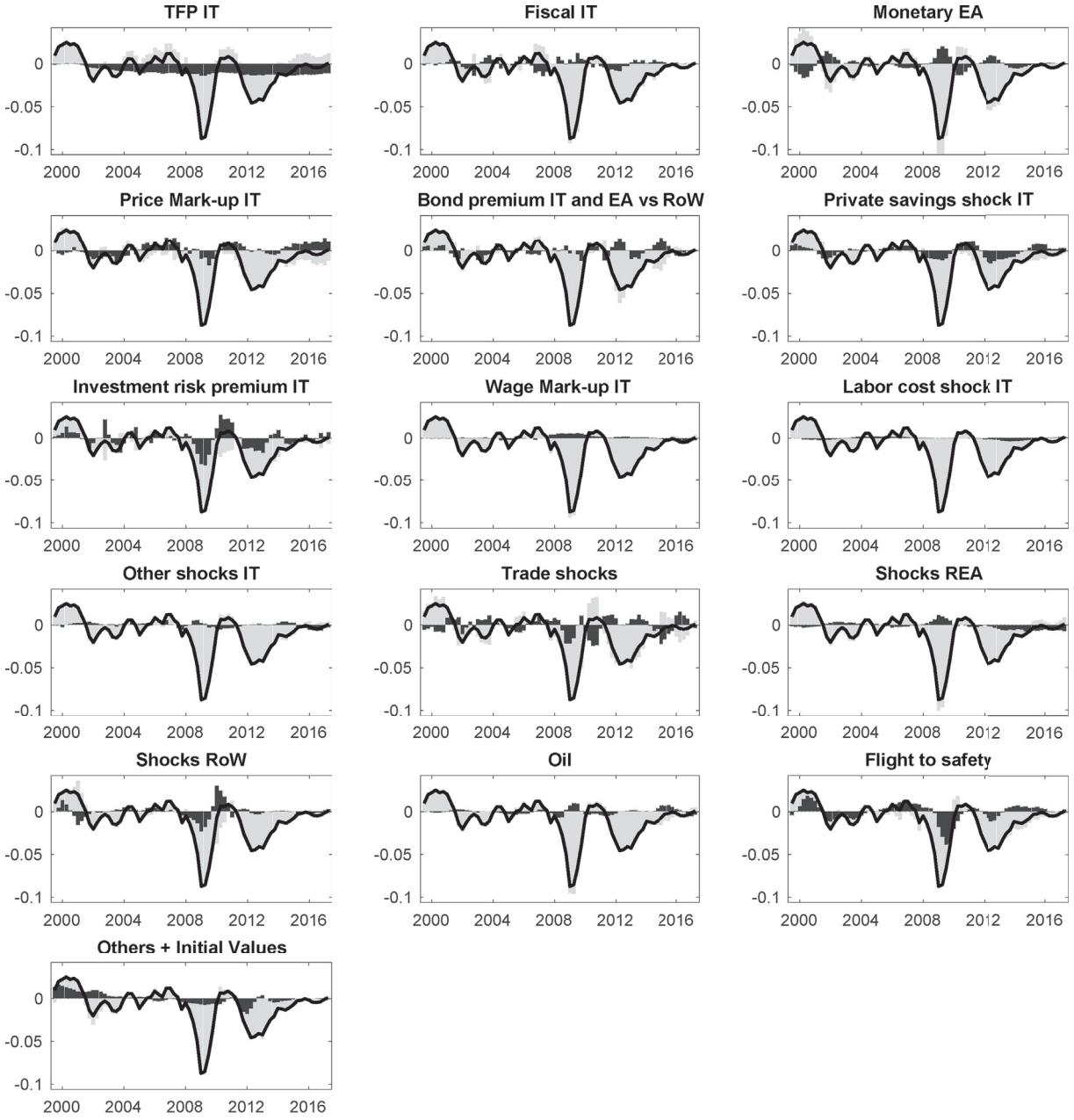


Fig. 10. Historical decomposition of real GDP growth in Italy.

4.3.5. Negative shock to the RoW savings rate (positive shock to foreign demand)

Fig. 6 presents dynamic responses to a positive foreign demand shock, namely a negative shock to RoW savings. Analogously to domestic saving shocks, the negative RoW savings shock is modeled by a decline in the subjective discount rate. The shock increases RoW demand and activity in combination with a real effective depreciation in the four countries, leading to trade balance improvements. The rise in policy and real interest rates in response to higher output and inflation in the EA dampens consumption and investment demand. Due to a lower estimated share of forward-looking price setters in Italy, GDP inflation increases less on impact, which boosts domestic consumption and activity compared to the other countries.

4.3.6. Positive shock to preferences for international bond (euro depreciation)

Fig. 7 presents dynamic responses to a preference shock for international bonds, which mimics a euro depreciation. The gain in competitiveness increases the trade balance via a rise in exports and a decline in import demand. Consequently, domestic GDP and employment increase. The real interest rate is negative on impact but increases due to the monetary policy response to inflation, which is primarily caused by a deterioration of the terms of trade. Lower domestic import demand (higher foreign prices) decreases consumption on impact. Investment decreases on impact due to capital outflows (preference shock towards foreign assets). Subsequently, both consumption and investment return to equilibrium following a path determined by the intertemporal substitution implied by the real interest rate.

The qualitative pattern of the transmission of shocks is rather homogeneous across countries, except for some stronger response of real variables to demand shocks and of nominal variables to external shocks in IT and ES. The similarity of the impulse responses, notably for real GDP and the trade balance, suggests that cross-country heterogeneity in real GDP growth and trade balance adjustment is not primarily driven by

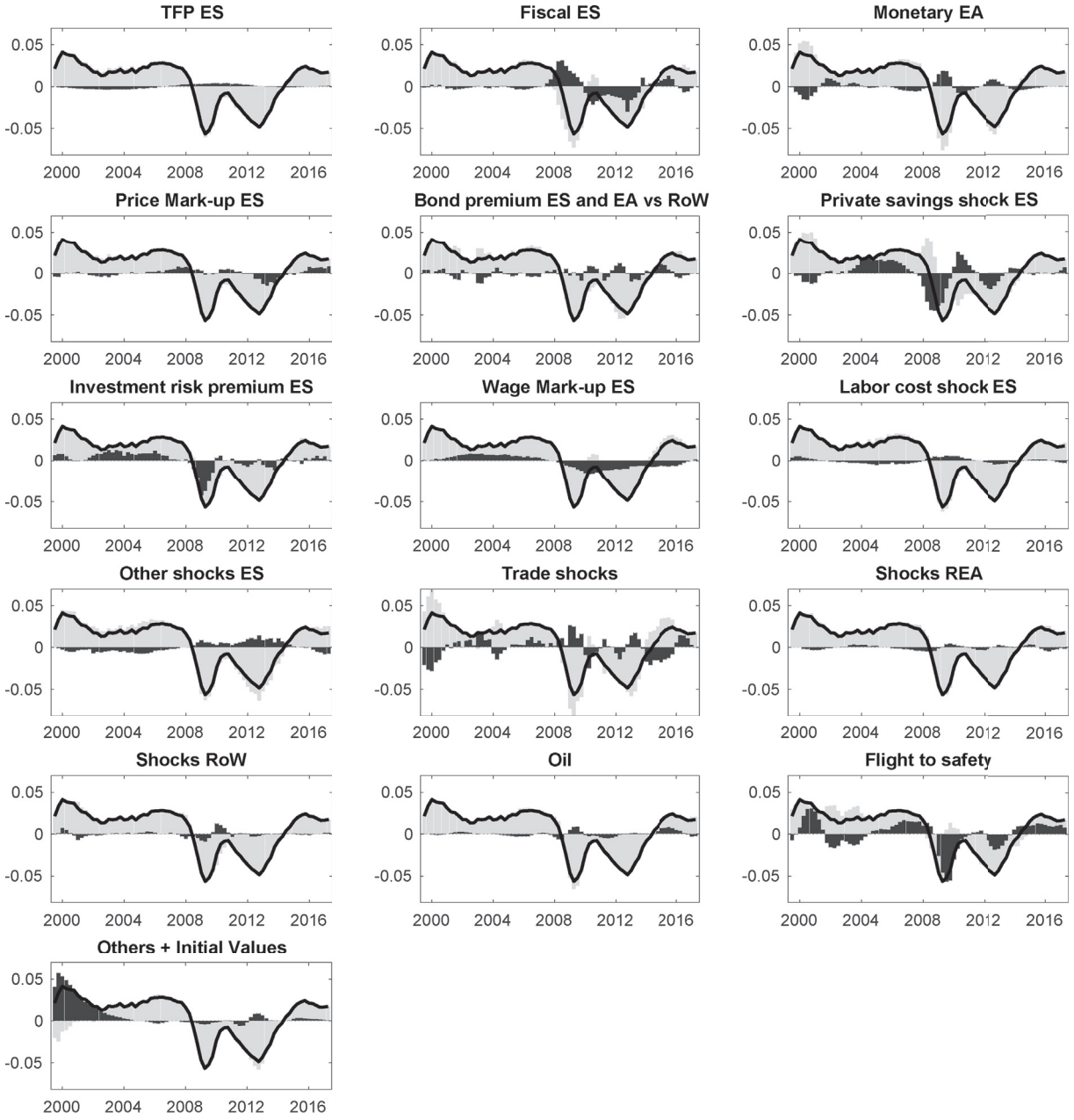


Fig. 11. Historical decomposition of real GDP growth in Spain.

cross-country differences in the transmission of shocks, i.e. by differences in the estimated parameters.

4.4. Historical decomposition

In this subsection, we analyse the drivers of the post-crisis slump and trade balance adjustments in the four largest EA Member States (DE, FR, IT, and ES) by analysing the contribution of different shocks to real GDP growth and the trade balance-to-GDP ratio during the period 2000q1-2017q2. Figs. 8–15 display the historical decomposition of the year-on-year growth rate of real GDP and the trade balance-to-GDP ratio (q-o-q) for each of the four countries.

In each subplot, the continuous black line shows historical time series from which the steady-state have been subtracted. The vertical black bars show the contribution of different groups of exogenous shocks (see below) to the historical data, while stacked light bars show the contribution of the remaining shocks. Bars above the horizontal axis (steady-state) represent positive shock contributions, while bars below the horizontal axis show negative shock contributions. The sum of all shock contributions equals the historical data.

We plot the contributions of the following (groups of) exogenous variables originating in the respective domestic country: (1) permanent shocks to TFP; (2) fiscal policy shocks; (3) EA monetary policy shocks; (4) price mark-up shocks; (5) interest parity shocks between the EA and RoW ('bond premium shock'); (6) shocks to the subjective discount factors of domestic households ('private savings shock'); (7) shocks to the domestic investment risk premium; (8) domestic wage mark-up shocks; (9) domestic labour demand shocks; (10) permanent productivity shocks to private and public consumption ('other shocks'); (11) shocks to the worldwide relative preference for domestically produced goods and foreign goods, and price mark-up shocks for exports and imports ('trade shocks'); (12) other shocks originating in REA; (13) shocks originating in RoW; (14) shocks to the oil price; (15) shocks to the risk free rate in the domestic country ('flight to safety shock'); (16)

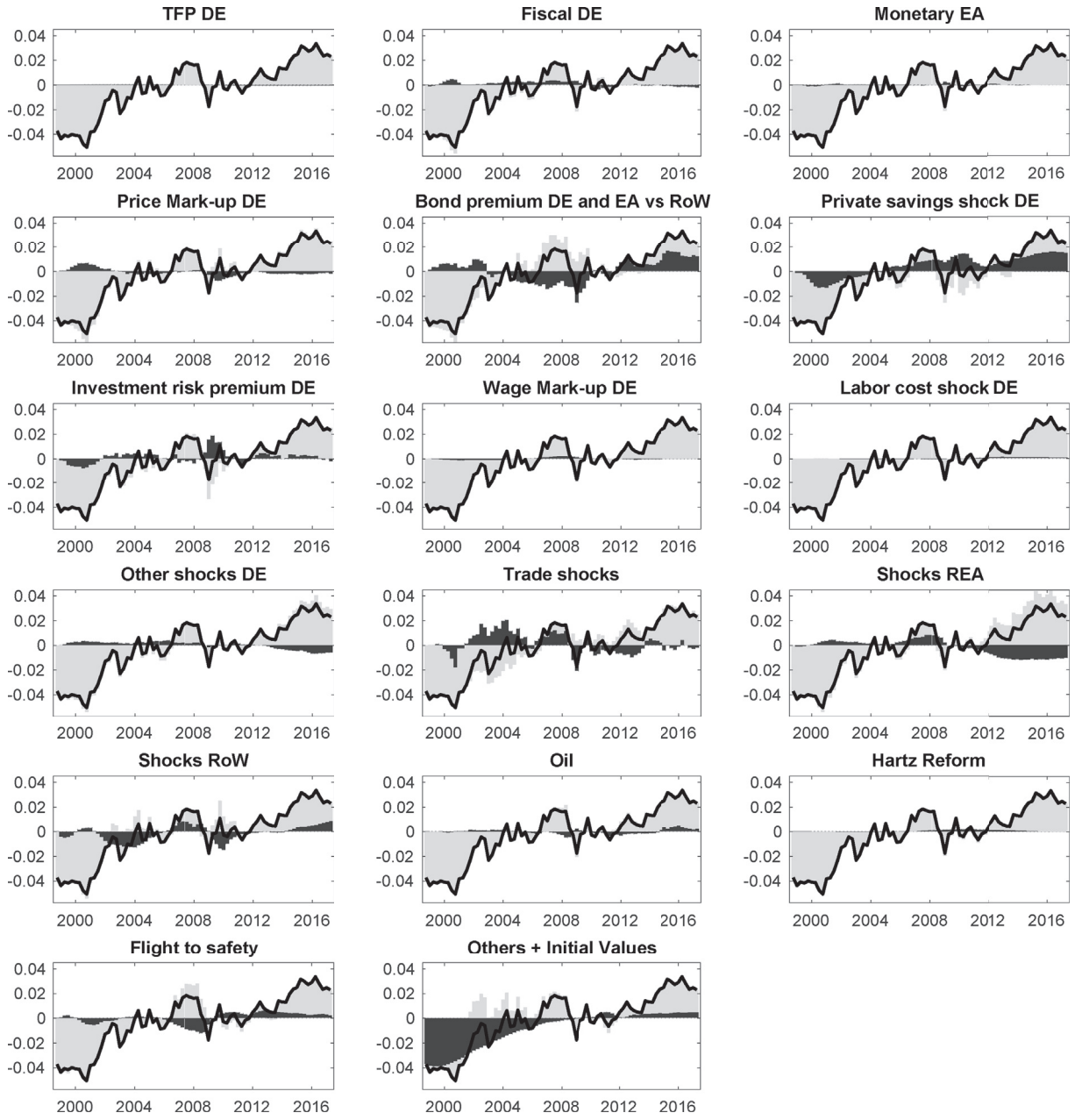


Fig. 12. Historical decomposition of the trade balance-to-GDP ratio in Germany.

for Germany we also plot the shock to the replacement rate to account for the 'Hartz reform'.

4.4.1. Shock decomposition of real GDP growth

A large share of real GDP growth fluctuations in all four countries during 1999–2017 are attributed to domestic demand shocks (in particular those driving investment demand and 'flight to safety'), whereas the role of supply shocks is much smaller. Regarding the pre-crisis period, (negative) private savings shocks were particularly prominent in Spain, which correspond to an increase in household debt and, among others, also contributed to the housing sector boom before the global financial crisis. In Germany, the 'Hartz Reform' made a noticeable positive contribution to GDP growth.

The growth slowdown during the financial crisis is largely associated with an increase in investment risk premia. In Spain, it was accompanied by a negative contribution of consumption (positive saving shock or 'deleveraging'), in France, Germany and Italy by price mark-up and trade shocks. In contrast, expansionary monetary and fiscal policy had a noticeable stabilising effect on domestic GDP growth in all four countries during the 2008–09 financial crisis.

In 2010, the crisis was followed by a relatively rapid partial recovery due to a fall in investment risk premia and foreign demand shocks. The main drivers during this period were relatively homogeneous across the four countries. The post-crisis slump in Italy and Spain was mainly driven by adverse shocks to risk premia on investment, negative consumption shocks (positive saving shocks or 'deleveraging'), and an increase in the intra-euro risk premia ('flight to safety'). Less pronounced negative domestic demand shocks have mitigated the economic slowdown in Germany and France. The fiscal austerity due to the sovereign debt and banking crisis made the strongest negative contribution in Spain.

The main drivers of above-trend GDP growth in Germany during the most recent years have been the fall in oil prices, positive trade shocks as well as the depreciation of the euro (explained in the model

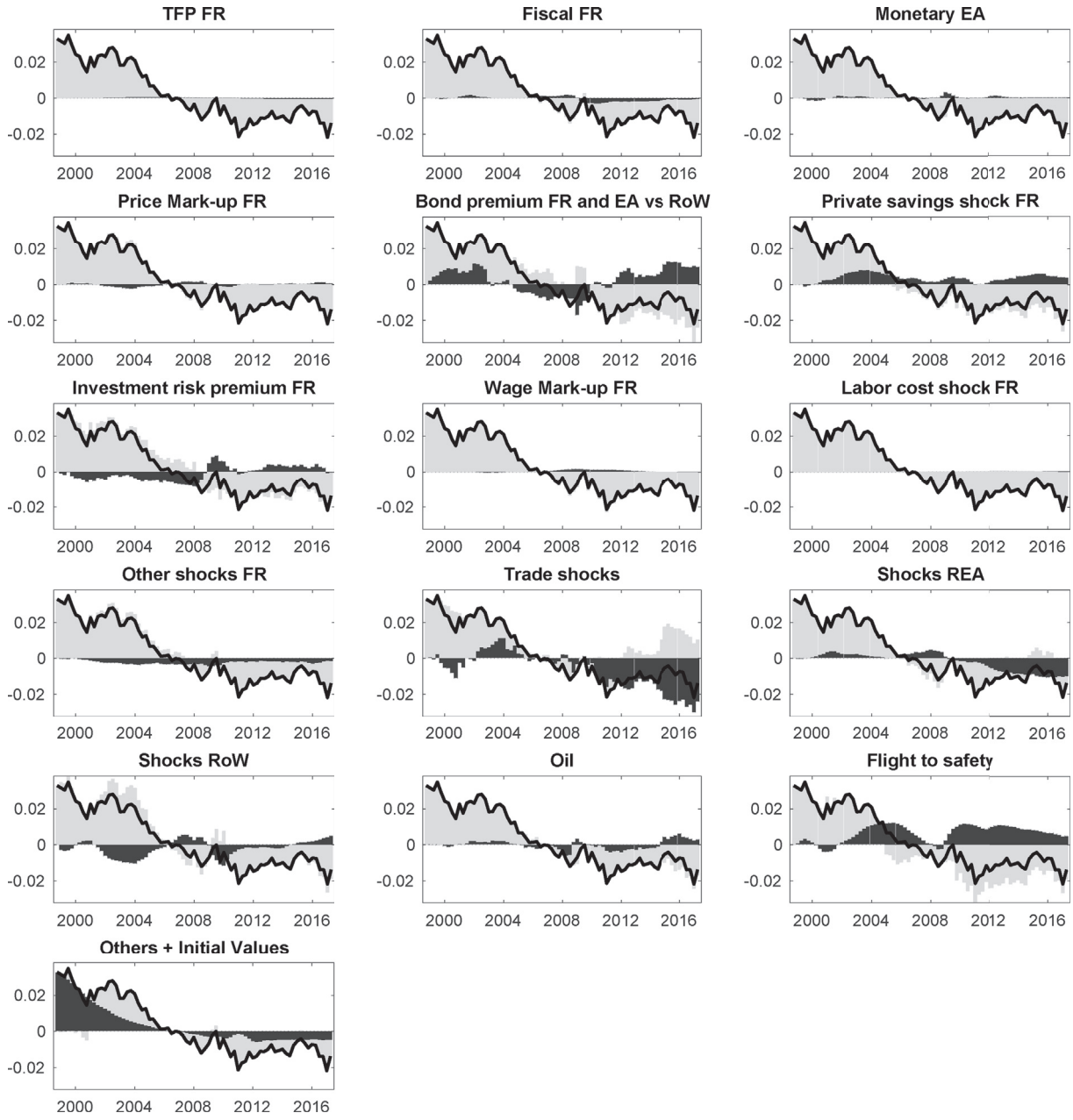


Fig. 13. Historical decomposition of the trade balance-to-GDP ratio in France.

by an increase in the risk premium on euro-denominated bonds). The recovery in Spain and Italy in recent years has been driven by negative price mark-up shocks and the flight-to-safety shock, i.e. a reduction in the intra-euro risk premium compared to the crisis years.

Our estimates suggest that EA monetary policy shocks had a relatively moderate effect on GDP growth.[22] Since we do not impose a zero lower bound on the nominal interest rate as a constraint on monetary policy, the negative contributions to GDP growth during 2013 and 2015 originate from a lower model-implied policy rate compared to the observed policy rate which is at the zero bound. Hence, the gap is closed by positive (tightening) monetary policy shocks. It has to be stressed that 'monetary policy' only refers to the Taylor rule shock and excludes non-conventional measures that are rather part of receding investment risk premia, declining savings rates, and exchange rate depreciation shocks in the logic of the model.

It is interesting to notice that the GM model attributes the subdued levels of the Italian output growth over the full sample to a sequence of persistent negative TFP shocks which act as a persistent drag to the economy. TFP shocks are a reduced form representation for whatever is left out from combining capital and labour inputs and their intensity in utilisation. Therefore, one can think of total factor productivity as bundling together intangible assets (i.e. unobservable or difficult to measure quantities) such as technological innovation and/or input misallocations. In light of this, the decomposition of the Italian output growth offers a narrative which is coherent with other studies that, by exploiting the cross-sectional variation, explain the Italian low produc-

[22] The moderate impact of monetary policy shocks on real GDP growth is in line with the study by Rafiq and Mallick (2008), which analyses the effects of monetary policy shocks on output in Germany, France and Italy. They conclude that monetary policy innovations play only a modest role in explaining fluctuations in output for these countries, thus making the problem of a one-size-fits-all policy in a currency union less worrying.

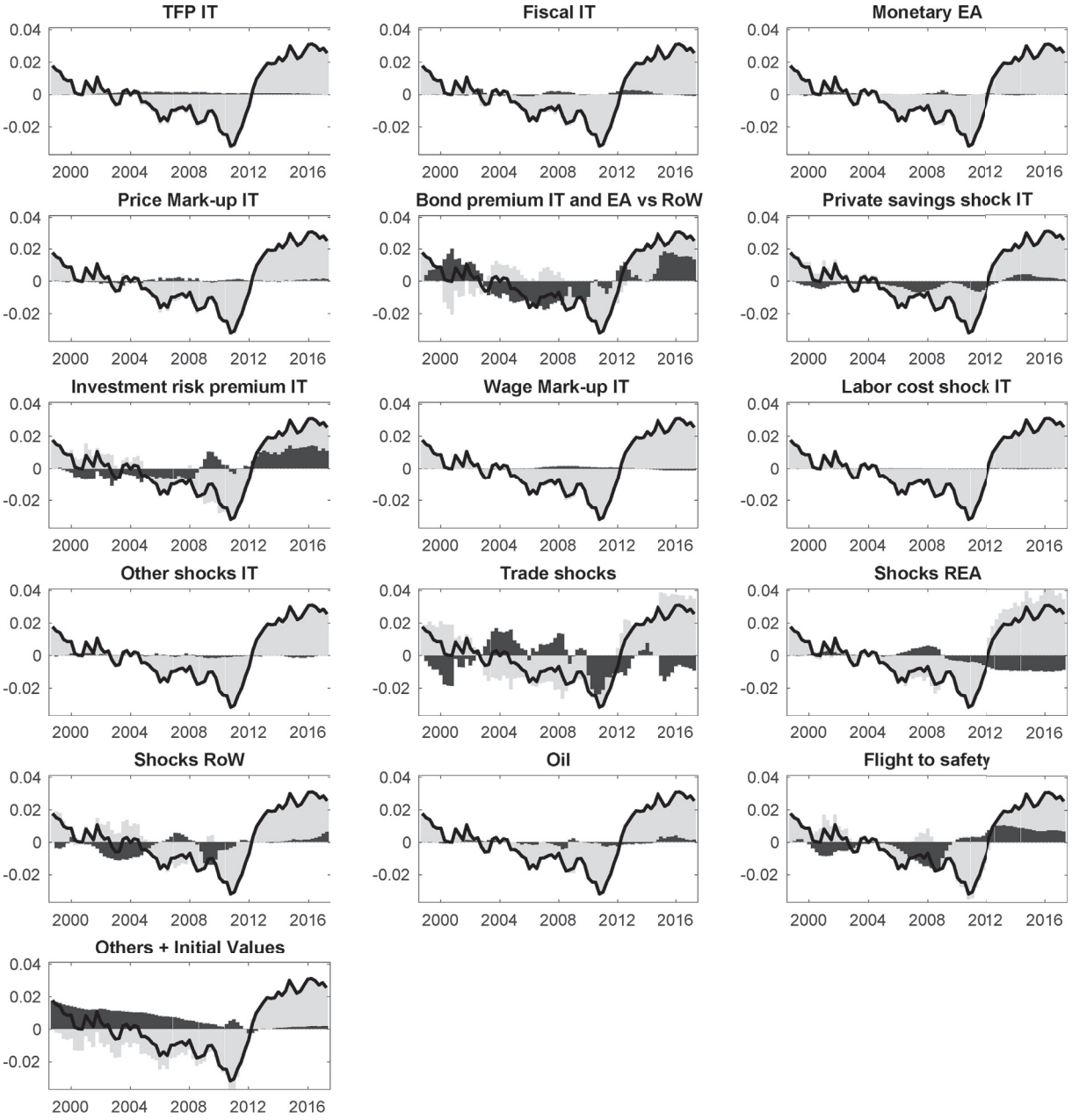


Fig. 14. Historical decomposition of the trade balance-to-GDP ratio in Italy.

tivity in terms of limited ICT investment and penetration (see Hassan and Ottaviano, 2013; Pellegrino and Zingales, 2017).

4.4.2. Shock decomposition of the trade balance-to-GDP ratio

The steady-states of the trade balance-to-GDP ratios for the four countries are set to the mean of the observed country-specific time series. Therefore, the trade balance steady-state in Germany is around 5% of GDP, in France around −1%, in Italy close to 0% and in Spain around −2% of GDP.

Germany's trade balance surplus has been accumulated since the beginning of the 2000s. Only during the global 2008–09 crisis, Germany's trade balance declined because of the simultaneous contraction of RoW real activity and global trade. Beside the traditionally high saving rate in Germany, the increase in global trade and RoW demand, the depreciation of the euro (explained in the model by an increase in the risk premium on euro-denominated bonds) and the decline in oil prices have led to an even more pronounced increase of Germany's trade balance surplus in recent years.

While France has shown a gradual and persistent trade balance deterioration since the beginning of the sample, Italy and Spain have experienced a rapid trade balance reversal since 2011. France has suffered more than the other three EMU countries considered from negative trade shocks after the financial crisis. Even positive contributions through a higher risk premium on investment (leading in the model to lower import demand), the euro depreciation and the heightened intra-euro risk ('flight to safety') did not compensate the deteriorating trend of France's trade balance.

Italy and Spain show a similar pattern in terms of trade balance adjustment in the aftermath of the global financial crisis. During the pre-crisis period, both countries have experienced a deterioration of the trade-balance-to-GDP ratios, mainly characterised by strong domestic demand (consumption and investment) and an appreciation of the euro. Our results suggest that the trade balance reversals in Italy and Spain were mainly driven by subdued investment and the depreciation of the euro. Additionally, the flight-to-safety contribution to the trade balance-to-GDP ratios has been considerably positive for Italy and

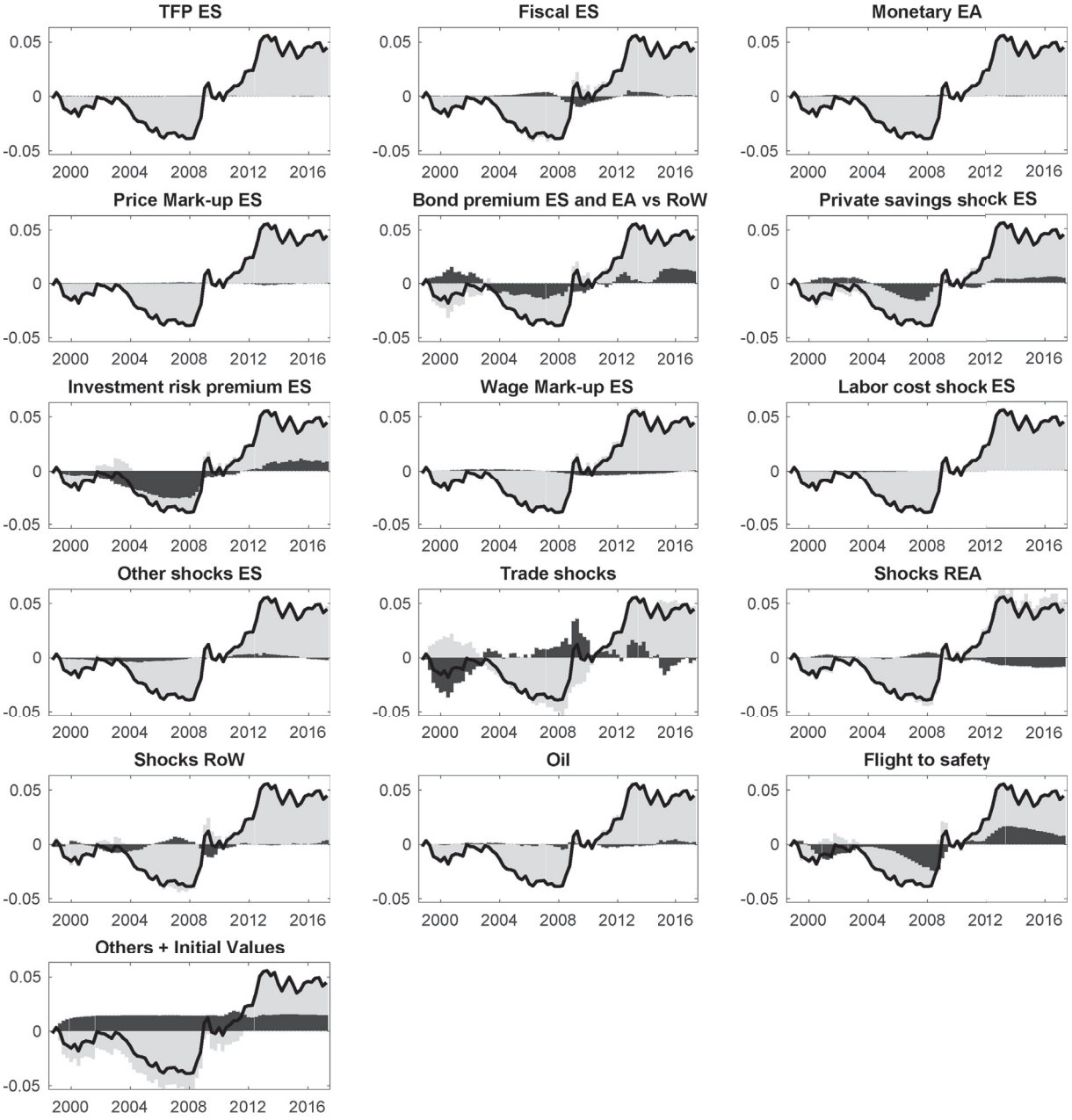


Fig. 15. Historical decomposition of the trade balance-to-GDP ratio in Spain.

Spain, capturing a heightened intra-euro risk vis-à-vis REA.

Summarising the key patterns of the historical decomposition across the countries, our results suggest that:

(1) The GDP growth slowdown during the 2008–2009 financial crisis was largely due to an increase in investment risk premia and negative shocks to foreign demand and trade. The positive contributions of stabilising fiscal and monetary policy during the financial crisis is visible across countries.
(2) The partial recovery in the aftermath of the crisis was due to a fall in investment risk premia and a recovery of world trade and demand, particularly for Germany.
(3) During most recent years, the main drivers of GDP growth have been a normalisation of consumption after a period of post-crisis deleveraging, the fall in oil prices, positive trade development and the euro depreciation. Fiscal shocks, i.e. policy normalisation after a period of crisis-induced austerity, have contributed considerably to GDP growth in Spain.
(4) The trade balance development in Germany differs substantially from those in the other countries. Overall, the improvement of the trade balance-to-GDP ratios after the financial crisis are mainly driven by increasing private savings (lower consumption demand), an increase in investment risk premia, the depreciation of the euro, heightened intra-euro risk premia and a recovery of world demand and trade. Weak foreign demand from REA has weighted negatively on the trade balance of the countries since the Great Recession.
(5) Supply shocks do not play a significant role, except for the sizable negative contribution of the productivity slowdown in Italy and for the overall productivity gap of the euro area vis-à-vis the rest of the world, partially captured by external (foreign) shocks.

Taken together, from the overall homogeneity of the IRFs, discussed in Subsection 4.3, and the country-specific patterns of shock decompositions, we can conclude that cross-country heterogeneity in the dynamics of real GDP growth and trade balance adjustments in the aftermath

of the financial crisis has been driven more by country-specific shocks than by different transmission of shocks.

5. Conclusion

This paper presents estimated versions of the European Commission's Global Multi-country (GM) model for the four largest Euro Area countries (Germany, France, Italy, and Spain) to assess and compare the main drivers of GDP and the trade balance in the aftermath of the global financial crisis. The GM model is a dynamic stochastic general equilibrium (DSGE) model with ex ante identical country structures and estimated on the basis of a unified information set, which allows for a clean cross-country comparison of parameter estimates and drivers of economic dynamics.

Our estimated models replicate key features of the EA Member State business cycles and provide reasonably good 1-year- and 2-year-ahead forecasts. The estimation results suggest that the cross-country heterogeneity in real GDP growth and trade balance adjustment observed after 2009 is mostly driven by cross-country differences in shocks rather than by differences in the shock transmission. The persistent post-crisis slump in Italy and Spain appears to be driven mainly by demand shocks, in particular adverse shocks to risk premia on investment, negative consumption shocks (positive saving shocks or 'deleveraging'), and an increase in the intra-euro risk premia ('flight to safety'). Fiscal policy (austerity) in Spain and the productivity slowdown in Italy, capturing the productivity differential vis-à-vis the Euro Area, have been additional sizable contributors to the economic downturn in these two countries, while lower foreign demand for export goods has been an additional negative driver in France. Less pronounced negative domestic demand shocks have mitigated the economic slowdown in Germany.

Our empirical analysis suggests that the euro depreciation, a widening of the intra-euro risk premia and subdued investment had a significant impact on the pronounced trade balance reversals in Italy and Spain. These positive contributions have been offset in France by a strong increase in imports and less exports to REA and RoW (negative trade shocks). Beside the traditionally high saving rate in Germany, the increase in global trade and RoW demand, the euro depreciation and the decline in oil prices have led to an even more pronounced increase of Germany's trade balance surplus after the global financial crisis.

Acknowledgment

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The opinions and views expressed in this paper are those of the authors only and should not be considered as official positions of the European Commission or the Banque de France, nor should it be interpreted as reflecting the views of the Federal Reserve Bank of Chicago or any other person associated with the Federal Reserve System.

Appendix A. Data source and transformations

We use quarterly and annual data for the period 1999q1 to 2017q2. Data for EMU countries and the Euro Area aggregate (EA19) are taken from Eurostat (in particular, from the European System of National Account ESA2010). Bilateral trade flows are based on trade shares from the GTAP trade matrices for trade in goods and services. The Rest of the World (RoW) data are annual data and are constructed using IMF International Financial Statistics (IFS) and World Economic Outlook (WEO) databases.

Series for GDP and prices in the RoW start in 1999 and are constructed on the basis of data for the following 58 countries: Albania, Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Czech Republic, Denmark, Egypt, Georgia, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Israel, Japan, Jordan, Korea, Lebanon, Libya, FYR Macedonia, Malaysia, Mexico, Moldova, Montenegro, Morocco, New Zealand, Nigeria, Norway, Philippines, Poland, Romania, Russia, Saudi Arabia, Serbia, Singapore, South Africa, Sweden, Switzerland, Syria, Taiwan, Thailand, Tunisia, Turkey, Ukraine, United Arab Emirates, United Kingdom, and Venezuela.

When not available, quarterly-frequency data are obtained by interpolating annual data. We seasonally adjust the following time series using the TRAMO-SEATS package developed by Gómez and Maravall (1996): nominal public investments (for EA19, Germany, France, Italy, and Spain), nominal social benefits other than transfers in kind (for EA19, Germany, France, Italy, and Spain), government interest expenditure (for EA19, Germany, France, Italy, and Spain), compensation of employees (for Germany, France, Italy, and Spain), general government net lending (for Italy and Spain), employees (for EA19, Germany, France, Italy, and Spain).

Table B.1 lists the observed time series. GDP deflators and relative prices of aggregates are computed as the ratios of current price value to chained indexed volume. The trend component of total factor productivity is computed using the DMM package developed by Fiorentini et al. (2012). The obtained series at quarterly frequency is then used to estimate the potential output. In Germany, we additionally observe the historical unemployment benefit ratio (constructed as the ratio of unemployment benefits to the wage rate).

We make a few transformations to the raw investment series. In particular, we compute the deflator of public investments based on annual data and then obtain its quarterly frequency counterpart through interpolation. This series together with nominal public investments is then used to compute real quarterly public investments. In order to assure consistency between nominal GDP and the sum of the nominal components of aggregate demand, we impute change in inventories to the series of investments.

Appendix B. Estimation results

Appendix B.1. List of observables

Table B.1
List of observables.

EMU countries	Euro Area*	Rest of the World
GDP (nominal and real)	GDP (nominal and real)	GDP (nominal and real)
TFP trend	GDP trend	GDP trend
Hours worked	Effective exchange rate (nominal)	Oil price
Wages (nominal)	Interest rate (nominal)	Interest rate (nominal)
Imports (nominal and real)	Imports (nominal and real)	Population
Exports (nominal and real)	Exports (nominal and real)	
Government consumption (nominal and real)	Population	
Government investment (nominal and real)		
Private consumption (nominal and real)		
Total investment (nominal and real)		
Government transfers (nominal)		
Government interest payments (nominal)		
Government debt (nominal)		
Active population rate		
Population		

* Note: We observe EA aggregate variables and compute model-consistent REA variables given the size of the EMU country.

Appendix B.2. Estimated key model innovations

Table B.2
Prior and posterior distributions of key model innovations.

		Prior distribution		Posterior distribution			
		Distr	Mean St. Dev	DE	FR	IT	ES
Autocorrelations of forcing variables							
Subjective discount factor	ρ^{UC}	B	0.5	0.88	0.84	0.86	0.79
			0.2	(0.81, 0.91)	(0.35, 0.89)	(0.69, 0.90)	(0.74, 0.87)
Investment risk premium	ρ^{S}	B	0.85	0.96	0.94	0.95	0.95
			0.05	(0.93, 0.98)	(0.90, 0.96)	(0.91, 0.97)	(0.93, 0.97)
Domestic price mark-up	ρ^{MUY}	B	0.5	0.73	0.69	–	–
			0.2	(0.64, 0.83)	(0.46, 0.85)		
Flight to safety	ρ^{FQ}	B	0.85	0.92	0.98	0.95	0.97
			0.05	(0.86, 0.95)	(0.91, 0.99)	(0.92, 0.97)	(0.95, 0.99)
Trade share	ρ^{M}	B	0.5	0.91	0.93	0.78	0.83
			0.2	(0.87, 0.94)	(0.89, 0.96)	(0.72, 0.86)	(0.76, 0.86)
International bond preferences	ρ^{BW}	B	0.5	0.91	0.95	0.89	0.75
			0.2	(0.86, 0.94)	(0.84, 0.97)	(0.81, 0.93)	(0.68, 0.88)
Standard deviations (%) of innovations to forcing variables							
Subjective discount factor	ε^{UC}	G	1	0.59	1.07	0.99	1.25
			0.4	(0.36, 1.18)	(0.44, 1.79)	(0.41, 1.59)	(0.82, 2.05)
Investment risk premium	ε^{S}	G	0.1	0.21	0.27	0.18	0.19
			0.04	(0.13, 0.28)	(0.15, 0.32)	(0.14, 0.27)	(0.14, 0.31)
Domestic price mark-up	ε^{MUY}	G	2	3.90	4.07	7.10	5.09
			0.8	(3.02, 6.11)	(2.32, 4.94)	(5.82, 8.30)	(4.36, 6.65)
Flight to safety	ε^{S}	G	0.1	0.09	0.08	0.08	0.09
			0.04	(0.06, 0.10)	(0.06, 0.09)	(0.07, 0.10)	(0.07, 0.10)
Trade share	ε^{M}	G	1	1.92	1.60	2.04	2.39
			0.4	(1.70, 2.20)	(1.43, 1.83)	(1.75, 2.24)	(2.15, 2.83)
International bond preferences	ε^{BW}	G	1	0.23	0.16	0.37	0.28
			0.4	(0.17, 0.47)	(0.010, 0.42)	(0.19, 0.54)	(0.16, 0.49)
Monetary policy	ε^{i}	G	1	0.10	0.10	0.10	0.10
			0.4	(0.08, 0.11)	(0.09, 0.11)	(0.09, 0.11)	(0.09, 0.12)
Government consumption	ε^{G}	G	1	0.17	0.10	0.37	0.34
			0.4	(0.14, 0.20)	(0.09, 0.12)	(0.32, 0.42)	(0.29, 0.38)
Gov transfers	ε^{T}	G	1	0.12	0.12	0.13	0.21
			0.4	(0.10, 0.13)	(0.11, 0.14)	(0.11, 0.15)	(0.18, 0.24)

(*continued on next page*)

Table B.2 *(continued)*

		Prior distribution		Posterior distribution			
		Distr	Mean St. Dev	DE	FR	IT	ES
Permanent TFP	$\varepsilon^{\overline{LAY}}$	G	0.1 0.04	0.12 (0.11, 0.15)	0.08 (0.07, 0.10)	0.11 (0.09, 0.12)	0.13 (0.12, 0.15)
Labor supply	ε^{U}	G	1 0.4	1.11 (0.85, 1.82)	1.30 (0.92, 2.00)	1.88 (0.64, 2.20)	2.14 (1.40, 3.19)

Notes: Cols. (1)–(2) list model innovations. Cols. (3)–(4) indicate the prior distribution function (B: Beta distribution; G: Gamma distribution). Identical priors are assumed across countries. Cols. (5)–(8) show the mode and the HPD intervals of the posterior distributions of DE, FR, IT, and ES key innovations, respectively.

Appendix B.3. Annual fit

Figs. B.1–B.4 show the unconditional 1- and 2-year ahead forecast of selected observed variables for the four EMU countries. The solid blue line depicts the observed annual time series, the red solid line shows the unconditional model-implied 1- and 2-year ahead prediction at each point (year) in time. The dashed slim green and blue lines connect the 1- and 2-year predictions, respectively.

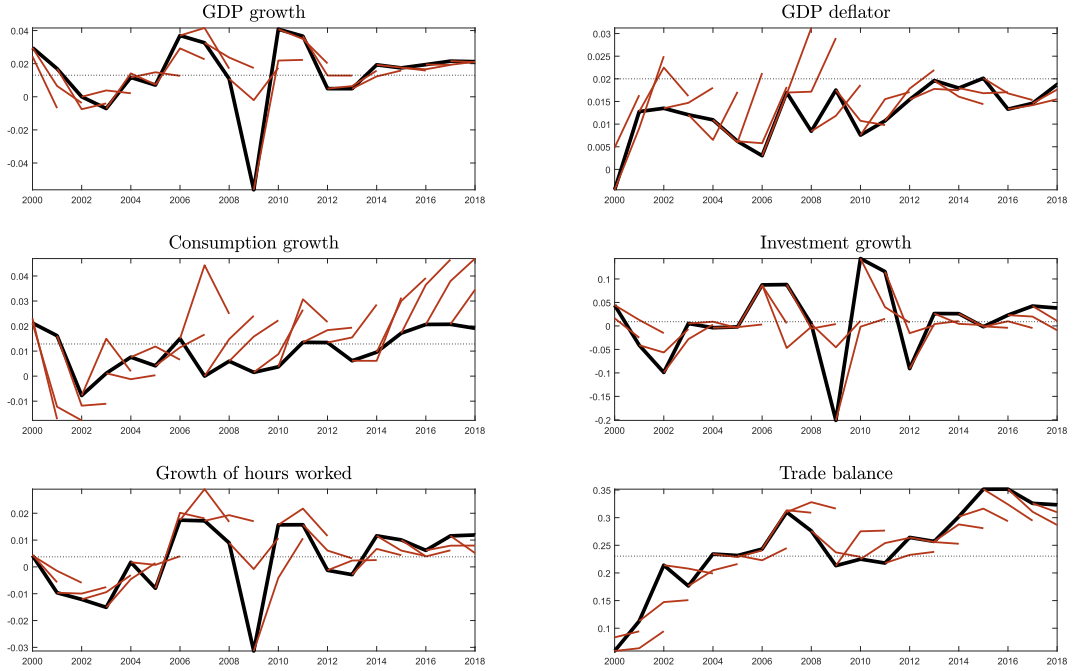
This graphical representation of the 1- and 2-year ahead forecast error, discussed in section 4.2, suggest that our estimated models deliver a relatively good (in-sample) forecast accuracy. For example, looking closer to the huge drop in real GDP growth during the global financial crisis for the four estimated countries, the models 2-year ahead predictions in 2008 forecast a further decrease in GDP growth in 2009 before it forecasts a recovery in 2010. We are also able to fit fairly well nominal and real export and import growth across countries. However, we face some difficulties in delivering a well-performing (in-sample) forecast accuracy, e.g., for consumption growth and GDP inflation in Germany and France.

Appendix B.4. Cross correlation

Figs. B.5–B.8 depict the lead-lag structure of real GDP growth with its main components (consumption, investment, employment, and the trade balance) and GDP inflation for the four EMU countries. We use first differences for the trade balance-to-GDP ratio and quarter-on-quarter growth rates for all other variables. It compares the model-generated cross correlations (black) (auto-correlation for GDP growth) with the ones of the observed data (blue). The horizontal dashed red lines represent the 95% confidence bounds.

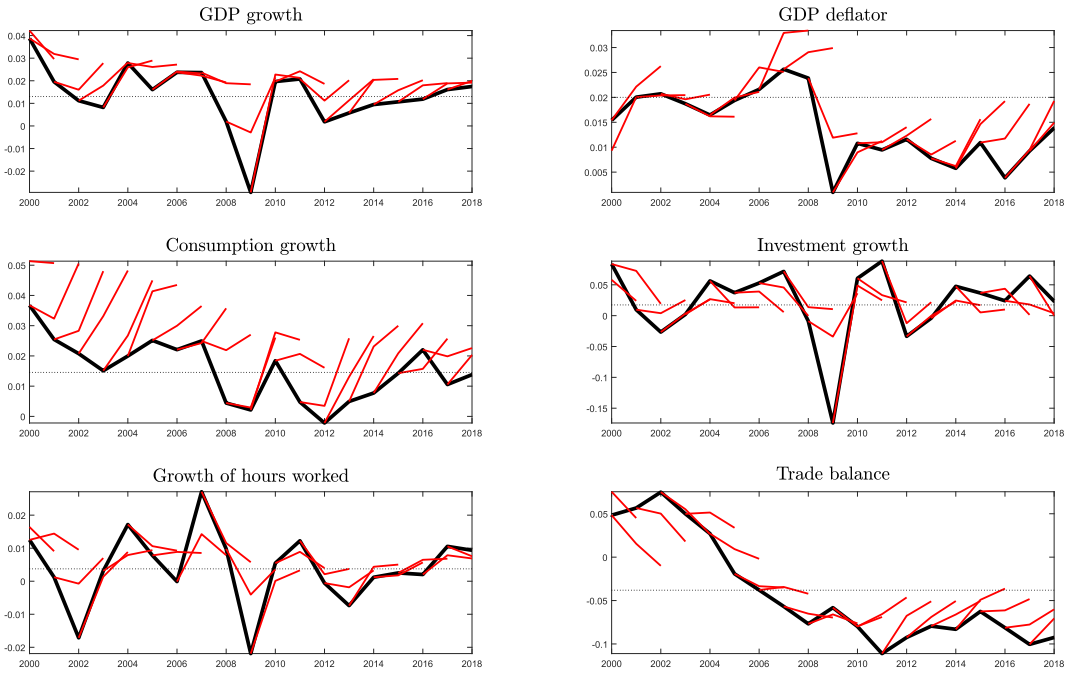
In the figures, *lag* refers to the timing of the second argument of the couple, where GDP is always the first. For example, looking at the subplot of consumption growth in B.5, it provides information on the cross-correlation of consumption growth, ranging from $t-2$ to $t+2$, on contemporaneous GDP growth at time t: when *lag* is positive, consumption leads GDP by *lag* periods; when *lag* is negative, consumption lags GDP by *lag* periods. Therefore, the cross-correlation of consumption growth in $t+2$ on GDP growth in t can also be interpreted as the cross-correlation of GDP growth in $t-2$ on consumption growth in t.

The figures suggest that most of the correlations between GDP growth and its components are fairly well captured. More precisely, all country models replicate the contemporaneous correlation of consumption, investment and employment with output. In our model the trade balance is positively correlated with output, but matches the data pattern only for Germany. Moreover, all estimated models generate a negative contemporaneous correlation between GDP inflation and GDP growth, which matches the data only in Germany and Italy. Persistency patterns are particularly well seized in Spain.



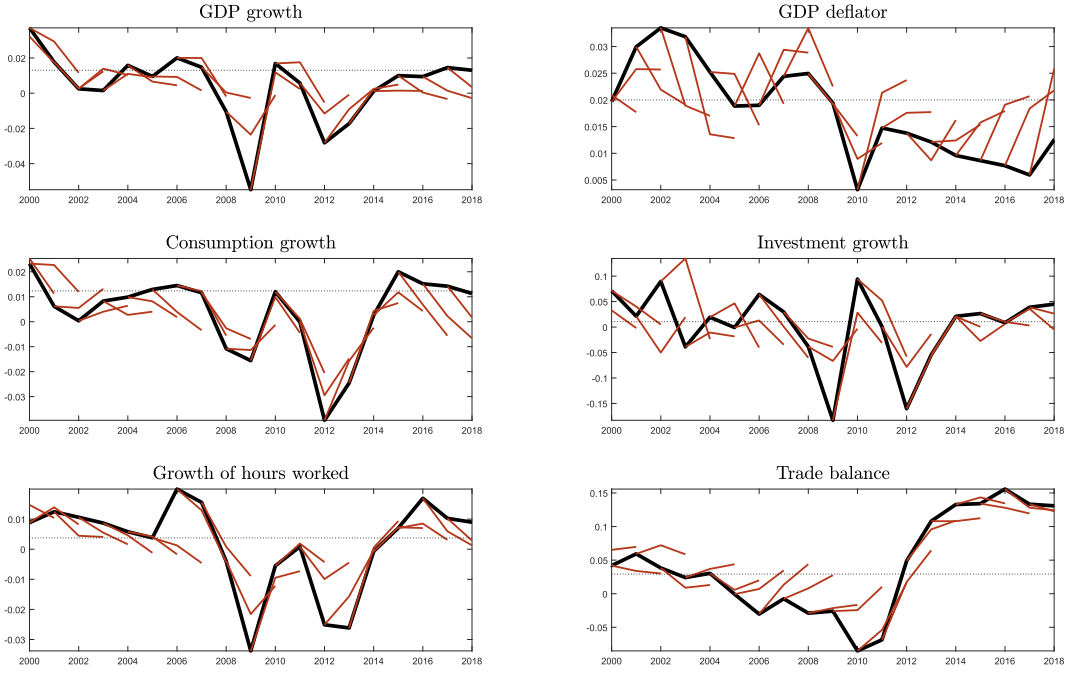
Note: The solid black line depicts the observed annual series, the red solid line shows the unconditional 1- and 2-year ahead prediction.

Fig. B.1 Annual fit for Germany.



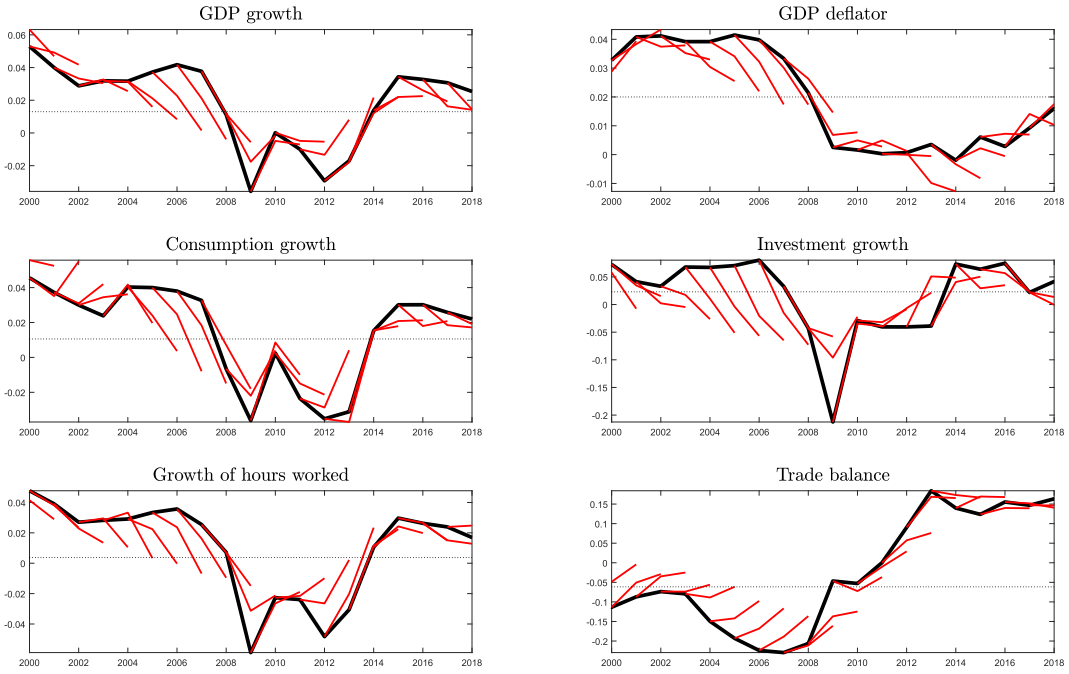
Note: The solid black line depicts the observed annual series, the red solid line shows the unconditional 1- and 2-year ahead prediction.

Fig. B.2 Annual fit for France.



Note: The solid black line depicts the observed annual series, the red solid line shows the unconditional 1- and 2-year ahead prediction.

Fig. B.3 Annual fit for Italy.



Note: The solid black line depicts the observed annual series, the red solid line shows the unconditional 1- and 2-year ahead prediction.

Fig. B.4 Annual fit for Spain.

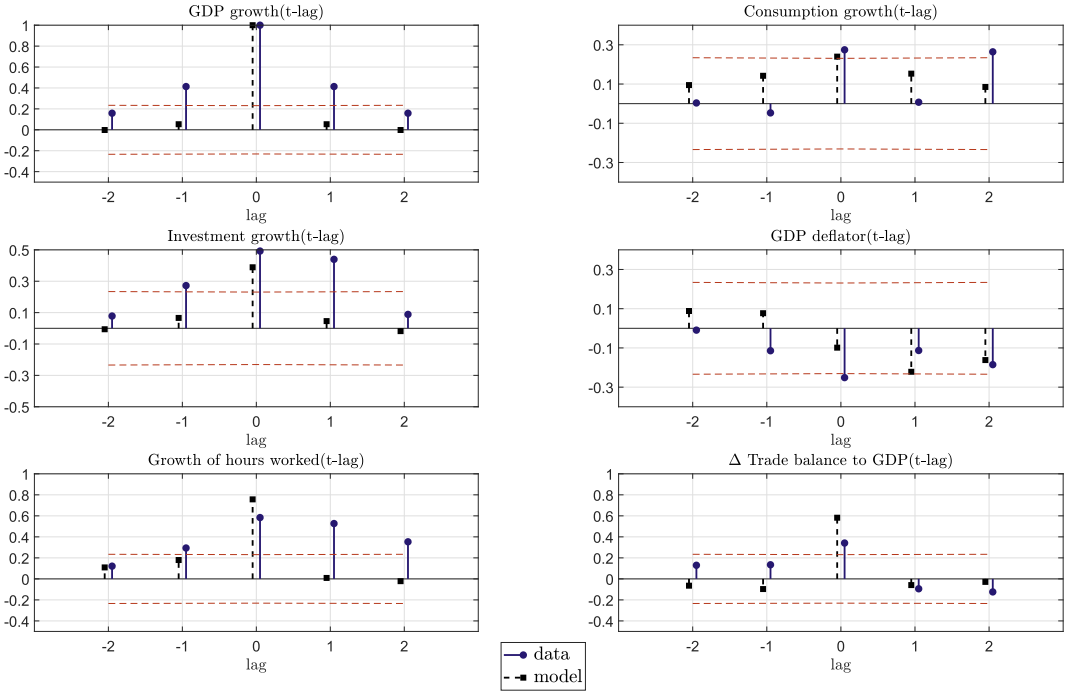


Fig. B.5 Lead-Lag structure of output growth with its main component and GDP inflation for Germany.

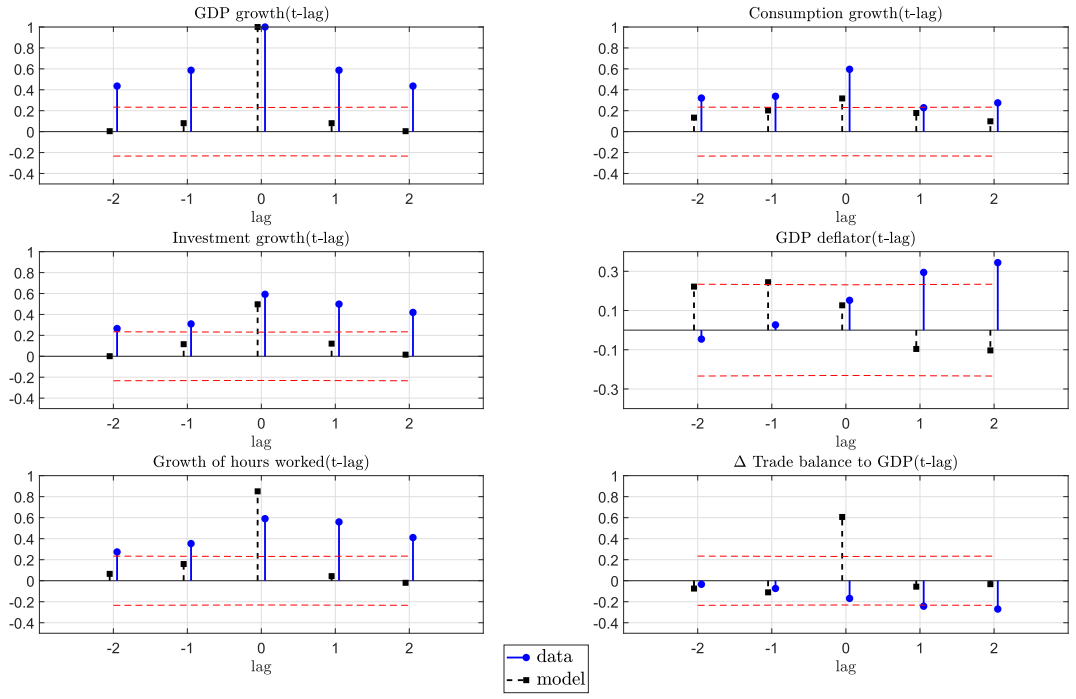


Fig. B.6 Lead-Lag structure of output growth with its main component and GDP inflation for France.

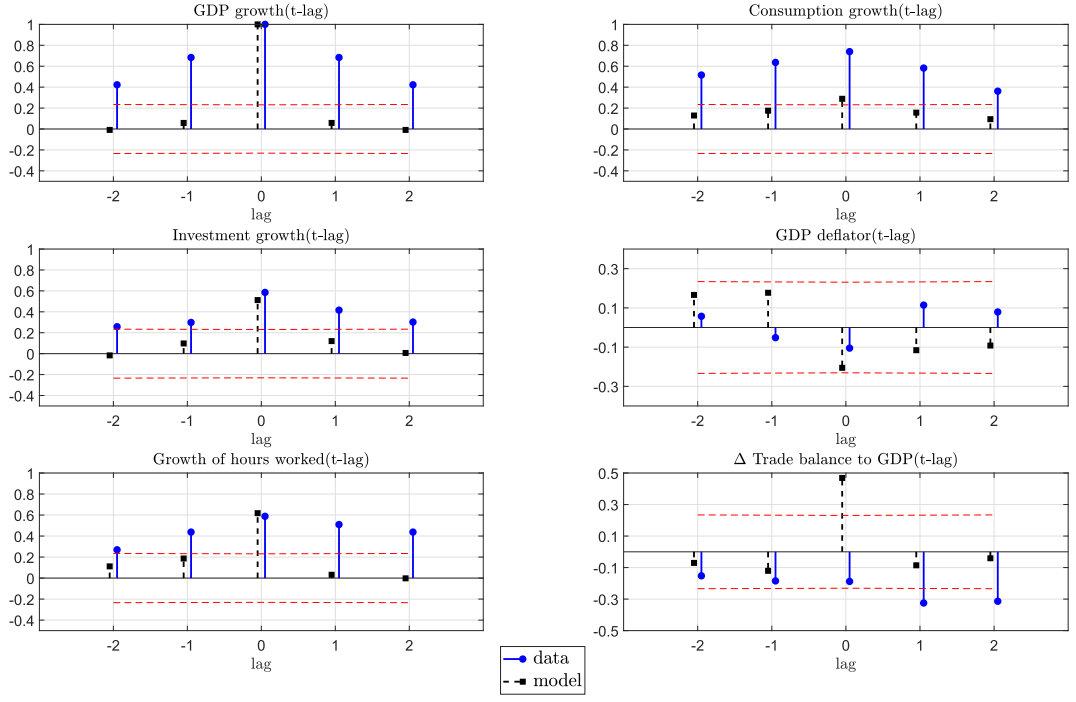


Fig. B.7 Lead-Lag structure of output growth with its main component and GDP inflation for Italy.

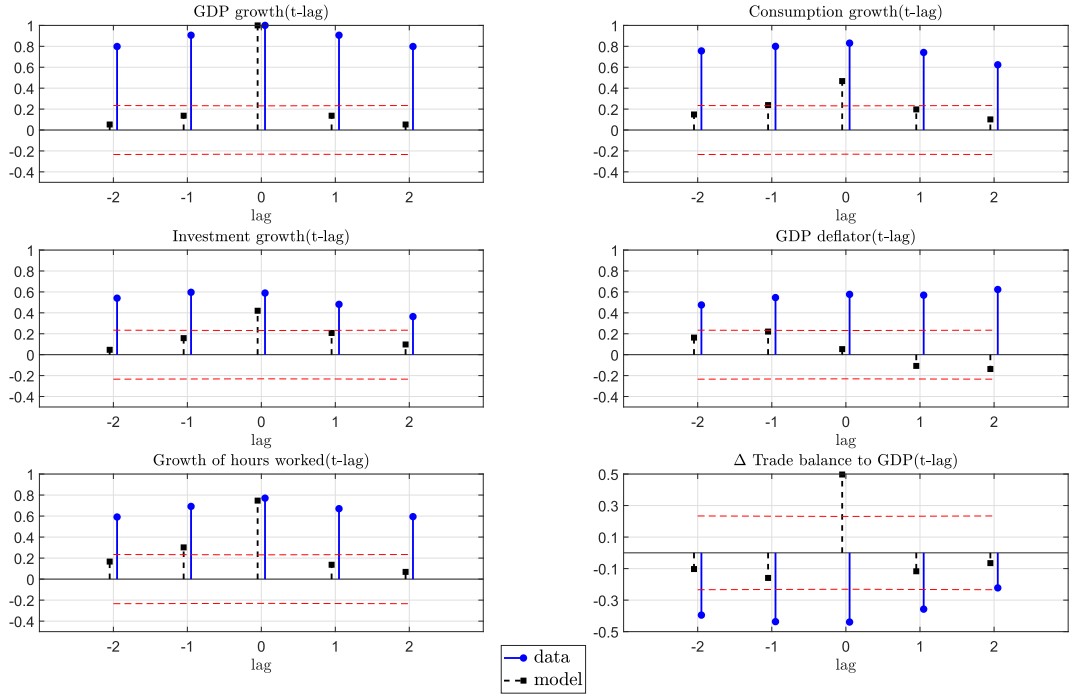


Fig. B.8 Lead-Lag structure of output growth with its main component and GDP inflation for Spain.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2019.04.016.

References

Adjemian, S., Bastani, H., Juillard, M., Karamé, F., Maih, J., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., Villemot, S., 2011. Dynare: Reference Manual Version 4. Dynare Working Papers 1. CEPREMAP.

Adolfson, M., Laséen, S., Lindé, J., Villani, M., 2008. Evaluating an estimated new Keynesian small open economy model. J. Econ. Dyn. Control 32, 2690–2721.

Albonico, A., Cales, L., Cardani, R., Croitorov, O., Di Dio, F., Ferroni, F., Giovannini, M., Hohberger, S., Pataracchia, B., Pericoli, F., Pfeiffer, P., Raciborski, R., Ratto, M., Roeger, W., Vogel, L., 2019. The Global Multi-Country Model (GM): an Estimated DSGE Model for Euro Area Countries. European economy - economic papers, forthcoming. Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Benigno, P., 2009. Price stability with imperfect financial integration. J. Money Credit Bank. 41, 121–149.

Bernanke, B., Gertler, M., Gilchrist, S., 1996. The financial accelerator and the flight to quality. Rev. Econ. Stat. 78, 1–15.

Blanchard, O., 2018. On the future of macroeconomic models. Oxf. Rev. Econ. Pol. 34, 43–54.

Blanchard, O., Galí, J., 2007. Real wage rigidities and the new Keynesian model. J. Money Credit Bank. 39, 35–65.

Bokan, N., Gerali, A., Gomes, S., Jacquinot, P., Pisani, M., 2018. EAGLE-FLI: a macroeconomic model of banking and financial interdependence in the euro area. Econ. Modell. 69, 249–280.

Burnside, C., Eichenbaum, M., 1996. Factor-hoarding and the propagation of business-cycle shocks. Am. Econ. Rev. 86, 1154–1174.

Bussière, M., Callegari, G., Ghironi, F., Sestieri, G., Yamano, N., 2013. Estimating trade elasticities: demand composition and the trade collapse of 2008-2009. Am. Econ. J. Macroecon. 5, 118–151.

Calés, L., Pericoli, F., Ratto, M., 2017. Rotated Slice Sampling: Applications for the Bayesian Estimation of DSGE Models. mimeo, European Commission.

Canova, F., Ferroni, F., Matthes, C., 2014. Choosing the variables to estimate singular DSGE models. J. Appl. Econom. 29, 1099–1117.

Christoffel, K., Coenen, G., Warne, A., 2008. The New Area-wide Model of the Euro Area: a Micro-founded Open-Economy Model for Forecasting and Policy Analysis. Working Paper Series 944. European Central Bank.

Coenen, G., Erceg, C., Freedman, C., Furceri, D., Kumhof, M., Lalonde, R., Laxton, D., Lindé, J., Mourougane, A., Muir, D., Mursula, S., de Resende, C., Roberts, J., Roeger, W., Snudden, S., Trabandt, M., in't Veld, J., 2012. Effects of fiscal stimulus in structural models. Am. Econ. J. Macroecon. 4, 22–68.

Coenen, G., Straub, R., 2005. Does government spending crowd in private consumption? Theory and empirical evidence for the euro area. Int. Financ. 8, 435–470.

Dieppe, A., Georgiadis, G., Ricci, M., Van Robays, I., van Roye, B., 2018. ECB-Global: introducing the ECB's global macroeconomic model for spillover analysis. Econ. Modell. 72, 78–98.

Dieppe, A., Gonzalez Pandiella, A., Willman, A., 2012. The ECB's New Multi-Country Model for the euro area: NMCM — simulated with rational expectations. Econ. Modell. 29, 2597–2614.

Dixit, A.K., Stiglitz, J.E., 1977. Monopolistic competition and optimum product diversity. Am. Econ. Rev. 67, 297–308.

Dolls, M., Fuest, C., Peichl, A., 2012. Automatic stabilizers and economic crisis: US vs. Europe. J. Public Econ. 96, 279–294.

European Commission, 2013. Report on Public Finances in EMU 2013. European Economy 4/2013.

Fiorentini, G., Planas, C., Rossi, A., 2012. A Fortran Program for Dynamic Mixture Models. Working Papers 11, Universitá degli Studi di Firenze Working Paper Series.

Fisher, J.D., 2015. On the structural interpretation of the Smets–Wouters "risk premium" shock. J. Money Credit Bank. 47, 511–516.

Gadatsch, N., Hauzenberger, K., Stähler, N., 2016. Fiscal policy during the crisis: a look on Germany and the Euro area with GEAR. Econ. Modell. 52, 997–1016.

Giovannini, M., Hohberger, S., Kollmann, R., Ratto, M., Roeger, W., Vogel, L., 2018. Euro Area and U.S. External adjustment: the role of commodity prices and emerging market shocks. J. Int. Money Finance 94, 183–205.

Gómez, V., Maravall, A., 1996. Programs TRAMO and SEATS, Instruction for User. Working Papers 9628. Banco de España.

Hassan, F., Ottaviano, G., 2013. Productivity in Italy: the Great Unlearning. VOX CEPR's Policy Portal.

Havik, K., Morrow, K.M., Orlandi, F., Planas, C., Raciborski, R., Roeger, W., Rossi, A., Thum-Thysen, A., Vandermeulen, V., 2014. The Production Function Methodology for Calculating Potential Growth Rates & Output Gaps. European Economy - Economic Papers 535. European Commission.

Helliwell, J.F., Meredith, G., Durand, Y., Bagnoli, P., 1990. Intermod 1.1 A G7 version of the IMF's MULTIMOD. Econ. Modell. 7, 3–62.

Hervé, K., Pain, N., Richardson, P., Sédillot, F., Beffy, P.-O., 2011. The OECD's new global model. Econ. Modell. 28, 589–601.

Hunt, B., Laxton, D., 2004. Some simulation properties of the major euro area economies in MULTIMOD. Econ. Modell. 21, 759–783.

in't Veld, J., Kollmann, R., Pataracchia, B., Ratto, M., Roeger, W., 2014. International capital flows and the boom-bust cycle in Spain. J. Int. Money Financ. 48, 314–335.

in't Veld, J., Pagano, A., Raciborski, R., Ratto, M., Roeger, W., 2015. Imbalances and rebalancing in an estimated structural model for Spain. Int. J. Central Bank. 11, 1–41.

Jeanfils, P., Burggraeve, K., 2008. "NONAME": a new quarterly model for Belgium. Econ. Modell. 25, 118–127.

Kamber, G., McDonald, C., Sander, N., Theodoridis, K., 2016. Modelling the business cycle of a small open economy: the Reserve Bank of New Zealand's DSGE model. Econ. Modell. 59, 546–569.
Karadi, P., Schmidt, S., Warne, A., 2017. The New Area-wide Model II: an Updated Version of the ECB's Micro-founded Model for Forecasting and Policy Analysis with a Financial Sector. mimeo, European Central Bank.
Kollmann, R., Pataracchia, B., Raciborski, R., Ratto, M., Roeger, W., Vogel, L., 2016. The post-crisis slump in the Euro Area and the US: evidence from an estimated three-region DSGE model. Eur. Econ. Rev. 88, 21–41.
Kollmann, R., Ratto, M., Roeger, W., in't Veld, J., 2013. Fiscal policy, banks and the financial crisis. J. Econ. Dyn. Control 37, 387–403.
Kollmann, R., Ratto, M., Roeger, W., in't Veld, J., Vogel, L., 2015. What drives the German current account? And how does it affect other EU Member States? Econ. Policy 30, 47–93.
Krishnamurthy, A., Vissing-Jorgensen, A., 2012. The aggregate demand for treasury debt. J. Political Econ. 120, 233–267.
Neal, R., 2003. Slice sampling. Ann. Stat. 31, 705–741.
Pellegrino, B., Zingales, L., 2017. Diagnosing the Italian Disease. NBER Working Paper 23964.
Planas, C., Ratto, M., Rossi, A., 2015. Slice Sampling in Bayesian Estimation of DSGE Models. mimeo, European Commission.
Rafiq, M., Mallick, S., 2008. The effect of monetary policy on output in EMU3: a sign restriction approach. J. Macroecon. 30, 1756–1791.
Ratto, M., Roeger, W., in't Veld, J., 2009. QUEST III: an estimated open-economy DSGE model of the euro area with fiscal and monetary policy. Econ. Modell. 26, 222–233.
Rotemberg, J.J., 1982. Monopolistic price adjustment and aggregate output. Rev. Econ. Stud. 49, 517–531.
Schmitt-Grohe, S., Uribe, M., 2003. Closing small open economy models. J. Int. Econ. 61, 163–185.
Sidrauski, M., 1967. Rational choice and patterns of growth in a monetary economy. Am. Econ. Rev. 57, 534–544.
Smets, F., Wouters, R., 2007. Shocks and frictions in US business cycles: a Bayesian DSGE approach. Am. Econ. Rev. 97, 586–606.
Stähler, N., Thomas, C., 2012. FiMod - a DSGE model for fiscal policy simulations. Econ. Modell. 29, 239–261.
Taylor, J.B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Conf. Ser. Public Policy 39, 195–214.
Taylor, J.B., Wieland, V., 2012. Surprising comparative properties of monetary models: results from a new model database. Rev. Econ. Stat. 94, 800–816.
Vitek, F., 2014. Policy and Spillover Analysis in the World Economy: A Panel Dynamic Stochastic General Equilibrium Approach. IMF Working Papers 14/200. International Monetary Fund.
Vitek, F., 2017. Policy, Risk and Spillover Analysis in the World Economy. A Panel Dynamic Stochastic General Equilibrium Approach. IMF Working Papers 17/89. International Monetary Fund.
Wallis, K.F., 2004. Comparing empirical models of the euro economy. Econ. Modell. 21, 735–758.
Wieland, V., Afanasyeva, E., Kuete, M., Yoo, J., 2016. New methods for macro-financial model comparison and policy analysis. In: Taylor, J.B., Uhlig, H. (Eds.), Handbook of Macroeconomics, vol. 2, pp. 1241–1319 chap. 15.
Wieland, V., Cwik, T., Müller, G.J., Schmidt, S., Wolters, M., 2012. A new comparative approach to macroeconomic modeling and policy analysis. J. Econ. Behav. Organ. 83, 523–541.