Adjustment dynamics and business-cycle heterogeneity in EMU: Evidence from estimated DSGE models

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Abstract

The paper reviews adjustment dynamics in the EMU on the basis of estimated DSGE models for four large EA Member States (DE, FR, IT, ES). We compare the response of the four countries to identical shocks and find a particularly strong response of employment and wages in ES, a high sensitivity of IT to investment-related shocks, and a comparatively strong impact of global shocks on the DE economy. We also perform a counterfactual exercise that applies the estimated shocks for ES to DE, FR, and IT. According to the results, business-cycle volatility in DE and IT would have been higher than in ES, except for employment and wages, whereas FR would have been the most resilient of the four countries. DE, FR and IT would also have shown stronger cyclical fluctuations with ES shocks than in the data. The conclusion is that both shocks and structure matter for business cycle heterogeneity across EA Member States in our estimated model.

JEL classification: E44, E52, E53, F41
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1. Introduction

Macroeconomic dynamics since the beginning of Economic and Monetary Union (EMU) have displayed a great deal of heterogeneity across Euro Area (EA) Member States (MS), including a boom in the EA "periphery" and rather meagre growth in the EA "core" in the early years of EMU, and a protracted recession in the EA "periphery" and much stronger recovery in the EA "core" after the global financial crisis. Whether the heterogeneity across EA countries reflects differences in shocks, or differences in the transmission of shocks (in particular, sluggish relative price adjustment) has been a longstanding question in the discussion of EMU. Bayoumi and Eichengreen (1992) in an early pre-EMU paper find shocks to be significantly more idiosyncratic across EU countries and the adjustment to shocks slower compared to US regions.

This paper looks at the experience with macroeconomic adjustment in the EMU through the lenses of an estimated dynamic stochastic general equilibrium (DSGE) model for individual EA MS. Following Albonico et al. (2017), we have estimated country blocks for the four largest economies in the EA, namely Germany, France, Italy, and Spain. The model is set up in a configuration with the respective MS (DE/FR/IT/ES), the rest of the EA (REA), and the rest of the world (RoW). The structure of the country blocks, i.e. model equations, time span, observable variables, prior parameter distributions, is ex-ante identical, so that differences between DE, FR, IT, and ES are expressed ex-post by differences in the estimated parameter values and the estimated shock processes.

The paper, hence, takes a comparative perspective. The model results that we provide focus on whether standard adjustment dynamics to comparable idiosyncratic shocks has been similar across EA MS, and whether it has been similar to the adjustment of the EA aggregate to EA-wide disturbances. The later aspect sheds light on the question of whether the absence of nominal exchange rate adjustment and monetary policy independence has slowed down macroeconomic adjustment at the level of MS. To the extent that adjustment to identical shocks is similar, differences in economic developments are accounted for by differences in the type and size of shocks experienced by the respective countries. A detailed account of cross-country heterogeneity in shocks is not the focus of this paper, however.

Our underlying model is a standard New Keynesian model with price and wage rigidity. It emphasizes the role of price and wage adjustment in the transmission of shocks as a means to achieve relative price adjustment and contain fluctuations in economic activity in response to
shocks. Financial frictions that have arguably played a substantial role for EA heterogeneity, notably the credit growth that has reinforced the boom and the deleveraging that has reinforced the recession in the EA "periphery", by contrast, are not modelled as endogenous transmission channels, but rather reflected in the estimated shocks.

The role of real exchange rate (REER) adjustment as a means to mitigate the impact of demand shocks (or demand rebalancing) on economic activity has been stressed by the literature for a long time (e.g., Krugman 1990). REER depreciation can, e.g., be expected to improve net exports and, hence, limit the output and employment loss associated with a contraction of domestic demand. At the same time, the REER is also affected by nominal exchange rate (EXR) fluctuations possibly detached from economic fundamentals, so that more REER persistence in the data does not necessarily reflect impaired adjustment. Therefore, we find it interesting to compare relative price adjustment for EA MS and compare them to adjustment dynamics of the EA aggregate as an economy with flexible exchange rate and independent monetary policy.

The remainder of the paper is structured as follows: Section 2 presents a number of stylized facts to deepen the motivation for the paper; section 3 outlines the general structure of the model; section 4 sketches the methodology for model solution and estimation; section 5 compares IRFs for individual EA countries and the EA aggregate for the shocks that are determined by the model as being the main driver of fluctuations in economic activity over the estimation horizon, and it presents a counterfactual to assess the importance of differences in the shock transmission for differences in macroeconomic performance over the sample period; section 6 summarizes the findings and concludes.

2. Some stylized facts

It is a general view that REERs move less for countries inside monetary union, due to the reduced impact of nominal EXRs and the rather sluggish adjustment of prices and wages. Figure 1 corroborates this view by showing that REER dynamics have been relatively muted for EA MS during the period 1999-2015 compared to G7 countries outside the EA. The picture is compatible with the classical Mussa (1986) result that REER fluctuations are dominantly driven by nominal EXR fluctuations, i.e. by the component that is fixed for the intra-EA part of the REER basket.
Figure 1: REERs in EA and non-EA countries

Note: REER is based on the GDP deflator and relative to the rest of 37 countries. An increase in the REER indicates real effective appreciation.
Source: AMECO

Figure 2: Average absolute year-on-year change in REER (1999-2015)

Note: REER is based on the GDP deflator and relative to the rest of 37 countries.
Source: AMECO
The observation of higher REER persistence inside the EA is underlined by Figure 2, which shows that absolute year-on-year changes in the REER have on average been smaller for EA MS compared to EU countries outside the EA and other OECD economies. Also note in Figure 2 that the upper bound of 1999-2015 REER volatility in the group of current EA MS comprises countries (such as the Baltics and Slovakia) that were still outside the EA during much of 1999-2015.¹

The stronger REER movement in non-EA countries in Figures 1-2 does not reveal whether the lower REER volatility for EA countries reflects weaker relative price adjustment to shocks, fewer shocks, or, in particular, the reduced importance of non-fundamental nominal EXR volatility.² Table 1 presents some suggestive summary statistics in this respect. It shows data moments for selected variables for DE, FR, IT, ES and the EA aggregate. In particular, it lists standard deviations as volatility measure and correlations of the respective variables with domestic real GDP. All variables are in quarter-on-quarter growth rates or first differences (real interest rate, TBY). While the individual MS are constrained with respect to nominal EXR adjustment, the EA aggregate represents an economic region with flexible nominal EXR and an independent monetary policy.

Table 1: Empirical business-cycle statistics, 1999q1-2016q2

<table>
<thead>
<tr>
<th>Variables</th>
<th>EA</th>
<th>corr (x,GDP)</th>
<th>DE</th>
<th>corr (x,GDP)</th>
<th>FR</th>
<th>corr (x,GDP)</th>
<th>IT</th>
<th>corr (x,GDP)</th>
<th>ES</th>
<th>corr (x,GDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>0.63</td>
<td>1</td>
<td>0.86</td>
<td>1</td>
<td>0.50</td>
<td>1</td>
<td>0.76</td>
<td>1</td>
<td>0.72</td>
<td>1</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.39</td>
<td>0.71</td>
<td>0.61</td>
<td>0.26</td>
<td>0.46</td>
<td>0.61</td>
<td>0.58</td>
<td>0.73</td>
<td>0.91</td>
<td>0.83</td>
</tr>
<tr>
<td>Investment</td>
<td>2.66</td>
<td>0.80</td>
<td>4.37</td>
<td>0.50</td>
<td>2.77</td>
<td>0.63</td>
<td>4.47</td>
<td>0.52</td>
<td>2.79</td>
<td>0.65</td>
</tr>
<tr>
<td>Hours worked</td>
<td>0.45</td>
<td>0.75</td>
<td>0.60</td>
<td>0.53</td>
<td>0.32</td>
<td>0.58</td>
<td>0.58</td>
<td>0.57</td>
<td>1.15</td>
<td>0.76</td>
</tr>
<tr>
<td>GDP deflator</td>
<td>0.22</td>
<td>0.04</td>
<td>0.33</td>
<td>-0.28</td>
<td>0.28</td>
<td>0.22</td>
<td>0.55</td>
<td>-0.16</td>
<td>0.47</td>
<td>0.64</td>
</tr>
<tr>
<td>CPI deflator</td>
<td>0.34</td>
<td>0.44</td>
<td>0.33</td>
<td>0.24</td>
<td>0.38</td>
<td>0.43</td>
<td>0.41</td>
<td>0.32</td>
<td>0.67</td>
<td>0.28</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.34</td>
<td>-0.20</td>
<td>0.58</td>
<td>-0.10</td>
<td>0.40</td>
<td>-0.05</td>
<td>0.76</td>
<td>0.19</td>
<td>1.02</td>
<td>-0.18</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>0.36</td>
<td>-0.03</td>
<td>0.31</td>
<td>-0.10</td>
<td>0.49</td>
<td>-0.15</td>
<td>0.50</td>
<td>-0.29</td>
<td>0.48</td>
<td>-0.45</td>
</tr>
<tr>
<td>Real exchange rate</td>
<td>2.37</td>
<td>0.23</td>
<td>2.17</td>
<td>0.09</td>
<td>1.90</td>
<td>0.01</td>
<td>2.38</td>
<td>0.00</td>
<td>2.10</td>
<td>-0.12</td>
</tr>
<tr>
<td>... relative to std of real GDP</td>
<td>3.79</td>
<td>-</td>
<td>2.53</td>
<td>-</td>
<td>3.81</td>
<td>-</td>
<td>3.13</td>
<td>-</td>
<td>2.92</td>
<td>-</td>
</tr>
<tr>
<td>Trade balance to GDP</td>
<td>1.13</td>
<td>0.01</td>
<td>0.68</td>
<td>0.34</td>
<td>1.58</td>
<td>0.32</td>
<td>1.62</td>
<td>0.06</td>
<td>2.79</td>
<td>-0.31</td>
</tr>
</tbody>
</table>

Note: First differences for real interest rate and trade balance; quarter-on-quarter growth rates for all other variables, an increase in the REER indicates real effective depreciation.

¹ Comparison on the basis of REER standard deviations instead of average absolute changes yields the same results for the comparison of EA versus non-EA countries.
² Non-fundamental here refers to nominal EXR movements that are driven by EXR-specific shocks (portfolio preference/currency risk shocks) rather than being part of the adjustment to other shocks.
Real GDP growth in DE, IT and ES has been more volatile than in the EA aggregate according to Table 1, which suggests stronger (asymmetric) shocks or weaker shock absorption at the MS level (except FR). REER volatility at the EA aggregate level has been higher than at the level of EA MS, also when measured relative to the volatility of domestic output (except for IT and FR, respectively), which suggests either more price adjustment thanks to euro nominal exchange rate adjustment in these cases, or additional REER volatility in the aggregate through shocks to the euro exchange rate. Finally, the contemporaneous correlation between output growth and changes in the REER is not very pronounced, which could either be the result of contemporaneous disconnection between both variables, or offsetting shocks. One should, e.g., expect domestic output growth to be associated with REER appreciation in case of positive domestic demand shocks (negative correlation between real GDP and REER in Table 1), and with REER depreciation in case of positive shocks to domestic aggregate supply (positive correlation between real GDP and REER in Table 1). In sum, Table 1 does not provide evidence for pronounced differences between the EA aggregate and the four large MS considered with respect to the strength of variations in the REER.

3. Model description

The analysis is based on the Global Multi-country (GM) model of the European Commission with an EA Member State (MS), the rest of the EA (REA), and the rest of the world (RoW) as building blocks (see Albonico et al. 2017). The EA MS block of the model is rather detailed, while the REA and RoW blocks are more stylized. The EA MS block assumes two (representative) households, firms and a government. EA MS households provide labour services to domestic firms. One of the two households (Ricardians) in each country has access to financial markets, owns her country’s firms and can smooth their consumption. The other household (liquidity-constrained) has no access to financial markets, does not own financial or physical capital, and consumes the disposable wage and transfer income in each period.

Final output in the EA MS is generated by perfectly competitive firms that combine domestic and imported intermediate inputs. Intermediates are produced by monopolistically competitive firms using local labour and capital as inputs. EA MS wages are set by monopolistic trade unions. Nominal differentiated goods prices and nominal wages are sticky. Governments purchase the local final good, make lump-sum transfers to local households, levy labour, con-
sumption and capital taxes and issue debt. All exogenous random variables in the model follow independent autoregressive processes. We next present the key aspects of a respective EA MS model block.\textsuperscript{3}

### 3.1. EA Member State households

The household sector consists of a continuum of households $j \in [0; 1]$. There are two types of households, savers ("Ricardians", superscript $s$) who own firms and hold government and foreign bonds and liquidity-constrained households (subscript $c$) whose only income is labour income and who do not save. The share of savers in the population is $\omega^s$.

Both households enjoy utility from consumption $C^r_{jkt}$ and incur disutility from labor $N^r_{jkt}$ ($r = s, c$). On top of this, Ricardian’s utility depends also on the financial assets held. Date $t$ expected life-time utility of household $r$, is defined as:

$$U^r_{jkt} = \sum_{s=t}^{\infty} \exp(\epsilon^r_{kst}) \beta^{s-t} w^r_{jkt}$$

where $\beta$ is the (non-stochastic) discount factor (common for both types of households) and $\epsilon^r_{kst}$ is the saving shock.

#### 3.1.1. Ricardian households

The Ricardian households work, consume, own firms and receive nominal transfers $T^s_{jkt}$ from the government. Ricardians have full access to financial markets and are the only households who own financial assets, $A^s_{jkt}$, where $P^c_{kt}$ is consumption price, including VAT.\textsuperscript{4} Financial wealth of household $j$ consists of bonds $B^s_{jkt}$ and shares $P^s_{jkt}S^s_{jkt}$, where $P^s_{kt}$ is the nominal price of shares in $t$ and $S^s_{jkt}$ the number of shares held by the household:

$$\frac{A^s_{jkt}}{P^c_{kt}} = \frac{B^s_{jkt}}{P^c_{kt}} + \frac{P^s_{jkt}S^s_{jkt}}{P^c_{kt}}$$

\textsuperscript{3} The description here abstracts from factor adjustment costs and variable capacity utilization rates assumed in the estimated model. A detailed description of the model can be found in Albonico et al. (2017).

\textsuperscript{4} Note that $P^c_{kt}$ is related to $P^c_k$, the private consumption deflator in terms of input factors, by the formula: $P^c_{kt} = (1 + \tau^c_k)P^c_k$, where $\tau^c_k$ is the tax on consumption.
It is assumed that households invest only in domestic shares. Bonds consist of government domestic, \( \frac{B_G^{jkt}}{P_{kt}^{c, vat}} \) and foreign bonds, \( \frac{B_F^{jkt}}{P_{kt}^{c, vat}} \), and private risk-free bonds, \( \frac{B_{rf}^{jkt}}{P_{kt}^{c, vat}} \) (in zero supply).

The period \( t \) budget constraint of a saver household \( j \) is:

\[
(1 - \tau^N)W_{kt}N_{jkt}^s + (1 + i_{kt-1}^G)B_{jkt-1}^G + (1 + i_{lt-1}^w)\epsilon_{ikt}^w B_{jkt-1}^w + (1 + i_{t-1}^{rf})B_{jkt-1}^{rf} \\
+ (P_{kt}^S + P_{kt}^Y d_{kt})S_{jkt-1} + \tau_{jkt}^s - \tau_{x}^s_{jkt} = P_{kt}^c c_{jkt} + A_{jkt}
\]

where \( W_{kt} \) is the nominal wage rate and \( \tau^N \) the labour tax rate. \( P_{kt}^Y \), is the GDP price deflator, \( i_{lt-1}^w \) are interest rates on foreign bonds of region \( l \), \( i_{t-1}^{rf} \) is interest rate on risk-free bond, \( T_{jkt}^s \) are government transfers to savers and \( \tau_{x}^s_{jkt} \) are lump-sum taxes paid by savers. Intermediate goods producers paying dividends \( d_{kt} \) to savers.

The instantaneous utility functions of savers, \( u^s(\cdot) \), is defined as:

\[
u^s\left(C_{jkt}^s, N_{jkt}^s, \frac{U_{jkt-1}^A}{P_{kt}^{c, vat}}\right)
\\
= \frac{1}{1 - \theta} \left(C_{jkt}^s - hC_{kt-1}^s\right)^{1-\theta} - \frac{\omega^N \epsilon_{ikt}^u}{1 + \theta^N} \left(N_{jkt}^s\right)^{1 + \theta^N}
\\
- \left(C_{jkt}^s - hC_{kt-1}^s\right)^{-\theta} \frac{U_{jkt-1}^A}{P_{kt}^{c, vat}}
\]

where \( C_{kt}^s = \int C_{jkt}^s \), and \( C_{kt} = \omega^SC_{kt}^s + (1 - \omega^S)C_{kt}^C \); \( h \in (0;1) \) measures the strength of external habits in consumption and \( \epsilon_{ikt}^u \) is the labor supply (or wage mark-up) shock. The disutility of holding financial assets, \( U_{jkt-1}^A \), is defined as:

\[
U_{jkt-1}^A = \left(\alpha_k^{b^0} + \epsilon_{kt-1}^b\right)B_{jkt-1}^G + \left(\alpha_k^{b^w_0} + \epsilon_{ikt-1}^b\right)\epsilon_{ikt-1}^w B_{jkt-1}^w + \frac{\alpha_k^{b^1}}{2} \left(\epsilon_{ikt-1}^b B_{jkt-1}^w \right)^2
\\
+ \left(\alpha_k^{s^0} + \epsilon_{kt-1}^s\right) P_{st-1}^s S_{jkt-1}
\]

The asset specific risk premium depends on an asset specific exogenous shock \( \epsilon_k^x, x \in \{b, bw, s\} \).

We aim at capturing the household preferences for the safe short term bonds, which generates endogenously a wedge between the return on risky assets and safe bonds (see, e.g. Fisher ,2015).

\[^5\text{ We assume only one type of foreign bonds, } B_{Rowkt}^w, \text{ issued by RoW and denominated in RoW currency.} \]
3.1.2. Liquidity-constrained household

The liquidity-constrained household consumes her disposable after-tax wage and transfer income in each period of time (‘hand-to-mouth’). The period $t$ budget constraint of the liquidity-constrained household is:

$$(1 + \tau^c_k)P^C_{kt}C^c_{jkt} = (1 - \tau^N_k)W_{kt}N^c_{kt} + T^c_{kt} - t_{ax^c_{jkt}}.$$  

The instantaneous utility functions for liquidity-constrained households, $\bar{u}^c()$, is defined as:

$$\bar{u}^c(C^c_{jk}, N^c_{jk}) = \frac{1}{1 - \theta} \left( C^c_{jk} - h C^c_{jkt-1} \right)^{1-\theta} - \left( C^c_{jk} \right)^{1-\theta} \frac{\omega^N \varepsilon^U_{kt}}{1 + \theta^N} (N^c_{kt})^{1+\theta^N}$$

with $C^c_{jk} = \int C^c_{jak}.$

3.1.3. Wage setting

Trade unions are maximizing a joint utility function for each type of labour. It is assumed that types of labour are distributed equally over Ricardian and liquidity-constrained households with their respective population weights. The wage rule is obtained by equating a weighted average of the marginal utility of leisure to a weighted average of the marginal utility of consumption times the real wage adjusted for a wage mark-up. Nominal rigidity in wage setting is introduced in the form of adjustment costs for changing wages. The wage adjustment costs are borne by the household. Real wage rigidity is also allowed, given the following optimality condition:

$$\left( (1 + \mu^w_k)^{\omega^N \varepsilon^U_{Ljk} + (1 - \omega^N) \varepsilon^U_{Cjk} (1 + \tau^c_k) P^C_{jk}} \right)^{(1 - \gamma^{wr})} \left( (1 - \tau^N_k) \frac{W_{kt-1}}{P^R_{kt-1}} \right)^{\gamma^{wr}}$$

$$(1 - \tau^N_k) \frac{W_{kt}}{P^R_{kt}} + \gamma^w (\pi^w_t - (1 - s f^w_t) \pi^w_{t-1}) (1 + \pi^w_t)$$

$$- \gamma^w E_t \left[ \frac{L_{t+1} \pi^y_{t+1}}{L_t + \pi^y_{t+1}} (\pi^w_{t+1} - (1 - s f^w_t) \pi^w_{t-1}) (1 + \pi^w_{t+1}) \right]$$

where $\mu^w_k$ is the wage mark-up, $\gamma^{wr}$ is the degree of real wage rigidity, $\gamma^w$ is the degree of nominal wage rigidity and $sf^w_t$ is the degree of forward-lookingness in the labour supply equation. $V^r_{N,jkt}$, for $r=s,c$, is the marginal disutility of labour, defined as:

$$V^r_{N,jkt} = \omega^N \exp(\varepsilon^U_{kt}) C^c_{jk}^{1-\theta} (N^c_{jk})^{\theta^N}$$
3.2. EA Member State Production Sector

3.2.1. Total Output Demand

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

$$O_{kt} = \left[ (1 - \frac{s_{Oil}}{\sigma})^\frac{1}{\sigma} (Y_{kt})^{\sigma-1} + (\frac{s_{Oil}}{\sigma})^\frac{1}{\sigma} (OIL_{kt})^{\sigma-1} \right]^{\frac{\sigma}{\sigma-1}}$$

where $s_{Oil}$ is the energy input share in total output and elasticity $\sigma$ is inversely related to the steady state gross output price mark-up. It follows that the demand for $Y_{kt}$ and $OIL_{kt}$ by total output producers is, respectively:

$$Y_{kt} = (1 - \frac{s_{Oil}}{\sigma})(\frac{P^Y_{kt}}{\bar{P}^Y_{kt}})^{-\sigma} O_{kt}$$

$$OIL_{kt} = s_{Oil}(\frac{P_{Oil}^0}{\bar{P}^0_{kt}})^{-\sigma} O_{kt}$$

where $P^Y_{kt}$ and $P_{Oil}^0$ are price deflators associated with $Y_{kt}$ and $Oil_{kt}$, respectively. Oil is assumed to be imported from RoW. The price index of total output $P^0_{kt}$ is:

$$P^0_{kt} = \left[ (1 - \frac{s_{Oil}}{\sigma})(\frac{P^Y_{kt}}{\bar{P}^Y_{kt}})^{1-\sigma} + s_{Oil}(\frac{P_{Oil}^0}{\bar{P}^0_{kt}})^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

3.2.2. Intermediate Goods Producer

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. Domestic final good producers then combine the different varieties into a homogenous good and sell them to domestic final demand goods producers and exporters.

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

$$Y_{ikt} = A^Y_{kt} (N_{ikt} - FN_{ikt})^\alpha (cu_{ikt} K_{ikt}^{tot})^{1-\alpha} - A^Y_{kt} FC_{ikt}$$

where $A^Y_{kt}$ is labour-augmenting productivity shock common to all firms in the differentiated goods sector. $cu_{ikt}$ and $FN_{ikt}$ are firm-specific level of capital utilization and labour hoarding.
captures fixed costs in production. Total Factor Productivity, $TFP_{kt}$, can therefore be defined as:

$$TFP_{kt} = (A^Y_{kt})^\alpha.$$  

We allow for two types of shocks that are related to a non-stationary process and its autoregressive component:

$$\log(A^Y_{kt}) - \log(A^Y_{kt-1}) = g^Y_{kt} + \varepsilon^L_{kt}$$

$$g^Y_{kt} = \rho^Y g^Y_{kt-1} + \varepsilon^g_{kt} + (1 - \rho^Y)g^Y_0 + \varepsilon^g_{kt}$$

where $g^Y_{kt}$ and $g^Y_0$ are the time-varying growth and the long-run growth of technology, respectively. Total capital is a sum of private installed capital, $K_{ikt}$, and public capital, $K^g_{ikt}$:

$$K^t_{ikt} = K_{ikt} + K^g_{ikt}$$

The producers maximize the value of the firm, $V_{kt}$, equal to a discounted stream of future dividends, $V_{kt} = d_{kt} + E_t[sdf_{kt+1}V_{kt+1}]$, with the stochastic discount factor

$$sdf_{kt} = \frac{(1 + i^d_{kt})}{(1 + \pi^c_{kt}vat)} \approx \frac{(1 + i^f_{kt-1} + rprem^c_{kt-1})}{(1 + \pi^c_{kt})}$$

which depends directly on the investment risk premium, $rprem^c_{kt-1}$. The dividends are defined as:

$$d_{ikt} = (1 - \tau^K_k) \left( \frac{P^Y_{ikt}}{P^Y_{kt}} Y_{ikt} - W_{kt} N_{ikt} \right) + \tau^K_k \delta \frac{P^l_{ikt}}{P^Y_{kt}} K_{ikt-1} - \frac{P^l_{ikt}}{P^Y_{kt}} l_{ikt} - adj_{ikt}$$

where $l_{ikt}$ is physical investment, $P^l_{ikt}$ is investment price, $\tau^K_k$ is the profit tax, $\delta$ is capital depreciation rate and $adj_{ikt}$ are adjustment costs associated with price $P^Y_{ikt}$ and labour input $N_{ikt}$ adjustment or moving capacity utilization $cu_{ikt}$, investment $l_{ikt}$, and labor hoarding $FN_{ikt}$ away from their optimal level:

$$adj_{ikt} = adj(P^Y_{ikt}) + adj(N_{ikt}) + adj(cu_{ikt}) + adj(l_{ikt}) + adj(FN_{ikt})$$

The maximization is subject to the production function, standard capital accumulation equation,

$$K_{ikt} = (1 - \delta)K_{ikt-1} + l_{ikt},$$

and the usual demand condition which inversely links demand for variety $i$ goods and the price of the variety:

$$Y_{ikt} = \left( \frac{P^Y_{ikt}}{P^Y_{kt}} \right)^{-\sigma^Y} Y_{kt}$$

From the FOC with respect to labour, labour hoarding, capital, investments and capital utilization, we can combine the FOC with respect to differentiated output price (which pins down the price mark-up) with the FOC with respect to labour to obtain the New Keynesian Phillips curve:
\[ y_{kt}^y \sigma_k^y = (1 - \tau_k^k)(\sigma_k^y - 1) + y_k^p \sigma_k^y \frac{p_{kt}^y}{p_{kt-1}^y} \left[ \frac{p_{kt}^y}{p_{kt-1}^y} - \exp(\bar{\eta}) \right] - y_k^p \sigma_k^y \left[ \frac{1}{1 + i_{kt+1}^y} \frac{p_{kt+1}^y}{p_{kt}^y} Y_{kt+1} \bigg( \frac{p_{kt+1}^y}{p_{kt}^y} - \exp(\bar{\eta}) \bigg) \right] + \sigma_k^y \epsilon_k^u \]

where \( \epsilon_k^u \) is the inverse of the price markup shock.

### 3.3. Trade

#### 3.3.1 Import sector

**Aggregate demand components**

The EA MS final aggregate demand component goods, \( C_{kt} \) (private consumption good), \( I_{kt} \), (private investment good), \( G_{kt} \) (government consumption good), and \( I_{kt}^G \) (government investment good) are produced by perfectly competitive firms by combining domestic output, \( O_{kt}^Z \), with imported goods, \( M_{kt}^Z \), where \( Z = \{C, I, G, I^G\} \), using the following CES technology:

\[ Z_{kt} = A_{kt}^{pZ} \left[ (1 - \exp(\epsilon_{kt}^M s^{M,Z}) \frac{1}{\sigma^Z} (O_{kt}^Z)^{-\sigma^Z} + \exp(\epsilon_{kt}^M s^{M,Z}) \frac{1}{\sigma^Z} (M_{kt}^Z)^{-\sigma^Z} \right] \]

with \( A_{kt}^{pZ} \) as shock to productivity in the sector producing goods \( Z \) and \( \epsilon_{kt}^M \) is a shock to the share \( s^{M,Z} \) of imports in domestic demand components. We assume that the log difference of the specific productivities, \( A_{kt}^{pZ} \) is an AR(1) process, \( \epsilon_{kt}^{pZ} \), with mean \( g^{pZ} \cdot \sigma^Z \) is the import elasticity of substitution between goods varieties. It follows that the demand for \( O_{kt}^Z \) and imported goods \( M_{kt}^Z \) are given by:

\[ O_{kt}^Z = \left( A_{kt}^{pZ} \right)^{-\sigma^Z} (1 - \exp(\epsilon_{kt}^M s^{M,Z}) \left( \frac{p_{kt}^O}{p_{kt}^Z} \right)^{-\sigma^Z} Z_{kt} \]

\[ M_{kt}^Z = \left( A_{kt}^{pZ} \right)^{-\sigma^Z} \exp(\epsilon_{kt}^M s^{M,Z}) \left( \frac{p_{kt}^M}{p_{kt}^Z} \right)^{-\sigma^Z} Z_{kt} \]

where \( p_{kt}^O \) and \( p_{kt}^M \) are the price deflators associated with \( O_{kt}^Z \) and \( M_{kt}^Z \), respectively, and the total final good deflator \( p_{kt}^Z \) is such that:

\[ p_{kt}^Z = \left( A_{kt}^{pZ} \right)^{-1} \left[ (1 - \exp(\epsilon_{kt}^M s^{M,Z}) (p_{kt}^O)^{1-\sigma^Z} + \exp(\epsilon_{kt}^M s^{M,Z}) (p_{kt}^M)^{1-\sigma^Z} \right]^{\frac{1}{1-\sigma^Z}} \]
Economy-specific final imports demand

Final imported goods are produced by perfectly competitive firms combining economy-specific homogenous imports goods, $M_{lkt}$, using CES production function:

$$M_{kt} = \left[ \sum_{l} (s_{lkt})^{\frac{1}{\sigma_{FM}}} (M_{lkt})^{\frac{\sigma_{FM}-1}{\sigma_{FM}}} \right]^{\frac{\sigma_{FM}}{\sigma_{FM}-1}}$$

where $\sigma_{FM}$ is the price elasticity of demand for country $l$'s goods and $\sum_{l} s_{lkt} = 1$ are import shares. The demand for goods from country $l$ is then:

$$M_{lkt} = s_{lkt}^{M} \left( \frac{P_{lkt}^{M}}{P_{kt}^{M}} \right)^{-\sigma_{FM}} M_{kt}$$

while the imports price:

$$P_{kt}^{M} = \left( \sum_{l} s_{lkt}^{M} (P_{lkt}^{M})^{1-\sigma_{FM}} \right)^{\frac{1}{1-\sigma_{FM}}}$$

with $P_{lkt}^{M}$ being the country-specific imports good prices. Since all products from country $l$ are initially purchased at export price $P_{lt}^{X}$, the economy-specific import goods price can be expressed as:

$$P_{lkt}^{M} = e_{lkt} P_{lt}^{X}$$

3.3.2. Export sector

The exporting firms are supposed to be competitive and the export price equals the output price, up to a shock, $\varepsilon_{kt}^{X}$:

$$P_{kt}^{X} = \exp(\varepsilon_{kt}^{X}) P_{kt}^{O}$$

Therefore, we do not use a pricing-to-market strategy, but rather a domestic-currency-pricing strategy.

3.4. EA Member State policy

3.4.1. EA monetary policy

Monetary policy is modelled by a Taylor rule where the ECB sets the policy rate $i_{t}$ in response to EA-wide inflation and the EA output gap. The policy rate adjusts sluggishly to deviations of inflation from their respective target level and to the output gap; it is also subject to random shocks:
\[ i_t - \bar{i} = \rho^i (i_{t-1} - \bar{i}) + (1 - \rho^i) \left( \eta^{in} \left( 0.25 \sum_{r=0}^{3} \pi^{c,pat}_{t-r} \right) - \pi^{c,pat} \right) + \eta^{iy} (y_t) + \varepsilon^i_t \]

where \( i = r + \pi^{yobs} \) is the steady state nominal interest rate, equal to the sum of the steady state real interest rate and GDP inflation and output gap \( \bar{y}_t = \log(Y_t) - \bar{y}_t \), where \( \bar{y}_t \) is (log) potential output.

### 3.4.2. Member State fiscal policy

The government collects taxes on labour, \( \tau^N_k \), capital, \( \tau^K_k \), and consumption, \( \tau^C_k \), as well as lump-sum taxes, \( Tax_k \), and issues one-period bonds, \( B^G_{kt} \), to finance government consumption, \( C^G_{kt} \), investment, \( I^G_{kt} \), transfers, \( T_{kt} \), and the servicing of the outstanding debt. The government budget constraint is:

\[ B^G_{kt+1} = (1 + i^G_{kt})B^G_{kt} - R^G_{kt} + P^G_{kt}G_{kt} + P^IG_{kt}I^G_{kt} + T_{kt} \]

where nominal government revenues, \( R^G_{kt} \), are defined as:

\[ R^G_{kt} = \tau^K_k (P^Y_k Y_{kt} - W_{kt} I_{kt} - P^l_{kt} \delta_k K_{kt-1}) + \tau^N_k W_{kt} I_{kt} + \tau^K_k P^C_{kt} C_{kt} + \tau^K_o P^Y_k Oil_t + Tax_{kt} P^Y_k Y_{kt} \]

Excise duty on oil imports from RoW, \( \tau^OiIl_k \), are determined exogenously. Government consumption, investment and transfers follow autoregressive processes. Government expenditure and receipts can deviate temporarily from their long-run levels in systematic response to budgetary or business-cycle conditions and in response to idiosyncratic shocks.

Government uses lump-sum taxes as budget closure and increases (decreases) taxes when the level of government debt and government deficit is above (below) the debt \( B^G_{kt} \) and deficit target \( def^T \), respectively:

\[ tax_{kt} = \rho^{tax} tax_{kt-1} + \eta^{DEF,T} \left( \frac{\Delta B^G_{kt-1}}{P_{kt-1} Y_{kt-1}} - def^T \right) + \eta^{B,T} \left( \frac{B^G_{kt-1}}{P^Y_{kt-1} Y_{kt-1}} - B^G \right) + \varepsilon^{tax}_{kt} \]

where \( B^G_{kt} \) is total nominal government debt.

### 3.5. Closing the economy

Market clearing requires that:

\[ Y_{kt} P^Y_k + \tau^OiIl_{kt} P^Y_o = P^C_{kt} C_{kt} + P^l_{kt} I_{kt} + P^IG_{kt} I^G_{kt} + T_{kt} \]

where the trade balance, \( T_{B_{kt}} \), is defined as the difference between exports and imports with domestic importers buying the imported good at the price \( P^X_l \):
\[ TB_{kt} = p^X_{kt}x_{kt} - \sum_{i} \frac{size_i}{size_k} e_{ikt} p^X_{ikt} M_{ikt} - e_{RoW_{kt}} p^{oil}_{RoW_{kt}} OIL_{RoW_{kt}} \]

Export is a sum of imports from the domestic economy by other countries:

\[ X_{kt} = \sum_{i} M_{ikt} \]

where \( M_{ikt} \) stands for imports of economy \( l \) from the domestic economy \( k \). Total imports are defined as:

\[ p^{Mtot}_{kt} M^{tot}_{kt} = p^M_{kt} M_{kt} + p^{oil}_{kt} OIL_{kt} \]

where non-oil imports are \( p^M_{kt} M_{kt} = p^M_{kt}(M^C_{kt} + M^I_{kt} + M^O_{kt} + M^G_{kt}) \).

Net foreign assets, \( NFA_{kt} \), evolve according to

\[ e_{RoW_{kt}} B^w_{k,t} = (1 + i_{bw}) e_{RoW_{kt-1}} B^w_{k,t-1} + TB_{kt} + ITR_k \frac{Y_{kt}}{p^Y_{kt}} Y_{kt} \]

Since we allow for a non-zero trade balance in the steady state, we include an international transfer, \( ITR_k \), calibrated in order to satisfy zero NFA in equilibrium. Finally, net foreign assets of each country \( l \) sum to zero:

\[ \sum_{i} NFA_{lt} size_i = 0. \]

### 3.6. The REA and RoW blocks

The model of the REA and RoW economy is a simplified structure with fewer shocks. Specifically, the blocks consist of a budget constraint for the representative household, demand functions for domestic and imported goods (derived from CES consumption good aggregators), a production technology that uses labour as the only input factor, and a New Keynesian Phillips curve. The REA and RoW block abstracts from capital accumulation. There are shocks to labour productivity, mark-ups, the subjective discount rate, the relative preference for domestic vs. imported goods, and to monetary policy shocks.
4. Model solution and econometric approach

We compute an approximate model solution by linearizing the model around its deterministic steady state. We calibrate a subset of parameters to match long-run data properties, and we estimate the remaining parameters using Bayesian techniques. We combine prior information about structural parameters and data likelihood to construct the posterior kernel and maximize it. The estimated model assumes 38 exogenous shocks, as it appears that many shocks are needed to capture the key dynamic properties of macroeconomic and financial data (e.g. Kollmann et al. 2015). The large number of shocks is also dictated by the fact that we use a large number of observables (37) for estimation. Note that the number of shocks has to be at least as large as the number of observables to avoid stochastic singularity of the model. The observables employed in estimation are listed in the Data Appendix. The estimation uses quarterly data for the period 1999q1-2016q2. The model has been estimated using the slice sampler algorithm proposed by Neal (2003). The calibrated parameters, steady state ratios and trade shares match average historical ratios of the four EA Member States considered in the paper and can be found in the Appendix A.1.

5. Estimation results

5.1. Posterior parameter estimates

The posterior estimates of key model parameters for the four EA MS, and the EA aggregate for comparison, are reported in Table 2. The EA posterior estimates are obtained from a slightly modified model version of Kollmann et al. (2016). The model properties discussed in what follows are evaluated at the posterior mode of the model parameters.

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6 We use the DYNARE software (Adjemian et al. 2011) to solve the linearized model and to perform the estimation.
7 According to Kollmann et al. (2015), we assume an additional exogenous shock for Germany by introducing an observable proxy (unemployment benefit ratio) for the labor market reform (‘Hartz reform’).
8 See also Planas et al. (2015) for a detailed description on the theory and practice of slice sampling.
Table 2: Estimates of selected structural parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Prior Distribution</th>
<th>Posterior Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dist.</td>
<td>Mean (Std.)</td>
</tr>
<tr>
<td>Preferences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption habit persistence</td>
<td>B</td>
<td>0.5 (0.20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk aversion</td>
<td>G</td>
<td>1.5 (0.20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverse Frisch elasticity of labour supply</td>
<td>G</td>
<td>2.5 (0.20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total import price elasticity</td>
<td>G</td>
<td>2 (0.40)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral import price elasticity</td>
<td>G</td>
<td>2 (1.00)</td>
</tr>
<tr>
<td>Nominal and real frictions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price adjustment cost</td>
<td>G</td>
<td>60 (40.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal wage adj. cost</td>
<td>G</td>
<td>5 (2.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real wage rigidity</td>
<td>B</td>
<td>0.5 (0.20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment adjustment cost</td>
<td>G</td>
<td>60 (40.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment adjustment cost</td>
<td>G</td>
<td>60 (40.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiscal policy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lump sum taxes persistence</td>
<td>B</td>
<td>0.5 (0.20)</td>
</tr>
<tr>
<td>Lump sum taxes response to deficit</td>
<td>B</td>
<td>0.03 (0.008)</td>
</tr>
<tr>
<td>Lump sum taxes response to debt</td>
<td>B</td>
<td>0.02 (0.01)</td>
</tr>
</tbody>
</table>

Note: Cols. (1) lists model parameters. Cols. (2-3) indicate the prior distribution functions (B: Beta distribution; G: Gamma distribution). Identical priors are assumed for country-specific parameters. Cols. (4)-(8) show the mean and the standard deviation (Std.) of the posterior distributions of the Euro Area, Germany, France, Italy and Spain, respectively.

Estimated habit persistence in consumption is particularly high in FR and IT (0.88), indicating a sluggish adjustment of consumption to income shocks, similar to the EA aggregate. The risk aversion coefficient is in the same range for the EA aggregate and all four countries, varying from 1.37 in IT to 1.61 in ES. In DE, IT and ES, we observe slightly more elastic labour supply. The total import price elasticity (elasticity between imports and domestic output) is higher in FR (1.97), the EA aggregate (1.87) and DE (1.62), and lower in IT (1.30) and ES (1.44), whereas the bilateral import price elasticity (the elasticity between imports from different sources) is significantly higher in FR (4.31). The model estimates also suggest substantial differences in price and wage rigidities. The model estimate for IT suggests much lower price rigidity (10.97) compared...
to FR (37.92), ES (24.83) and the EA average (31.90). Nominal wage adjustment costs seem to be low in ES (1.91), while real wage inertia (wage norm) is high for all countries. The most striking difference in the posterior estimates possibly concerns employment adjustment costs, where FR (151.74) and ES (9.34) strongly contrast with the middle position of DE, IT and the EA average. Investment adjustment costs appear comparable across DE, FR, and IT, but indicate substantially higher rigidity in ES (64.56) and the EA aggregate (63.57). The fiscal feedback rule on lump-sum taxes exhibits relatively high persistence for FR (0.92), ES (0.95), and the EA average (0.92), implying a more drawn-out response to debt and deficit levels in this cases.

5.2 Impulse responses (structural differences across countries)

Looking at impulse response functions (IRFs) is helpful to better understand the role of structural differences for the transmission of shocks in the model. In case of structural similarity one would expect to see similar transmissions of shocks across the four countries. This sub-section presents IRFs for four exemplary drivers (consumption and investment demand, foreign demand, and labour supply) of economic dynamics. The focus on demand shocks derives from the fact that they have been the main driver of business-cycle volatility and divergence in the EA in our models, as discussed in Kollmann et al. (2015), Kollmann et al. (2016), and in’t Veld et al. (2014). We normalise the shock size across countries (a purely illustrative 1% of GDP on impact for demand shocks) and set the AR(1) parameter to 0.8 for this exercise.

Figure 3 shows the response to a positive private saving shock (savings increase), which is modelled as a persistent fall in the subjective rate of time preference of MS households. The shock triggers a persistent reduction in aggregate consumption. With sluggish price and wage adjustment, the domestic GDP and employment decline. The shock triggers a fall in the policy and a decline in the real interest rate in the medium term, leading to an increase in investment. The trade balance improves on impact due to a combination of lower import (domestic demand contraction) and stronger export demand (real exchange rate depreciation).

Figure 3 also shows that the negative shock to domestic consumption has particularly negative consequences on activity and employment in ES, whereas the decline in employment in other MS is dampened by stronger employment adjustment frictions (labour hoarding). Consequently, real wages in ES decline, whereas real wages increase elsewhere due to less decline in labour demand and higher estimated wage stickiness.
Figure 3: Positive shock to the saving rate (negative shock to consumption demand)

Figure 4 presents the dynamic adjustment to an increase in the investment risk premium (financing costs), which leads to a decline in domestic investment demand. The decline of investment lowers aggregate demand, GDP and employment; domestic price inflation also declines. The decline in demand and prices triggers a reduction in the risk free interest rate, which strengthens the demand for consumption.

The decline in investment demand and activity is particularly pronounced in IT, for which the estimation indicates comparatively costs of adjusting the stock of capital and the amount of investment. The strong response of activity in IT leads to comparatively strong REER depreciation and TBY improvement via less import demand and increasing price competitiveness. ES shows a similar decline in employment for less investment decline due to its estimated lower labour adjustment costs, which translates into declining real wages in ES.
Figure 4: Positive shock to the investment risk premium (negative shock to investment demand).

Figure 5 presents dynamic responses to a foreign demand shock, namely a positive shock to savings (negative shock to private demand) in the RoW. Analogously to the MS saving shocks, the positive RoW savings shock is modelled by a rise in the subjective discount rate in the RoW and its illustrative size chosen to generate 1% of GDP RoW consumption decline on impact. The shock lowers RoW demand and activity in combination with real effective appreciation in the EA and EA MS. The reduction in policy and real interest rates in response to lower output and inflation in the EA strengthens consumption and investment demand in EA MS. The fall in the domestic savings rate (consumption increase) and the increase in the investment rate lead to a decline in the trade balance in the EA.

Among the EA MS, DE experiences the strongest negative response of activity, inflation, the REER and TBY due to its stronger trade openness to the RoW. At the same time, falling inflation comes with a pronounced rise in DE real wages as nominal wages adjust less rapidly than prices.
Figure 5: Positive shock to the RoW saving rate (negative shock to foreign demand)

Figure 6 finally shows dynamic responses to an increase in domestic labour supply in the EA and the EA MS respectively. The labour supply shock reduces the real wage and increases employment and GDP. The improved profitability and the reduction in the policy rate strengthen investment demand. The REER depreciates and the TBY improves, where the competitiveness gain outweighs the impact of higher domestic demand.

ES stands out in Figure 6 with the strongest positive employment, GDP and domestic demand effects, which are due to the particularly low estimated wage and labour adjustment costs in ES. The negative price response implies a stronger initial increase in the real interest rate, which somewhat dampens investment growth. Comparatively strong downward price adjustment in ES leads to pronounced REER depreciation and the strongest TBY improvement compared to other EA MS.
In sum, the preceding IRFs indicate broadly similar adjustment behaviour to shocks across EA MS. There are some marked differences, however. In particular, demand and supply shocks generate a comparatively strong response of employment and real wages in ES given low degrees of estimated wage and labour adjustment costs. Shocks to investment conditions show a particularly pronounced response of activity and inflation in IT due to relatively low estimated values of capital stock and investment adjustment costs in IT. Finally, DE appears to be particularly sensitive to shocks in the RoW given its higher openness to extra-EA trade.

5.3 Counterfactual
In this final subsection we show a counterfactual to assess the importance of differences in goods and factor market adjustment for the resilience of the different EA MS to shocks. In particular, we take the estimated shock processes for ES (including also the foreign shocks in the ES-REA-RoW model) and simulate the models for the other three EA MS considered with the same shocks.
Table 3 shows model moments for the different EA MS under the ES counterfactual. According to the simulations, real GDP, consumption and investment would have fluctuated more in DE compared to ES for the same set of shocks. The same holds for real GDP and, in particular, investment in IT. In contrast, domestic demand and real GDP would have been more stable in FR. Due to higher estimated wage stickiness and employment persistence (labour hoarding) in DE, FR and IT, none of the three MS shows as strong fluctuations in real wages and employment as ES. Comparing data moments from Table 1 above with the counterfactual moments in Table 3 further suggests that DE, FR, and IT with their estimated parameters for goods and factor market adjustment would all three have experienced more pronounced cyclical fluctuations in real GDP growth if they had been hit by the same set of shocks as the ES economy during 1999q1-2016q2.

<table>
<thead>
<tr>
<th>Variables</th>
<th>DE</th>
<th></th>
<th>FR</th>
<th></th>
<th>IT</th>
<th></th>
<th>ES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>std (%)</td>
<td>corr (x,GDP)</td>
<td>std (%)</td>
<td>corr (x,GDP)</td>
<td>std (%)</td>
<td>corr (x,GDP)</td>
<td>std (%)</td>
<td>corr (x,GDP)</td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td>1.09</td>
<td>1</td>
<td>0.60</td>
<td>1</td>
<td>0.86</td>
<td>1</td>
<td>0.81</td>
<td>1</td>
</tr>
<tr>
<td>Consumption</td>
<td>1.38</td>
<td>0.25</td>
<td>1.11</td>
<td>0.28</td>
<td>0.89</td>
<td>0.15</td>
<td>1.31</td>
<td>0.47</td>
</tr>
<tr>
<td>Investment</td>
<td>4.72</td>
<td>0.26</td>
<td>2.80</td>
<td>0.31</td>
<td>5.59</td>
<td>0.51</td>
<td>3.04</td>
<td>0.45</td>
</tr>
<tr>
<td>Hours worked</td>
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<td>0.62</td>
<td>0.35</td>
<td>0.65</td>
<td>0.64</td>
<td>0.61</td>
<td>1.17</td>
<td>0.67</td>
</tr>
<tr>
<td>GDP inflation</td>
<td>0.79</td>
<td>-0.13</td>
<td>1.00</td>
<td>0.09</td>
<td>1.57</td>
<td>-0.15</td>
<td>1.45</td>
<td>0.05</td>
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<tr>
<td>CPI inflation</td>
<td>0.83</td>
<td>0.17</td>
<td>0.97</td>
<td>0.17</td>
<td>1.27</td>
<td>-0.01</td>
<td>1.28</td>
<td>-0.02</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.65</td>
<td>0.12</td>
<td>0.38</td>
<td>-0.07</td>
<td>0.77</td>
<td>0.22</td>
<td>1.04</td>
<td>0.08</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>0.28</td>
<td>-0.32</td>
<td>0.26</td>
<td>-0.53</td>
<td>0.47</td>
<td>-0.31</td>
<td>0.30</td>
<td>-0.27</td>
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<tr>
<td>Real exchange rate</td>
<td>2.18</td>
<td>0.05</td>
<td>1.96</td>
<td>-0.06</td>
<td>2.53</td>
<td>0.01</td>
<td>2.24</td>
<td>-0.08</td>
</tr>
<tr>
<td>...rel. to std of real GDP</td>
<td>3.26</td>
<td>2.94</td>
<td>2.76</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Trade balance to GDP</td>
<td>0.94</td>
<td>0.49</td>
<td>0.64</td>
<td>0.29</td>
<td>0.63</td>
<td>0.27</td>
<td>0.75</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Note: The table reports model-predicted standard deviations (std in %) and correlations to real GDP (corr) for DE, FR and IT given the occurrence of shocks that have been estimated for Spain. First differences for real interest rate and trade balance; quarter-on-quarter growth rates for all other variables, an increase in the REER indicates real effective depreciation.
6. Conclusions

The paper has reviewed adjustment dynamics in EMU through the lenses of estimated multi-country DSGE models for large (individual) Euro Area (EA) Member States (MS), the rest of the EA (REA), and the rest of the world (RoW). In particular, we have analysed to what extent goods and factor market frictions (price, nominal wage, and real rigidities) differ across countries and, hence, generate different or similar dynamic responses to identical shocks. Our results suggest broadly similar adjustment behaviour to shocks across EA MS. There are some marked differences, however. In particular, demand and supply shocks generate a comparatively strong response of employment and real wages in ES given low estimated values of wage and labour adjustment costs. Shocks to investment conditions show a particularly pronounced response of activity and inflation in IT due to relatively low estimated values of capital stock and investment adjustment costs in IT. Finally, DE appears to be particularly sensitive to shocks in the RoW given its higher openness to extra-EA trade.

In a counterfactual analysis we have applied estimated shocks for the Spanish (ES) economy to the models for Germany (DE), France (FR), and Italy (IT) to assess whether ES shocks (including financial ones) would have led to similar fluctuations in economic activity ("boom-bust") in these countries given the estimated strength of goods and factor market rigidities. According to the simulations, real GDP, consumption and investment would have fluctuated substantially more in DE and to lesser degree in IT compared to ES for the same set of shocks, whereas domestic demand and real GDP would have been more stable in FR. None of the three MS would have shown as strong fluctuations in real wages and employment according to the model, because of the higher estimated wage stickiness and employment persistence (labour hoarding) in DE, FR and IT. Comparing data moments for DE, FR, and IT with the counterfactual further suggests that DE, FR, and IT with their estimated parameters for goods and factor market adjustment would have experienced more pronounced cyclical fluctuations in real GDP growth if they had been hit by the same set of shocks as the ES economy during 1999q1-2016q2. The finding suggests that structural differences in goods and factor markets matter for business cycle heterogeneity inside the EA. At the same time, the difference between data and counterfactual moments underlines that differences in the sets of estimated shocks account for an important share of the difference in economic performance across EA MS. The findings are hence in line with results from earlier papers, including Bayoumi and Eichengreen (1992), which have found
differences in structure and differences in shocks to account for business-cycle heterogeneity across EA countries. Limitations of our analysis include the simple structure of the financial sector in the model, which omits amplifying mechanisms such as credit expansion and deleveraging dynamics. These mechanisms, which have arguably been very important for ES, enter our model through shocks rather than as part of the shock transmission. A further limitation is the symmetric treatment of upward and downward adjustment, which excludes asymmetries in the sense of, e.g., stronger downward price or nominal wage rigidity.
References


Appendix A:

A.1 Calibrated parameters and steady-state ratios of EA Member States

<table>
<thead>
<tr>
<th>Description</th>
<th>DE</th>
<th>FR</th>
<th>IT</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EA Monetary Policy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal interest rate in SS</td>
<td>0.0053</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI inflation in SS</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate persistence</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response to inflation</td>
<td>1.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response to GDP</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Preferences</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Intertemporal discount factor</td>
<td>0.9975</td>
<td>0.9975</td>
<td>0.9975</td>
<td>0.9975</td>
</tr>
<tr>
<td>Degree of openness</td>
<td>0.34</td>
<td>0.28</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>Preference for imports from RoW</td>
<td>0.53</td>
<td>0.44</td>
<td>0.53</td>
<td>0.51</td>
</tr>
<tr>
<td>Preference for imports from REA</td>
<td>0.47</td>
<td>0.56</td>
<td>0.47</td>
<td>0.49</td>
</tr>
<tr>
<td>Substitutability btw domestic varieties</td>
<td>3.28</td>
<td>4.13</td>
<td>2.92</td>
<td>9.33</td>
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<tr>
<td>Preference for gov't bonds</td>
<td>0.00015</td>
<td>-0.00038</td>
<td>0.0014</td>
<td>0.0015</td>
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<tr>
<td>Preference for stocks</td>
<td>0.00032</td>
<td>-0.0013</td>
<td>-0.0013</td>
<td>-0.0024</td>
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<tr>
<td>Preference for foreign bonds</td>
<td>-0.0025</td>
<td>-0.0025</td>
<td>-0.0025</td>
<td>-0.0025</td>
</tr>
<tr>
<td>Weight of disutility of labour</td>
<td>14.28</td>
<td>26.88</td>
<td>51.41</td>
<td>23.96</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobb-Douglas labour share</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
</tr>
<tr>
<td>Depreciation of private capital stock</td>
<td>0.0144</td>
<td>0.015</td>
<td>0.0136</td>
<td>0.0123</td>
</tr>
<tr>
<td>Depreciation of public capital stock</td>
<td>0.0144</td>
<td>0.015</td>
<td>0.0136</td>
<td>0.0123</td>
</tr>
<tr>
<td>Share of oil in total output</td>
<td>0.017</td>
<td>0.017</td>
<td>0.017</td>
<td>0.017</td>
</tr>
<tr>
<td>Linear capacity utilization adj. costs</td>
<td>0.015</td>
<td>0.016</td>
<td>0.014</td>
<td>0.017</td>
</tr>
<tr>
<td><strong>Fiscal policy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Consumption tax</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
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<tr>
<td>Corporate profit tax</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Labour tax</td>
<td>0.41</td>
<td>0.54</td>
<td>0.46</td>
<td>0.36</td>
</tr>
<tr>
<td>Deficit target</td>
<td>0.019</td>
<td>0.020</td>
<td>0.032</td>
<td>0.016</td>
</tr>
<tr>
<td>Debt target</td>
<td>2.57</td>
<td>2.72</td>
<td>4.4</td>
<td>2.17</td>
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<tr>
<td><strong>Steady state ratios</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private consumption share in SS</td>
<td>0.567</td>
<td>0.546</td>
<td>0.600</td>
<td>0.579</td>
</tr>
<tr>
<td>Private investment share in SS</td>
<td>0.177</td>
<td>0.189</td>
<td>0.175</td>
<td>0.219</td>
</tr>
<tr>
<td>Gov't consumption share in SS</td>
<td>0.187</td>
<td>0.230</td>
<td>0.192</td>
<td>0.183</td>
</tr>
<tr>
<td>Gov't investment share in SS</td>
<td>0.024</td>
<td>0.039</td>
<td>0.031</td>
<td>0.038</td>
</tr>
<tr>
<td>Transfers share in SS</td>
<td>0.169</td>
<td>0.182</td>
<td>0.175</td>
<td>0.132</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of the country (% of world)</td>
<td>4.58</td>
<td>3.53</td>
<td>2.89</td>
<td>1.83</td>
</tr>
<tr>
<td>Trend of total factor productivity</td>
<td>0.0030</td>
<td>0.0018</td>
<td>0.0027</td>
<td>-2e-5</td>
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<tr>
<td>Trend of private consumption specific productivity</td>
<td>0.0009</td>
<td>0.0009</td>
<td>-0.0009</td>
<td>-0.0016</td>
</tr>
<tr>
<td>Trend of gov't consumption specific productivity</td>
<td>0.0006</td>
<td>2e-6</td>
<td>-0.0010</td>
<td>-0.0005</td>
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<tr>
<td>Trend of private investment specific productivity</td>
<td>-0.0009</td>
<td>0.0012</td>
<td>-0.0003</td>
<td>0.0045</td>
</tr>
<tr>
<td>Trend of gov't investment specific productivity</td>
<td>-0.0009</td>
<td>0.0012</td>
<td>-0.0003</td>
<td>0.0045</td>
</tr>
</tbody>
</table>
A.2 Data

A.2.1 Data sources
Data for the EA Member States (quarterly national accounts, fiscal aggregates, quarterly interest and exchange rates) are taken from Eurostat. Corresponding data for the US (which is part of RoW) come from the Bureau of Economic Analysis (BEA) and the Federal Reserve. Bilateral trade flows are based on trade shares from the GTAP trade matrices for trade in goods and services. ROW series are constructed on the basis of the IMF International Financial Statistics (IFS) and World Economic Outlook (WEO) databases.

A.2.2 Constructing of data series for ROW variables
Series for GDP and prices in the ROW starting in 1999 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. The ROW data are annual data from the IMF International Financial Statistics (IFS) and World Economic Outlook (WEO) databases.

A.2.3 List of observables
The estimation uses the following time series for the EA Member States: GDP, GDP deflator, population, total employment, employment rate, employment in hours, participation rates, relative prices with respect to GDP deflator (VAT-consumption, government consumption, private investment, export, and import), government investment price relative to private investment, nominal policy rate, and nominal shares of GDP (consumption, government consumption, investment, government investment, government interest payment, transfers, public debt, wage bill and exports). The list of observables also includes the oil price and the US exchange rate with respect to EA and ROW. For the ROW we use data on population, GDP, GDP deflator and the nominal policy rate.