Asymmetric Shocks and Monetary Policy in the Euro Area*

Davor Kunovac,[a,c] Diego Rodriguez Palenzuela,[b] and Yiqiao Sun[b]

[a]Hrvatska narodna banka

[b]European Central Bank

[c]University of Rijeka, Faculty of Economics and Business

We analyze the role of asymmetric macroeconomic shocks for conduct of monetary policy of the euro area, as a monetary union. Taking an international business cycle perspective, we distinguish between symmetric shocks, which affect countries similarly, and asymmetric shocks, which cause diverging movements across countries. Applying a Bayesian sign- and zero-restricted structural vector autoregression (BVAR) model, we find that global symmetric shocks predominantly drive business cycles in most euro-area countries. Linked to this, we find evidence of a euro-area-specific cycle. Through the lens of our framework, we also find empirical support for the optimum currency area (OCA) endogeneity hypothesis: upon adopting the euro, new member countries, on average, experience faster convergence in their share of symmetric shocks relative to the euro-area aggregate. Our econometric framework also allows us to derive an optimum currency area index for the euro area based on a *shocks-similarity principle*. Our index captures not only the relative importance of symmetric shocks but also the extent of cross-country heterogeneity. This OCA index highlights that, while the OCA features of the euro area remain

*We thank an anonymous referee, Ivan Zilic, Lucija Fioretti, Karlo Kotarac, Jurica Zrnc, and Milan Deskar-Škrbić for valuable comments and helpful suggestions. We also thank, for their comments, participants at the International Conference “Reassessment of the Optimal Currency Area Theory in the Persistently Heterogeneous European Union” in Vilnius. The views expressed are those of the authors only and do not necessarily reflect those of the Eurosystem, the European Central Bank, or the Hrvatska narodna banka. A version of this paper was previously circulated under the title “A New Optimum Currency Area Index for the Euro Area.” Author e-mails: davor.kunovac@hnb.hr (corresponding author), diego.rodriguez@ecb.europa.eu, yiqiao.sun@ecb.europa.eu.

firmly established, their further improvement has stagnated over time. All in all, current levels of the OCA index suggest a broadly similar level as at the start of the euro, underscoring the importance of not being complacent with the policy goal of EU single market integration.

JEL Codes: F33, F44, E42, E52.

1. Introduction

It is well known that when a set of countries or regions forgo their sovereign currency and independent monetary policy to form a shared monetary union, important gains in terms of economic integration may be attained, as exchange-rate-related transaction costs and volatility are eliminated and price transparency is enhanced. To assess the net gains in forming the union, benefits need to be compared to the costs of losing monetary autonomy at country level: Once in the monetary union, the country has lost the full power of an important instrument of macroeconomic stabilization, as monetary policy has demonstrated to be a key policy tool to address macroeconomic shocks, in particular of a demand nature. The costs of lost monetary independence will be attenuated, however, if the various countries or regions forming the union are subject to broadly similar or symmetric macroeconomic shocks. In the limit, if macroeconomic shocks were perfectly correlated across countries, the cost of foregone monetary independence would be nihil. Understanding the relative importance of symmetric versus asymmetric macroeconomic shocks is thus crucial for assessing the costs of forming a monetary union, and ultimately its desirability: When the business cycles of the union members, at country or regional level, are primarily driven by common or symmetric shocks and, therefore, positively correlated, the single *one-size-fits-all* monetary policy is in a stronger position to stabilize all countries in the union simultaneously; see Alesina, Barro, and Tenreyro (2002). Conversely, asymmetric shocks, with an uneven impact across countries, tend to impair the conduct of the common monetary policy.

These same premises determine the net benefits for a single country in *joining* an established and ongoing monetary union, as is the case for candidate countries considering the best timing for joining the euro area, such as the Czech Republic and Romania are currently. If the candidate countries' business cycles are sufficiently synchronized with those of the euro area, the costs of giving up their sovereign currency and monetary policy should be of lesser concern.

The role of asymmetric shocks has been from the outset at the center of optimum currency area (OCA) theory, a widely accepted framework for assessing whether the conditions for a group of countries to form a currency union are met. At the initial development of the OCA theory, seminal contributions from Mundell (1961), McKinnon (1963), and Kenen (1969) identified a number of prerequisites, in the form of necessary structural conditions, for successfully forming a currency union. Prominent among these were nominal flexibility in goods and labor markets, factor mobility, production diversification, and fiscal integration. In a subsequent phase of OCA theory, the focus shifted to the costs of fixing irreversible exchange rates and adopting a common currency, along with the role of financial integration; see Corden (1972), Ishiyama (1975), and Mundell (1975).

The combination of the former conditions and latter cost features gave rise to a set of *OCA criteria*, that is, a set of indicators to assess the viability and desirability of forming a monetary union. Yet, while the identified criteria are conceptually well grounded, in practice it has proven difficult to measure empirically the degree to which some of the criteria are fulfilled, both ex ante or on an ongoing basis. Much of the empirical literature on OCA conditions, such as Bayoumi and Eichengreen (1992), Masson and Taylor (1993), Alesina, Barro, and Tenreyro (2002), and Mongelli (2002), suggested that *similarity of shocks* driving union members would qualify as a *catch-all* OCA property capturing the interaction between several of these properties at once. However, one important aspect, the measurement of the similarity of macro shocks across countries, has remained a particularly daunting task.

To better understand the similarity of shocks and business cycle coherence across members, the existing literature, strongly influenced by Bayoumi and Eichengreen (1992), mostly weighs the cross-country correlation of the measurable proxies for shocks. This is done usually without placing emphasis on the separate identification of symmetric versus asymmetric shocks. While this approach is intuitive and easily implementable, it clearly falls short of capturing the structural diversity of shocks and the complexity of shock transmission mechanisms across diverse economies. This important gap in the literature is precisely where our paper makes a contribution. Instead, we take a fundamentally different approach, setting up an econometric framework that permits the identification and measurement of symmetric versus asymmetric shocks and, among the latter, of supply versus demand shocks. Our econometric framework builds on a sign- and zero-restricted Bayesian structural vector autoregression (BVAR) model, allowing for a more structural and reliable analysis of shock dynamics at various levels of aggregation, namely global, euro area, and local (country level).

A further central theme of OCA theory where shock similarity plays a key role relates to how *fit* or well prepared a candidate country stands as a new member of a possibly complex and heterogeneous monetary union. Being well prepared for membership is closely linked to how the business cycle coherence between the candidate country and the monetary union evolves once the country joins the union. The *OCA endogeneity hypothesis*, as proposed by Frankel and Rose (1997, 1998), suggests that business cycles and shock similarities across new members and the rest of the union are not independent. Similarities are, under this view, expected to gradually increase ex post and as a consequence of the currency area enlargement: joining the currency union should foster stronger trade linkages and deeper investment connections. Nonetheless, counterarguments to the OCA endogeneity theory have been made. Krugman (1993) suggests that a country joining an existing monetary union could lead to increased specialization in specific sectors of the enlarged union, thereby potentially reducing business cycle coherence, with a deterioration of the union's OCA properties. These conflicting theories highlight the need not only to evaluate the ex ante conditions for currency union membership but also to monitor the evolution of ex post convergence (in line with the OCA endogeneity view) or lack thereof (as suggested by the increasing sectoral specialization view).

The main contribution of our paper is that we formalize a precise and measurable definition of asymmetric shocks for the euro area, both from a country-specific and a union-wide perspective.[1]

[1] Although the European Central Bank (ECB) makes it clear the focus of its monetary policy is the euro area as a whole, the country perspective remains

To quantify the relative importance of symmetric versus asymmetric shocks for euro-area members, we rely on a set of identified BVAR models, which yields a shock accounting exercise of interest on its own. This exercise in turn serves as the building block to study in more detail the role and relative importance of symmetric versus asymmetric shocks for the smooth monetary policy conduct and for the suitability of euro adoption for new member countries, as well as the performance of the latter once in the monetary union. These results provide a novel approach and test of the OCA endogeneity hypothesis through the lens of our structural BVAR framework. Finally, as a by-product of our shock accounting exercise, we propose a new OCA index based on the relative importance of symmetric shocks.

To preview our results, we show that symmetric shocks emerge as the dominant drivers of GDP growth across euro-area countries. Among the symmetric shocks, an important fraction are global in nature, which partly explains why the ECB's monetary policy is often well aligned with that of other central banks, notably the U.S. Federal Reserve. Additionally, we find evidence of a significant comovement across euro-area members that is independent from the identified global commonality—i.e., a distinct euro-area business cycle. Our results contribute to ongoing debates in the literature on this topic: while some studies, such as those by Artis (2003) or Camacho, Perez-Quiros, and Saiz (2006), have struggled to identify a clear European cycle, our findings align with those of Inklaar and de Haan (2001), Kose, Otrok, and Whiteman (2003), or Ferroni and Klaus (2015), among others, who argue in favor of its existence and relevance.

While we show that a large proportion of shocks are symmetric, this is not sufficient per se to conclude on a benign assessment on the conditions for the common policy to stabilize the euro area. The effectiveness of the common monetary policy depends strongly on the structural nature and the composition of shocks underlying business cycle dynamics. In particular, a larger prevalence of symmetric *demand* shocks is often related to more favorable conditions

important. In a case in which a member country is affected by different shocks compared to the rest of the union, the common monetary policy cannot be equally desirable for all, which could create tensions between countries or even a possible breakup.

to stabilize the euro area, while, on the other hand, symmetric supply shocks may create a dilemma for central bankers, who may or may not be in a position to react to them, as highlighted by Beaudry, Carter, and Lahiri (2022), Madeira, Madeira, and Monteiro (2023), or Tenreyro et al. (2023). We show that both demand- and supply-side shocks at euro-area level are important in driving the euro-area business cycle dynamic.

While the results highlighted so far bode well for the OCA properties of the euro area, it remains to be checked whether country-level shocks of demand nature are not dominant. Indeed, from a country perspective, of either a candidate new-member country or an existing member, the loss of the independent monetary policy is more severe when idiosyncratic demand shocks are more prevalent. Reassuringly for the assessment of euro-area OCA conditions, we find that country-level shocks from the demand side are relatively rare, suggesting that the costs of lost monetary policy at country level are likely limited. In particular, we find that business cycle dynamics of Central and Eastern European countries—both euro-area members and candidate countries—are becoming increasingly similar to the euro-area aggregate, in terms of shock composition. This finding would seem to mitigate concerns sometimes expressed that euro-area enlargement would increase the risks of asymmetric shocks, as raised, e.g., by De Grauwe (2003). Our results suggest that these risks have diminished over time.

More generally, our framework serves to shed light on the role of euro adoption in the alignment process for business cycle dynamics for countries adopting the euro. For this purpose, we test how the euro adoption affects the importance of symmetric shocks for *new* members, i.e., the countries in our sample that joined at later enlargement stages—Slovakia, Slovenia, Estonia, Latvia, and Lithuania. This is the context to which we apply and test the *OCA endogeneity hypothesis* of Frankel and Rose (1998). To investigate if the euro adoption has indeed promoted business cycle synchronization, we rely on difference-in-difference (D-I-D) estimation. Recent findings in the methodological literature, however, point out drawbacks of a standard D-I-D approach,[2] whenever there are multiple

[2]Here, a panel regression with time and country fixed effects and euro membership being a *treatment* dummy.

treatment periods (i.e., different entry dates); see Callaway and Sant'Anna (2021) for an explanation. Therefore, in our case, given that countries enter the euro area in different years, we apply both the standard D-I-D and the method by Callaway and Sant'Anna (2021). The results provide evidence of the positive impact of euro adoption on shock synchronization. This finding may be relevant with respect to the ongoing policy debate on some non-euro-area EU countries considering the euro-area membership.[3]

Finally, based on the basic *signal-to-noise ratio* concept, we propose an indicator aimed at summarizing our findings on the behavior of both cross-country average and dispersion of relative importance of symmetric shocks. We regard this indicator as a suitable *OCA index*, and we show how it applies for the euro area over time. Our indicator underscores that high relative importance of symmetric shocks across countries alone may not be sufficient to improve OCA features of a currency union, whenever there are important differences between countries. In particular, a monetary union with a high cross-country average importance of symmetric shocks may be characterized as poor in terms of its OCA features in a case where the relative importance of symmetric shocks is overly dispersed across countries. Our OCA index for the euro area thus reflects the view that cross-country heterogeneity in business cycle fluctuations makes the common currency not equally desirable for all area members, which could create tensions between countries (De Grauwe 1996) and eventually even threaten the political viability of EMU (Orphanides 2020). Increased heterogeneity across union members has important implications for policy as well, as the policy stance in a currency union during the crises may be difficult to calibrate, despite given predominance of symmetric shocks on average. Signal-to-noise ratio may, therefore, serve as a useful complement to average importance of symmetric shocks in tracking OCA properties, especially during the crises. Our OCA index is slow-moving and a good reflection of changing underlying economic structures across the euro area and, therefore, informative about the ability of monetary policy to

[3]For largely positive sentiment toward the euro adoption in candidate countries, see https://www.brusselstimes.com/858918/czechia-to-take-concrete-steps-to-adopt-the-euro for Czechia and https://www.euractiv.com/section/politics/news/romania-wants-to-push-euro-adoption-by-2026/ for Romania.

stabilize the euro-area economy in the medium run. We show that an index that takes both moments into account is able to properly signal different types of crises in a currency union: those that originate in the rest of the world, outside the euro area (e.g., the Global Financial Crisis, or GFC), but also those locally or inside the euro area, originating in one or few euro-area member countries (e.g., the euro debt crisis). Otherwise, an index based on the relative importance of symmetric shocks only remains blind to the latter type of crisis. Through the lens of our OCA indicators, we observe that cyclical convergence in the euro area proceeds gradually, with OCA features showing signs of stagnation at levels close to those seen before the launch of the euro.

2. Relation to the Literature

This paper contributes to several strands of literature on the desirability and performance of forming and over time enlarging a monetary union: first, in connection to the identification and measurement of symmetric and asymmetric shocks among euro-area members and their implications for the common monetary policy; second, on the testing the OCA endogeneity theory; and, third, to the literature on OCA indices.[4]

A symmetric macroeconomic shock refers to an unexpected event that affects all union members similarly and simultaneously (European Commission 1990). Surprisingly, given the importance for its OCA conditions, the differentiation between symmetric and asymmetric shocks affecting euro-area countries has not been a primary focus in the literature. Instead, most studies have emphasized *the similarity of shocks*, a concept initially developed within a structural VAR framework by Bayoumi and Eichengreen (1993). This framework has become widely used, appearing, e.g., in Fidrmuc and Korhonen (2003) and Campos and Macchiarelli (2016), among others. These studies separately identify demand and supply shocks

[4]More broadly, our paper is also naturally related to the literature on international business cycles and, more specifically, to business cycle synchronization among euro-area countries; see, for example, Camacho, Perez-Quiros, and Saiz (2006), Giannone, Lenza, and Reichlin (2008), or Ferroni and Klaus (2015).

across European countries using the Blanchard-Quah methodology (Blanchard and Quah 1989) and assess the costs of forgoing autonomous monetary policy, relying on cross-country shock correlations. However, simple correlations between shocks falls short as an indicator to evaluate the costs of having a common monetary policy. In particular, the correlation between shocks may be high, but their overall macroeconomic importance across countries may be very different. In that case, a common one-size-fits-all monetary policy cannot be equally suitable for all countries in a monetary union and the costs of having a common currency are unevenly distributed across constituent countries. For this reason, we take a different track and distinguish the impact of symmetric from asymmetric shocks using a historical shock decomposition based on BVAR models. In contrast to simple correlation between shocks, a measure based on our shock accounting approach is dynamic in that it takes into account how the shocks propagate through the economy and contribute to overall macroeconomic variability.

The assessment of symmetric shocks has been prevalent in the VAR literature, but mainly in the context of analyzing bilateral linkages between the euro area and non-euro-area countries. Examples include Peersman (2011) for the U.K., Audzei and Brazdik (2018) for selected Central and Eastern European countries, and, more recently, Deskar-Škrbić, Kotarac, and Kunovac (2020) for Croatia, Bulgaria, and Romania, the three candidate countries intending to join the euro area, and Deskar-Škrbić and Kunovac (2020) for EU members (Sweden, Czech Republic, Hungary, and Poland) not intending or ready to join the euro area. The main focus in this paper, in contrast, is on the coherence of business cycles of existing euro-area members with respect to the rest of the euro area.

Our identification strategy is similar to that of Peersman (2011), who identifies symmetric and asymmetric shocks for the U.K. and euro area by directly imposing cross-country sign restrictions. However, unlike Peersman (2011), who defines asymmetric shocks as those affecting different economies with the opposing sign, we follow a different strategy and argue that asymmetric shocks are more accurately represented by two distinct types of shocks. The first type refers to local (or country-level) shocks, which cannot possibly affect other regions, and the second consists of a narrower subset of common shocks that affect a country and the rest of the euro area asymmetrically. Our definition aligns with that in an early report by the European Commission: "One Market, One Money" (European Commission 1990). In order to practically implement the identification and estimation of these shocks within BVAR framework, two modifications of a standard model are required. First, to identify country-specific shocks, we impose block exogeneity (or small economy) restrictions, as explained in Comunale and Kunovac (2017) and Deskar-Škrbić, Kotarac, and Kunovac (2020). Second, to identify asymmetric common shocks, we compare the reaction of output in a member country and the rest of the euro area from the estimated historical shock decomposition. Our method, thus, shares similarities with *the narrative sign restrictions approach* described in Antolin-Diaz and Rubio-Ramírez (2018).

We also contribute to the existing literature on formal OCA indices that largely rests on the work pioneered by Bayoumi and Eichengreen (1997, 1998). This framework was extensively used to evaluate the costs of adopting the euro ahead of its launch, and then again later, in the context of candidate countries, as mentioned in Horváth and Komárek (2003), Vieira and Vieira (2012), Skorepa (2013), and Frydrych and Burian (2017). The methodology proposed by Bayoumi and Eichengreen (1997) simply relates nominal exchange rate volatility to some salient OCA features, typically the similarity of business cycles or the strength of trade linkages. Their OCA index is then constructed based on the observation that countries where the nominal exchange rate volatility implied by certain proxies for the OCA criteria is sufficiently low are, supposedly, more prone to abandon their autonomous monetary and exchange rate policy. Clearly, the OCA criteria and the notion of importance of symmetric shocks are not less important for countries *already in a currency union.* Indices developed by Bayoumi and Eichengreen, however, are based on the volatility of nominal exchange rate between a candidate and the currency union and, therefore, are not suitable to keep track of OCA properties of an existing currency union. The absence of formal OCA indices for the euro area is an important measurement gap that we aim to address by constructing a new OCA index, now based on the relative importance of symmetric shocks.

Finally, we contribute to literature on OCA endogeneity for the euro area, a concept advocated by Frankel and Rose (1997), who challenge the static formalization of traditional OCA theory. There has been no consensus on how euro adoption affects the synchronization of a member with the euro area so far (with limited data availability playing a role in this regard). Interestingly, Campos, Fidrmuc, and Korhonen (2019) conduct a large meta-analysis that is supportive of the OCA endogeneity hypothesis. Willett, Permpoon, and Wihlborg (2010) or Caporale, DeSantis, and Girardi (2015), by contrast, suggest that the conclusion that one needs not worry ex ante about optimum currency area conditions, as suggested by the OCA endogeneity theory supporters, is overly benign. To select among these opposing views, a test for the OCA endogeneity hypothesis is required. For this, the literature usually relies on simple correlations between business cycles or, alternatively, on simple ordinary least squares (OLS) specifications used to identify the effect of bilateral trade patterns on income correlations. These approaches suffer from lack of identification and a structural interpretation of the results. Instead, we propose a formal test for OCA endogeneity by studying how the incidence of symmetric shocks evolves over time after a country joins a currency union. In doing so, we use D-I-D methods from Callaway and Sant'Anna (2021) and compare how the incidence of common shocks evolves for new members, in comparison to similar non-euro-area EU European countries. By including a proper control group of countries into the analysis, we address concerns raised in the literature that increased correlation between members may not be a consequence of joining the euro area only (see Willett, Permpoon, and Wihlborg 2010).[5]

3. Modeling Framework

We first specify a structural BVAR model for each euro-area member under analysis to separate local (idiosyncratic) from common shocks underlying GDP growth. We then show how to use this

[5]Willett, Permpoon, and Wihlborg (2010) report: "While the correlations of growth rates among euro area countries rose substantially after the creation of the euro, the correlations of the non-euro area European countries with the euro area countries rose even more, so clearly something besides just the creation of the euro was going on."

decomposition to separate the impact of symmetric from that of asymmetric shocks on GDP growth.

3.1 A Small Open-Economy BVAR for a Euro-Area Country

We start by specifying an open-economy Bayesian vector autoregression (BVAR) model for 15 euro-area countries[6] each in turn. The model is thus defined from the perspective of the individual country and includes six variables: GDP growth and the inflation rate of euro-area country i, which is considered the *home* country, the rest of the euro area (REA, the euro area excluding country i), and the rest of the world (RoW).[7] All details of the data used in this paper are described in Table A.1 of the appendix.

Consider a generic structural VAR with k lags that is represented as follows:

$$A_0 y_t = \mu + A_1 y_{t-1} + \ldots + A_k y_{t-k} + \varepsilon_t, \qquad t = 1, \ldots, T, \tag{1}$$

where y_t is an $n \times 1$ vector of observed variables, A_j are fixed $n \times n$ coefficient matrices with invertible A_0, μ is an $n \times 1$ fixed vector, and ε_t are structural economic shocks with a zero mean and covariance matrix I_n. The reduced-form VAR model is obtained from (1) by pre-multiplying the equation by $(A_0)^{-1}$:

$$y_t = c + B_1 y_{t-1} + \ldots + B_k y_{t-k} + u_t, \qquad t = 1, \ldots, T, \tag{2}$$

where $B_j = A_0^{-1} A_j$, $c = A_0^{-1} \mu$, $u_t = A_0^{-1} \varepsilon_t$, and $E(u_t u_t') = \Omega = (A_0' A_0)^{-1}$. To identify the structural model in Equation (1) additional restrictions are required. It is important to note that for any $n \times n$ orthogonal matrix Q (i.e., $QQ^T = Q^T Q = I$), pre-multiplying (1) by Q results in an observationally equivalent structural model, i.e., whose reduced-form representation is also Equation (2). Identification methods relying on *sign restrictions* are generally based on

[6] Our country coverage includes 15 euro-area countries, excluding Malta, Cyprus, Luxembourg, Ireland (due to exceptionally volatile GDP series), and Croatia (which joined the union in 2023).

[7] GDP for the rest of the world is represented by the sum of GDP of Norway, Switzerland, Turkey, Russia, USA, Canada, Mexico, Brazil, Australia, New Zealand, Japan, China, Hong Kong, Korea, and the EU but non-euro-area countries. Inflation is calculated from trade-weighted CPI, from 11 main trading partners of the euro area.

this principle (see, e.g., Canova and De Nicolo 2002, Rubio-Ramírez, Waggoner, and Zha 2010, and Arias, Rubio-Ramírez, and Waggoner 2014, 2018).

To separately identify country-specific shocks from common shocks, it is necessary to impose two types of restrictions. First, to ensure that country-specific shocks cannot affect foreign (REA and RoW) variables, restrictions on the impulse response function at $t = 0$ have to be imposed. In practice, zero restrictions on matrix A_0^{-1}, in addition to sign restrictions, can be implemented as suggested by Arias, Rubio-Ramírez, and Waggoner (2014, 2018). However, these restrictions alone do not prevent country-specific shocks from affecting foreign variables at horizons beyond $t = 0$. To achieve these *small country* or *block exogeneity* restrictions, zero restrictions on additional regression parameters are required. In other words, while in the reduced-form model (2) domestic GDP depends on its own lags as well as lags of foreign variables, foreign variables depend on their own lags only.[8] To impose zero restrictions on the regression parameters, we rewrite (2) in a more compact form:

$$y_t = X_t'\beta + u_t, \tag{3}$$

where $X_t' = I_n \otimes [1, y_{t-1}', \dots, y_{t-k}']$ and $\beta = vec([c, B_1 \dots B_k]')$. Within the Bayesian estimation framework, β can be restricted by setting an appropriate prior distribution. The usual choice of the natural conjugate (normal-inverse-Wishart) prior, although beneficial in terms of tractability of the posterior probability density function and computational speed, is not suitable for this purpose because it assumes a Kronecker-type structure of the prior covariance of VAR coefficients that is rather inflexible. In this case, the prior covariances are proportional to each other across equations so that it is not possible to independently set the prior for a subset of parameters in selected equations as would be needed to impose block exogeneity. Kadiyala and Karlsson (1997), Sims and Zha (1998), Koop and Korobilis (2010), or Carriero, Clark, and Marcellino (2019) explain

[8]Kadiyala and Karlsson (1997) and Miranda-Agrippino and Ricco (2018) provide another example where asymmetric treatment of the endogenous variables in a VAR is appropriate and in line with *prior beliefs*: economic theory suggests that *money neutrality* implies that the money supply does not Granger-cause real output.

why standard conjugate priors may appear as an overly restrictive choice for some applications of BVAR models.[9] Instead, an *independent* normal-inverse-Wishart prior is more appropriate in our case, as the prior beliefs for the VAR coefficients and error covariance matrix are set independently, as also implemented in Deskar-Škrbić, Kotarac, and Kunovac (2020):

$$\beta \sim N(\underline{\beta}, \underline{V}_\beta), \qquad \Omega \sim IW(\underline{M}, \underline{\gamma}).$$

Conditional posterior distributions $p(\beta|y,\Omega)$ and $p(\Omega|y,\beta)$ for this prior have the following form:

$$\beta|y,\Omega \sim N(\overline{\beta}, \overline{V}_\beta), \qquad \Omega|y,\beta \sim IW(\overline{M}, \overline{\gamma}),$$

where

$$\overline{V}_\beta = \left(\underline{V}_\beta^{-1} + \sum_{t=1}^{T} X_t \Omega^{-1} X_t'\right)^{-1},$$

$$\overline{\beta} = \overline{V}_\beta \left(\underline{V}_\beta^{-1} \underline{\beta} + \sum_{t=1}^{T} X_t \Omega^{-1} y_t\right),$$

and

$$\overline{\gamma} = T + \underline{\gamma}, \qquad \overline{M} = \underline{M} + \sum_{t=1}^{T} (y_t - X_t'\beta)(y_t - X_t'\beta)'.$$

While the posterior distribution is no longer available in the closed form, conditional posterior distributions are readily available, and a Gibbs sampler is therefore used to draw an approximate sample from the posterior of the reduced-form parameters, β and residual covariance matrix Ω. To evaluate the properties of a simulated sample from the posterior, in Appendix Section A.4 we provide a detailed Markov chain Monte Carlo (MCMC) convergence diagnostics; see Geweke (1992) or Chib (2001).

[9]There are, however, alternative approaches proposed in the recent literature to circumvent this forced symmetry imposed by standard normal-inverse-Wishart prior. For instance, Chan (2019) proposes *asymmetric conjugate priors* that do not preserve the VAR Kronecker structure when forecasting with large Bayesian VARs. An alternative strategy for implementing asymmetric priors is proposed by Carriero, Clark, and Marcellino (2019).

To impose zero restrictions on some regression parameters using an independent normal-inverse-Wishart prior, we assume zero-mean priors with very small variance for all small country parameters in the REA and the RoW equations. For example, to restrict the j-th element of β, we can set $\left(\underline{\beta}\right)_j = 0$ and $\left(\underline{V}_\beta\right)_{jj} = \varepsilon$, with ε being some small positive number. This attaches a large weight to the zero-mean prior parameters when calculating posteriors. Thus, sample information is largely ignored, as the posteriors of these coefficients will be predominantly influenced by the prior. Other elements of $\underline{\beta}$ and $\underline{V}_\beta$ are set to shrink posterior parameters in the spirit of the Minnesota prior. Hyperparameters are set to $\lambda_1 = 1$, $\lambda_2 = 1$, $\lambda_3 = 1$, and $\lambda_4 = 10^4$, which reflects our choice to use non-informative priors.

The structural BVAR models used in our analysis are all specified in log differences and estimated at a quarterly frequency on period 1996:Q1–2023:Q3 using two lags. Experimenting with different lag numbers did not change our results significantly.

3.2 Shock Identification: Local vs. Common Shocks

We identify six shocks in each of the country BVARs using the sign and zero restrictions as summarized in Table 1. We impose restrictions directly on the impulse response functions on impact only. Additional zero restrictions on autoregressive parameters are set as explained in Section 3.1.

Country-specific aggregate demand and supply shocks affect domestic GDP growth and inflation, but cannot affect real activity and prices in the REA or RoW. A demand shock is associated with positive correlation between GDP growth and inflation, and supply shocks are associated with a negative correlation between the two, as usually assumed in related literature; see, for example, Comunale and Kunovac (2017), Forbes, Hjortsoe, and Nenova (2018), or Bobeica and Jarociński (2019). In addition, only supply shocks can have a long-run impact on GDP, whereas the cumulative response to demand-side shocks is restricted to zero in the long run; see, for example, Blanchard and Quah (1989) and Forbes, Hjortsoe, and Nenova (2018).[10] Finally, by appropriately restricting the

[10] A standard view, as implemented in our specification, that all shocks with a permanent effect on output are supply shocks and those with a transitory effect

Table 1. Short-Run and Long-Run Restrictions

Shock/Variable	GDP_{Home}	$HICP_{Home}$	GDP_{REA}	$HICP_{REA}$	GDP_{RoW}	π_{RoW}
	Short-Run Restrictions at t = 0					
Local AD (Country Specific)	+	+	0	0	0	0
Local AS (Country Specific)	+	−	0	0	0	0
Common AD (Euro Area)	+	+	+	+	0	0
Common AS (Euro Area)	+	−	+	−	0	0
Common AD (Global)	+	+	+	+	+	+
Common AS (Global)	+	−	+	−	+	−
	Long-Run Restrictions					
Local AD (Country Specific)	0	?	?	?	?	?
Local AS (Country Specific)	?	?	?	?	?	?
Common AD (Euro Area)	0	?	?	?	?	?
Common AS (Euro Area)	?	?	?	?	?	?
Common AD (Global)	0	?	?	?	?	?
Common AS (Global)	?	?	?	?	?	?

Note: AD denotes aggregate demand and AS denotes aggregate supply. (+) = positive response; (−) = negative response; (0) = no response; (?) = unrestricted response. GDP_{Home} denotes GDP growth of a euro-area country, GDP_{REA} for the rest of the euro area, and GDP_{RoW} for the rest of the world; $HICP_{Home}$ denotes HICP inflation for a euro-area country, $HICP_{REA}$ for the rest of the euro area, and π_{RoW} inflation for the rest of the world. Details about all variable definitions are listed in Table A.1 of the appendix.

autoregressive coefficients, we also impose that REA and RoW variables must not depend on lagged values of home-country variables. This assumption, together with restrictions imposed on the impulse response function (IRF) at $t = 0$, is sufficient to fully separate local shocks from other shocks at all horizons.

Common euro-area aggregate demand and supply shocks affect macroeconomic indicators (GDP growth and inflation) in the home country and the rest of the euro area, but cannot affect RoW. Initially at $t = 0$, that impact is symmetric, but it may become asymmetric afterward, so later we distinguish between common symmetric and common asymmetric shocks. Demand-side and supply-side common shocks are, respectively, characterized by a positive and negative correlation between GDP growth and inflation. Besides that, only supply shocks can affect GDP in the home country in the long run. We assume that the two euro-area-specific common shocks cannot affect GDP growth or inflation in the rest of the world. To achieve that, we need to impose both restrictions at $t = 0$, but also on corresponding regression coefficients in equations for RoW variables.

Common global shocks are two global shocks that simultaneously affect all regions—the country under consideration, the rest of the euro area, and the rest of the world. Expansionary common global demand shocks initially affect all six variables under analysis positively. Expansionary global supply shocks affect GDP growth positively in all regions and affect negatively consumer inflation across all blocs. We also assume that global common demand shocks cannot affect home GDP in the long run.[11]

are demand shocks is questioned by recent literature. Furlanetto et al. (2021) attempt to identify demand shocks that can have a permanent effect on output through hysteresis effects; Coibion, Gorodnichenko, and Ulate (2017) point to cyclical sensitivity of mainstream estimates of potential output; and González-Torres, Gumiel, and Szörfi (2023) show how output gap estimates are affected when we allow for supply shocks with transitory effect only. For that reason, different approaches to separate demand versus supply should not be interpreted unconditionally, independently from the underlying identifying assumptions. Separation between symmetric versus asymmetric shocks, based on exact exclusion and sign restrictions—a focus of our paper—is, in contrast, less arbitrary.

[11] To impose restrictions that only supply shocks may affect GDP in the long run, we impose long-run restrictions on how demand shocks affect domestic GDP only. Ideally, we may want to impose some more restrictions—perhaps also on

3.2.1 Relative Importance of Shocks: Historical Shock Decomposition

The relative importance of the identified country-specific and common shocks in individual euro-area countries can be gauged from the historical shock decomposition of the estimated country BVARs. The *relative importance* of shock k to variable j at period t can be calculated from

$$\widetilde{y_{jt}^{k}} = \frac{\left|y_{jt}^{k}\right|}{\sum_{l=1}^{n}\left|y_{jt}^{l}\right|}, \tag{4}$$

where y_{jt}^{k} represents the contribution of shock k to the historical shock decomposition of variable j at period t and n denotes the total number of shocks. Relative importance of individual shocks could alternatively be evaluated using the variance decomposition. However, historical decomposition, by construction, seems to be better suited for tracking the importance of various shocks *over time.*

3.3 Mapping Local vs. Common to Symmetric vs. Asymmetric Shocks

In this section we reorganize the identified common and local shocks into symmetric versus asymmetric shocks, which is the decomposition of central interest for our analysis. *Asymmetric shocks* are not only all country-specific shocks but also those common shocks that affect a country and the rest of the euro-area asymmetrically, despite being initially *common* by definition. In fact, some shocks common to the entire euro area may have asymmetric impact on different euro-area members, possibly due to the differences in the initial cyclical states, economic structures, economic behavior, or preferences across the countries; see, e.g., European Commission (1990). Such a definition of (a)symmetric shocks spells out the idea that whenever a country's economy is predominantly driven by country-specific or

how these common demand shocks affect REA and RoW growth, but this is prevented by *the order condition*; see Arias, Rubio-Ramírez, and Waggoner (2014) for an explanation. Nevertheless, we experimented with different combinations of long-run restrictions—for example, instead of always restricting reaction of home GDP, we would restrict GDP of the RoW and REA—which resulted in very similar results.

common shocks with an asymmetric impact, the membership to the monetary union is more costly.

The relative importance of country-specific shocks can be calculated directly using Equation (4). To separately identify asymmetric from symmetric common shocks, we compare the effect of common shocks on the individual country under consideration and REA using historical shock decomposition of GDP in each period. Formally, let *home* and *REA* index any euro-area country and the REA, respectively, and let k denote an identified common shock (euro area or global). Then, a common shock k is said to be *asymmetric*[12] in period t whenever the home country and REA react to this shock with the opposite sign, i.e., $y^k_{home,t} y^k_{REA,t} < 0$. *Symmetric shocks*, in contrast, are those common shocks k for which $y^k_{home,t} y^k_{REA,t} > 0$ in period t.

Regarding the interpretation of our shock decomposition, the identified common shocks are not the same for all members, as real activity in the REA is different for different home countries. Therefore, the *symmetry*, as defined in our model, is to be seen from the individual country's point of view. Relative importance of symmetric shocks for each country is a country-specific measure of net benefits or *welfare* from sharing the common monetary policy. For example, a shock that affects a country and the rest of the euro area with the same sign is, according to our definition, symmetric for that country, irrespective of a possible mixed response among other currency union members. Those countries that react, at the same time, very differently from the rest of the euro area consequently derive lower

[12]Our definition of asymmetric common shocks is based on *the phase synchronicity* between business cycles measured by GDP growth. This choice, however, is not unique; there are alternative definitions. For example, we may be interested in those asymmetric shocks that affect various countries with the same sign but with very different amplitudes; see, for example, Mink, Jacobs, and de Haan (2012) for a concept of *similarity* between cycles. The COVID-19 shock, for instance, while affecting all the countries negatively, has increased the heterogeneity among euro-area members in terms of the severity of recession (Muggenthaler, Schroth, and Sun 2021). Alternative variants of asymmetric shocks would be more arbitrary compared to ours. In a case in which asymmetric shocks are identified using the similarity of business cycles, a threshold on the level of contribution of shocks should be imposed (or estimated) in order to distinguish between symmetric and asymmetric shocks with our *quasi-narrative* approach. It is, however, not clear how to identify this threshold.

levels of *welfare* upon such a shock occurring, because they are hit asymmetrically and a policy stance of one-size-fits all policy is most likely unsuitable. In that sense, our definition of symmetric shocks departs from a definition where a symmetric shock is assumed to affect *all* the members of a currency union in the same way.

4. Empirical Results

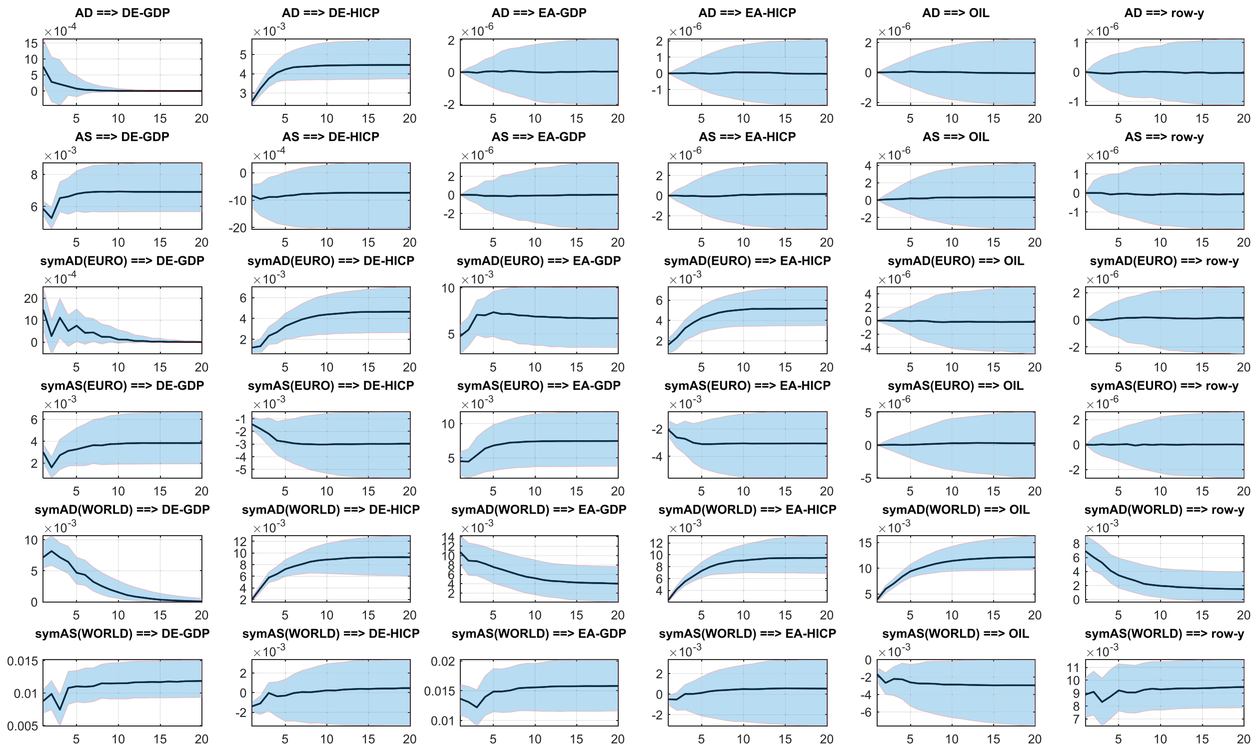
We first review the results from country BVARs in order to show that our identifying assumptions are sufficient to properly distinguish local from common euro-area and global shocks. After that, we study the difference between common and symmetric shocks, as they need not be the same. We finally conduct a detailed *shock accounting* exercise to study drivers of GDP growth in euro-area members. Based on this shock decomposition, we provide a new test for OCA endogeneity and construct a timely OCA index for the euro area.

4.1 BVAR Results—Local vs. Common Shocks

We show impulse responses for Germany (Figure 1) and for other countries in Appendix Section A.2 (Figures A.2–A.5), to verify that the sign and zero restrictions from Table 1, together with additional zero restrictions on autoregressive parameters, are sufficient to separate the local and the two common shocks. Two local shocks in the top rows cannot influence the rest of the euro area or the rest of the world over any time horizon. Likewise, common euro-area shocks in the third and the fourth row cannot affect the RoW. In contrast, the common global shocks in the two bottom rows affect all three *regions* similarly.

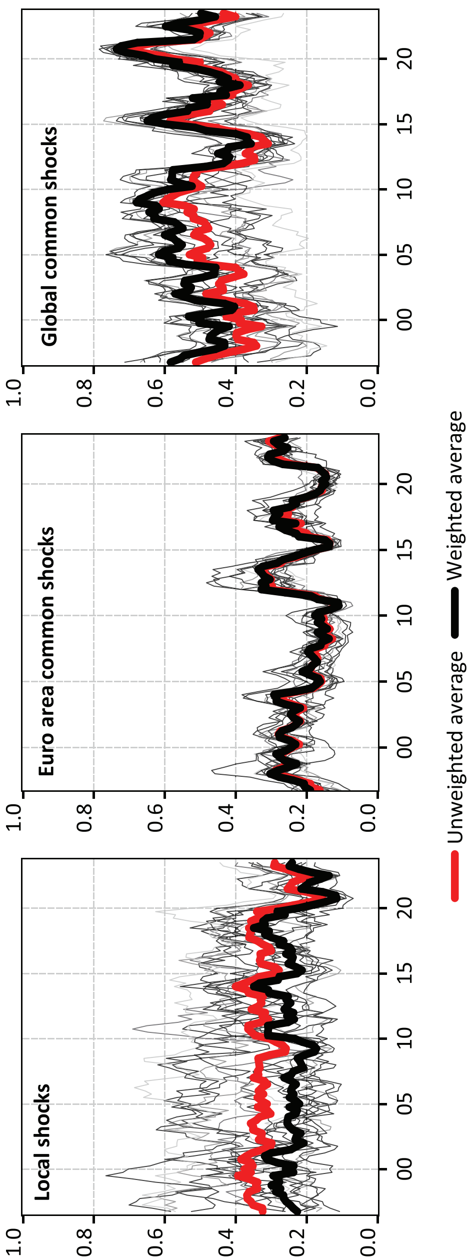
Figure 2 compares the relative importance of local, euro-area common, and global common shocks for GDP growth across countries. To summarize the results obtained from identified country BVARs, we also show the cross-country average importance of each shock—both unweighted and (GDP-)weighted versions. At this point, we do not explicitly label each country in the graph and focus on the properties of cross-country distribution. The global common shocks are clearly the most important type of shocks, accounting for the biggest share of all shocks, confirming in particular the small

Figure 1. Impulse Response Functions for Germany (median and 68 percent posterior bands)



Note: Impulse responses of each variable are in separate columns: German GDP and inflation (GDP and HICP), rest of the euro area GDP and inflation (GDP_{REA} and $HICP_{REA}$), and the rest of the world GDP and inflation (GDP_{RoW} and $INFL_{RoW}$). There are overall six shocks in the rows: local aggregate demand and supply (AD and AS), euro-area-specific symmetric AD and AS (symAD(EURO) and symAS(EURO)), and global symmetric AD and AS (symAD(WORLD) and symAS(WORLD)).

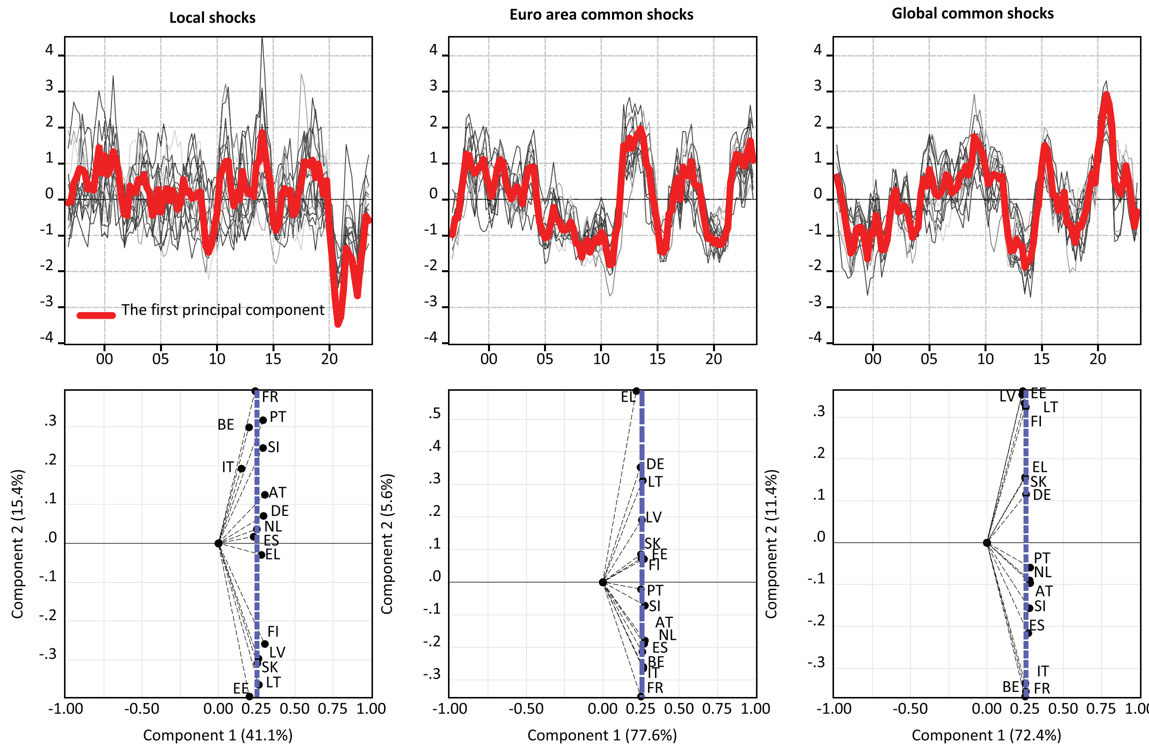
Figure 2. Relative Importance of Local vs. Euro-Area Common vs. Global Common Shocks across Member States



open-economy nature of the euro area. The cross-country variation is overall the largest for local and global shocks, but diminishing over time. For local shocks, the unweighted average hovers around 30 percent, above the weighted average. Conversely, for global shocks, the unweighted average lies below the weighted average. For both local and global common shocks, the difference between the two averages has been closing in over the sample, mostly driven by smaller, *new* euro-area members that are being increasingly more exposed to global symmetric shocks and less so to idiosyncratic economic disturbances. Also the dispersion of global shocks across the countries reduced significantly in the last decade, but the share of global shocks was much less stable, and peaked during the pandemic shock. As regards the euro-area-specific common shocks, they are less dispersed and generally stable in importance over the observed period. In line with the usual narrative, they peak during the euro debt crisis. Non-negligible importance of common euro-area shocks—also illustrated by yellow contributions to GDP growth in Figures A.6–A.9—supports the existence of a European business cycle emerging from our analysis. This has been discussed intensively in the literature, but without reaching a firm consensus.

Results in Figure 2 are informative about *the level* of the relative importance of various shocks over time and across countries. However, in order to better understand the comovement behind estimated importance of shocks—a feature that may be overlooked easily when looking at Figure 2 only—we rely on the principal component analysis (PCA), based on standardized data; see Figure 3 (upper panel). After the transformation, the high dispersion of local shocks across countries still persists, while the relative importance of global shocks appears highly correlated across countries. Euro-area-specific contributions were already very little dispersed before standardization, and this transformation had little impact here. A simple PCA, applied within our methodological framework, can illustrate the commonality among euro-area members very well. The first principal component explains 77.6 percent and 72.4 percent of the common variation for euro-area and global common shocks, respectively, in contrast to only 41 percent for local shocks (x-axis, Figure 3, lower panel). To illustrate that all countries load similarly to first components of common shocks, we perform a simple visual test and compare calculated country loadings (the black dots) with

Figure 3. Relative Importance of Local vs. Common Shocks: A Principal Component Analysis



Note: The relative importance of shocks in the upper panel is standardized to have zero mean and unit standard deviation. Blue vertical lines in the lower panel refer to the average loadings of the first principal component. The black dots refer to the loadings of individual countries to the first principal component.

the cross-country average loading (the blue vertical lines). Our simple test suggests that no country deviates systematically from the common cycles; only Greece exhibits a slightly larger deviation from the European cycle.

There is some remaining commonality captured by the second principal component, 5.6 percent for euro-area common and 11.4 percent for global common shocks, shown on the y-axis. Interestingly, some country groups emerge to form clusters. In particular, there is evidence of clustering patterns according to *geographical proximity*—the Baltic countries and Finland form a cluster in the case of global common shocks. These countries also show up among the countries that are less affected by common euro-area shocks during the debt crisis—Greece (EL), Germany (DE), Finland (FI), and the Baltics (EE, LT, LV). This is not to be confused with a wrong conclusion that Greece was not affected by the sovereign debt crisis. It was strongly affected, however mostly through local idiosyncratic shocks that would later spill over to other members, but not through euro-area common shocks, as was the case for other countries, such as Italy, Portugal, or Spain. Our empirical model is capable of properly differentiating these types of shocks. Local shocks are unrelated across countries by construction. Nevertheless, some clustering evidence emerges that relative importance is less important for old euro-area members compared to new members in the case of local shock loadings.

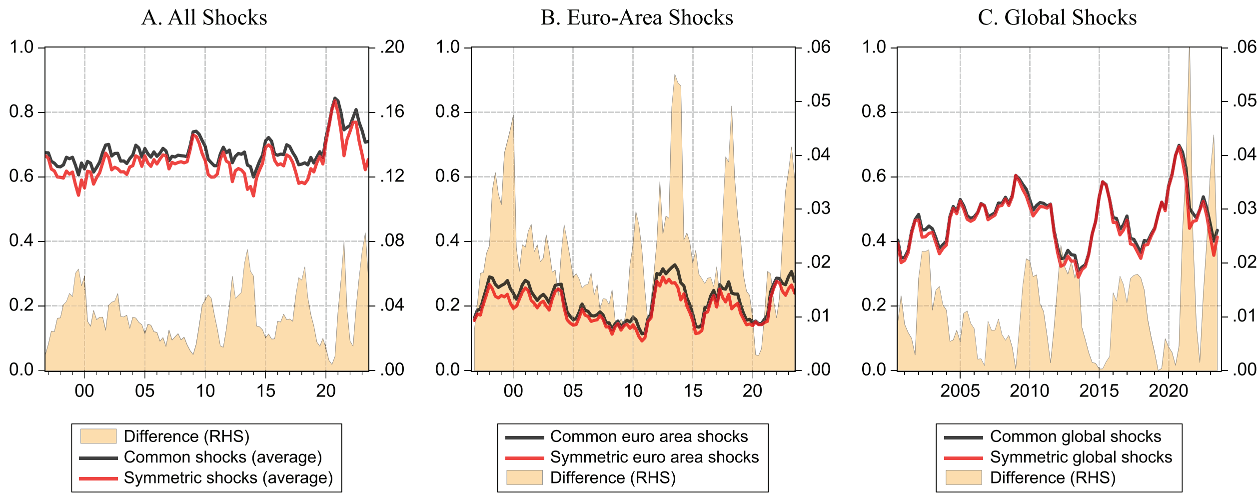
4.2 Shock Accounting: Symmetric vs. Asymmetric Shocks and Implications for Monetary Policy

After we explain the difference between common and symmetric shocks, we show the results of our *shock accounting* exercise. First we document some differences in composition of shocks between countries and then, finally, study relative importance of individual shocks for the euro area as a whole and implications for monetary policy.

4.2.1 Common and Symmetric Shocks: A Comparison

Asymmetric shocks, as explained in Section 3.3, include both local shocks and asymmetric common shocks. Equivalently, not all common shocks are symmetric. Figure 4 compares cross-country average

Figure 4. Common and (a)symmetric Shocks



Note: Cross-country average share of symmetric shocks is represented by red lines; cross-country average share of common shocks is represented by black lines. The difference between the two measures is represented by the yellow area, measured against the right-hand axis.

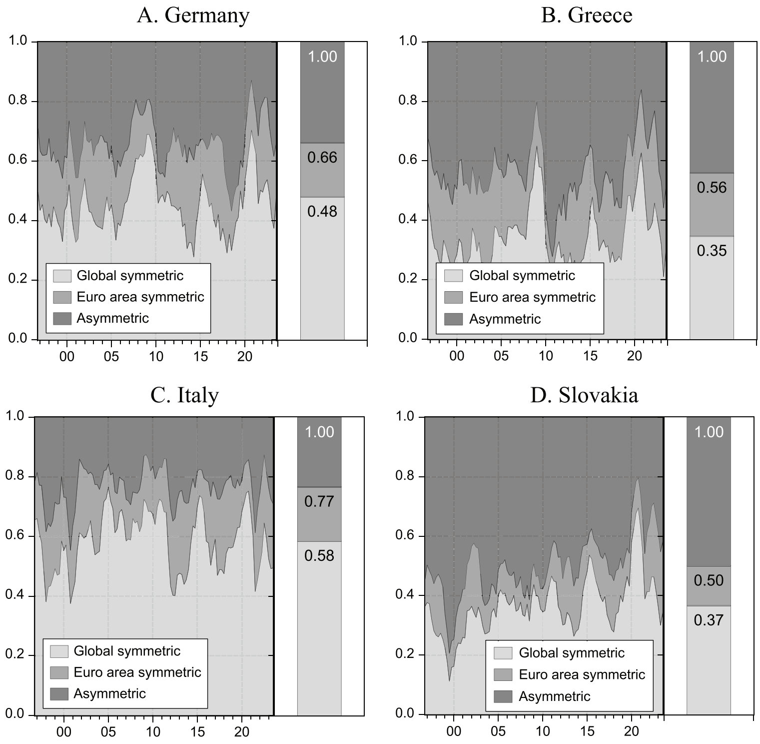
of common and symmetric shocks using our definitions and suggests that the difference between the two is small. Some common shocks could indeed be asymmetric, but never more than 8 percentage points (pp) of overall variation in GDP growth, with only 3 pp on average over the observed period; see Figure 4A. Most of the asymmetric common shocks are identified as euro-area common shocks (mean = 2.2 pp, max = 5.5 pp), less often global (mean = 1.1 pp, but higher max = 6.2 just after COVID); see Figure 4, panels B and C. European asymmetric common shocks may intensify just after the periods of increased commonality: notably, they peak after the euro debt crisis. Global asymmetric shocks, similarly, peaked right after the pandemic, suggesting that major crises tend to evoke uneven reactions across countries.

4.2.2 Shock Decomposition by Country

The relative importance of symmetric versus asymmetric shocks is not always homogeneous across euro-area members. Typically, factors that drive the differences among them are related to how previous crises (GFC or euro debt crisis) affected different members, when they join the euro area (*old* or *new* members), or how individual members align with global developments in general.

To better understand the differences observed across countries, Figure 5 compares the relative importance of symmetric versus asymmetric shocks for four euro-area countries, capturing distinct and particularly interesting shock configurations: Germany, Greece, Italy, and Slovakia. Greece is a member with a generally large share of asymmetric shocks—around 44 percent of overall variation in GDP growth; see Figure 5B. These shocks were especially important around the European sovereign debt crisis, when they dominated and drove 70 percent of the overall business cycle variation. Unlike in other countries, the macroeconomic deterioration was due to local shocks that later spread throughout Europe. However, later on, Greece has been increasingly affected by common symmetric shocks. In Germany, the largest euro-area economy, we also find a fairly large share of asymmetric shocks; see Figure 5A. This could come as a surprise as, by its sheer size, the German economy is well correlated to the overall euro area. It is, however, less well correlated with the rest of the euro area. Indeed, due to its size, a difference in

Figure 5. Shock Contributions in Select Member Countries

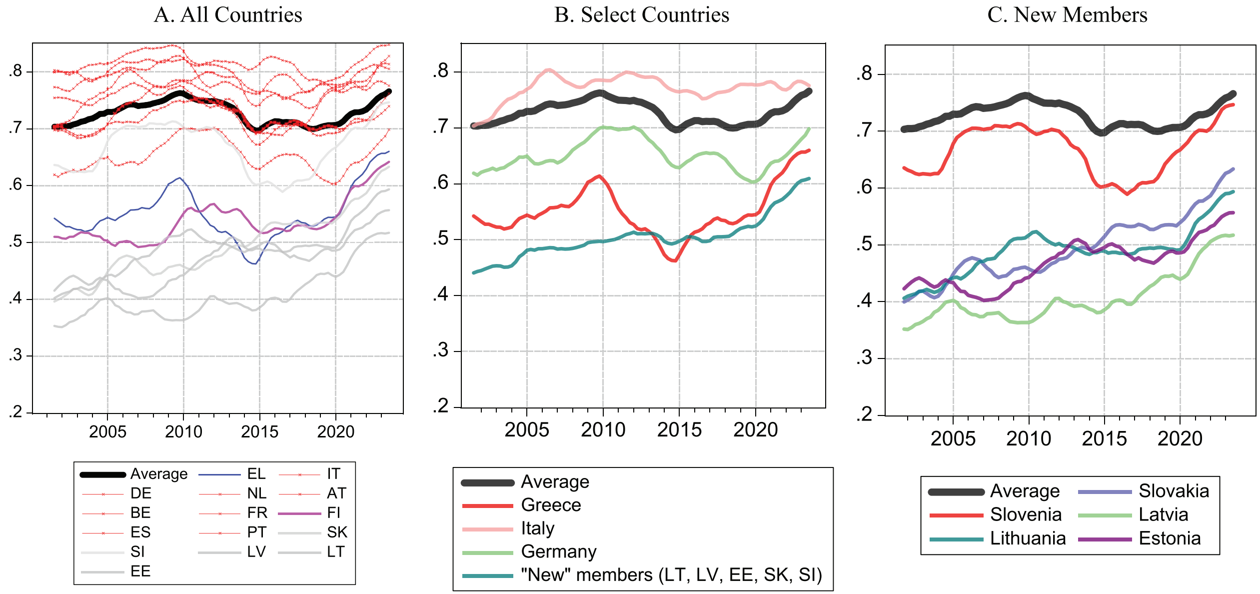


Note: Sample average for each shock is presented in bars on the right (cumulative).

correlation of Germany to total euro area in contrast to correlation to rest of the euro area (i.e., Germany excluded) is sometimes large; see Figure A.1, panel C. Our framework recognizes this distinction and occasionally points to a relatively large share of asymmetric shocks. Asymmetric shocks—in contrast to Greece, for example—have often been due to stronger performance of the German economy compared to the REA. One such episode was the period immediately following the GFC, when German GDP, in contrast to the rest of the euro area, recovered exceptionally fast. A detailed explanation of a fast recovery in Germany can be found, for example, in an International Monetary Fund report (IMF 2011). Historical shock decomposition of GDP growth in Italy (Figure 5C) suggests that common symmetric shocks dominate throughout the sample period even more. In fact, according to the results from our BVARs, the relative importance of symmetric shocks here mostly exceeds those of all other countries in our sample. This is in line with Belke, Domnick, and Gros (2017) and Ferroni and Klaus (2015) who, somewhat to their own surprise, also find very strong cyclical coherence between Italy and other euro-area countries. Local shocks have gained importance in driving GDP growth only very sporadically. The three exemplary countries are compared to aggregate euro area in Figure 6B. Our last example of Slovakia (Figure 5C) shows the typical behavior of a *new* member that is catching up to old member countries, while starting off with a very large share of local shocks that would steadily diminish. Figure 6C compares the weighted average of all member countries with the relative importance of symmetric shocks for other new members as well. Indeed, a clear pattern emerges that all new members (except for Slovenia, which is already in a more mature stage of the same process) are catching up with the euro-area average. An interesting question we also ask is to what extent is this convergence affected by the euro adoption.

Four typical countries illustrate how profiles of relative importance of symmetric versus asymmetric shocks vary across countries and over time. There is another source of possible dissimilarity of shocks if the type of shock—demand or supply—is taken into consideration. Figure A.15 shows the relative importance of asymmetric shocks (local) versus symmetric shocks (euro area or global), decomposed further into demand- versus supply-side shocks. It can be seen that among symmetric shocks, those of a global nature dominate. Asymmetric shocks are relatively more important than euro-area symmetric shocks, with a number of countries being exposed to local shocks exceeding 50 percent of all shocks. Local and euro-area symmetric shocks tend to be more often supply-side shocks than demand-side shocks. In the case of global shocks, demand- and supply-side shocks are more or less equally frequent. As already seen in a less refined decomposition onto local versus common shocks in Figure 2, dispersion decreases for local shocks, mainly driven by new members. Importantly, the crisis periods display distinct mean and standard deviation profiles of the relative importance of the shocks. Around the European debt crisis the relative importance of

Figure 6. Symmetric Shocks: Some Country Differences



Note: All series are transformed to five-year moving averages. In panel A, all *new* members are represented by the gray lines and all other countries, except Finland and Greece, are in red.

symmetric euro-area supply shocks increased significantly as well as the cross-country heterogeneity. The GFC and pandemic were global crises, where the importance of symmetric shocks rose but with very low dispersion.

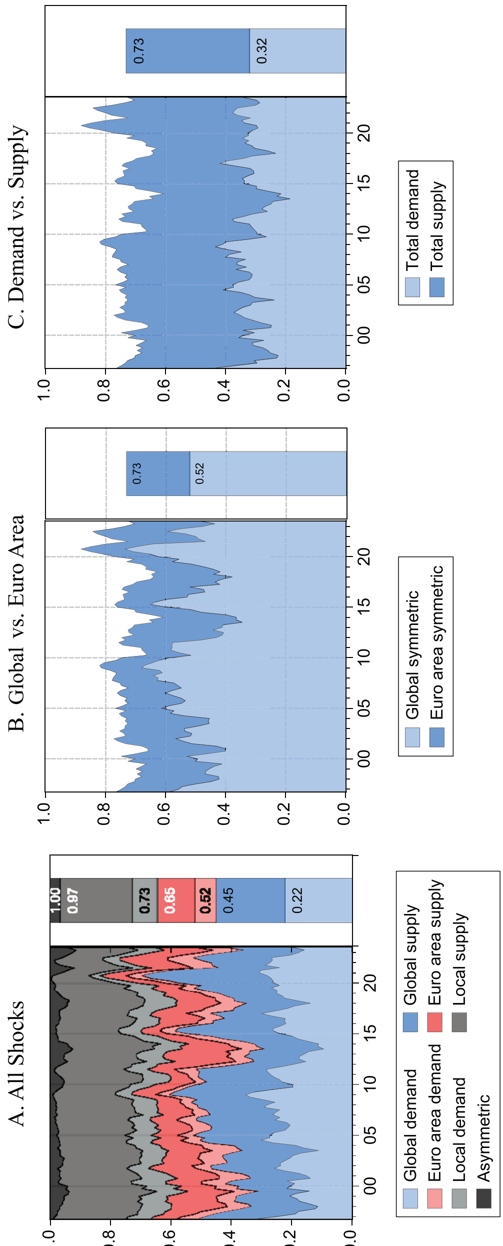
4.2.3 Shock Decomposition for the Euro Area and Implications for Monetary Policy

While relative importance of symmetric versus asymmetric shocks at the country level is important, the focus of *one-size-fits-all* monetary policy is on euro area as a whole. For that reason, we aggregate results from country BVARs and calculate cross-country average relative importance of each type of shock. Results from individual countries are aggregated using GDP as weights.

Figure 7A compares the relative importance of each shock for the euro area as a whole and points to some interesting results. First, symmetric shocks—global in blue and euro-area-specific in red—are the dominant drivers of GDP growth for the euro area as a whole. On average, across countries and over time, they explain a large portion of overall variability in GDP growth—around 73 percent. Among the symmetric shocks, most of them, around 52 pp, are global shocks, and another important part of them, around 19 pp, is due to euro-area-specific shocks; see decomposition in Figure 7B. This finding on the dominance of global symmetric shocks explains why monetary policy of the ECB is often well synchronized with that of other major central banks. Also, the finding that a sizable portion of the euro-area activity is driven by common euro-area shocks, together with insights from historical shock decomposition at a country level (Figures A.6–A.9), provide additional evidence of the existence of the euro-area-specific cycle.

The predominance of symmetric shocks per se is not sufficient for monetary policy to stabilize the union—the nature of the symmetric shocks matters as well. Symmetric shocks are, therefore, regrouped in Figure 7C in order to compare relative importance of symmetric demand versus supply shocks. Both demand (with 32 percent) and supply (with 41 percent) are, on average, important drivers of overall variability of business cycle of the euro area. A large portion of the comovement explained by supply shocks, however, points to possible common inflationary pressures that monetary policy may not be in

Figure 7. Shock Accounting: Symmetric vs. Asymmetric Shocks



a good position to battle against. As a consequence, an overall large share of symmetric shocks does not necessarily signal an increased potential for common policy to stabilize a currency union.

From a country perspective, of either a candidate country or an existing member, relinquishing its own monetary policy entails higher costs in an environment of more prevalent idiosyncratic demand shocks. Presumably, monetary policy is best suited to deal with these types of shocks and, therefore, their dominance is related to larger costs of not having autonomous monetary policy. The decomposition presented in Figure 7A is suitable to address this concern. Importantly, we show that these shocks are a minor driver of business cycles across members of the union—only around 5 percent of overall variability in GDP growth is due to domestic demand. These findings support a view that the costs of abandoning autonomous country-level monetary policy are likely to be contained. Indeed, the results indicate that, on its own, the country's monetary policy would largely face the same type of shocks as countries within the union or, occasionally, when facing local shocks, these would often be local supply shocks, for which the costs of absence of own monetary policy are considerably lower.

Finally, as a by-product, our framework can also be used to gauge a measure of output gap—an important input for monetary policy to understand the link between real economy and inflation. One approach to estimate output gap is accumulating the contribution of demand shocks from BVARs; see Camba-Mendez and Rodriguez-Palenzuela (2003), Coibion, Gorodnichenko, and Ulate (2017), or Chen and Gornicka (2020), for example. However, this is based on a standard, but fairly strong, assumption that all supply shocks have permanent effects on output; see Blanchard (2018) for explanation. In our application, output gap can then additionally be decomposed in terms of local, euro-area, or global shock contributions. We show in Figure A.14 that the euro-area output gap is dominantly being driven by symmetric global shocks according to our model.[13] Our estimate resembles a standard Hodrick-Prescott approach relatively

[13]A simple variance decomposition exercise suggests that global symmetric, euro-area symmetric, and local shocks explain 77 percent, 17 percent, and 6 percent, respectively, of overall variation in our measure of output gap; see Lindeman, Merenda, and Gold (1980) for methodology used.

well before the GFC and less so afterward, especially during and after the COVID episode, and these differences are likely related to our definition of demand and supply where all demand shocks are cyclical and potential output is being affected by supply only.

4.2.4 Testing for OCA Endogeneity

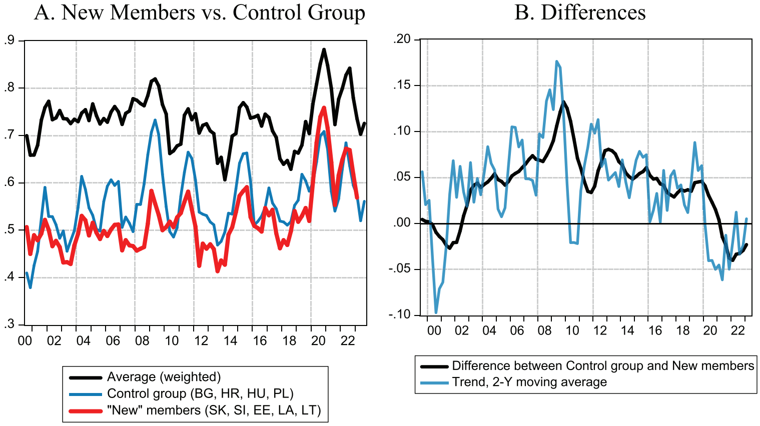
Our results, as shown in Figure 6, illustrate that new member countries, in terms of the incidence of symmetric shocks, converge to the euro-area average. We are now interested in *the euro effect*: how joining the euro area affected the importance of symmetric shocks in these Central and Eastern European countries that all joined the union after 2007—Slovakia, Slovenia, Estonia, Latvia, and Lithuania (SK, SI, EE, LV, LT). For that purpose, by using our identification we first calculate the relative importance of symmetric shocks for these countries and, then, visually compare how the incidence of symmetric shocks has been evolving in comparable non-euro-area countries.[14] After that, to quantify this impact more formally, we use both a standard difference-in-difference regression (denoted D-I-D) as well as an approach from recent advances in the difference-in-difference literature with complex treatment timing; see Callaway and Sant'Anna (2021).[15]

A visual comparison of the overall dynamics of symmetric shocks in new members with a *control group* consisting of non-euro EU countries—Bulgaria, Croatia, Hungary, and Poland—resulted in some interesting findings. Figure 8A suggests that both new members and control group are catching up to the euro area over the

[14]Our sample ends in 2023:Q3 and Croatia joined the euro area in January 2023. For that reason, we ended our estimation sample a bit earlier, in order to not include post-euro-adoption period.

[15]A standard D-I-D estimation based on two-way fixed-effects regression works nicely when dealing with a standard two-periods two-units problem where the untreated group never participates in the treatment, and the treated group becomes treated in the second period. However, there are drawbacks to this approach in a case with more than two time periods and where different units can become treated at different points in time. For example, in our case, a standard D-I-D regression compares the effect of euro adoption with countries that already adopted the euro (and thus maybe behave differently) and those that never adopted the euro (never treated) and those that have not adopted the euro yet. In contrast, the Callaway and Sant'Anna method takes these considerations into account.

Figure 8. Relative Importance of Symmetric Shocks by Country Groups

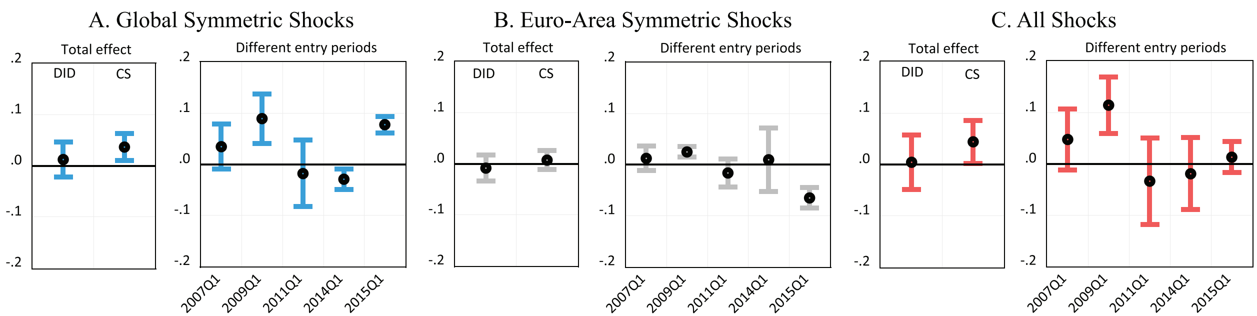


Note: Relative importance of symmetric shocks for control group is calculated using the methodology explained in Section 3.2.

sample. This is not surprising—all these Central and Eastern European countries went through a similar economic transition and reorientation process toward Western Europe. As a result, the incidence of symmetric shocks has increased in both groups. We are, however, interested in how joining the euro area affected (possibly sped up) this catching-up process. Figure 8B documents the difference between the importance of symmetric shocks in our control group of countries and in new members and provides an informal assessment of the euro effect. Initially, since the euro inception, symmetric shocks in the control group were somewhat more prevailing compared to new members, and the difference between the two groups was trending upward. Over that period, all new members were still outside the euro area. However, it seems that the period when this trend turned broadly coincided with the period when the first new members started joining the euro area.

Figure 9 and Table A.2 provide formal evidence of the euro effect, based on estimated difference-in-difference specifications. In order to understand better these effects, in addition to how all symmetric shocks are affected by euro adoption, we also estimate effects

Figure 9. Difference-in-Difference: Two-Way Fixed Effects (D-I-D) and Callaway and Sant'Anna Method (CS)



Note: The figure compares total effects based on alternative difference-in-difference estimators: standard two-way fixed effects (D-I-D) and the Callaway and Sant'Anna method (CS). D-I-D and CS estimates are shown together with a two-standard-deviation interval. For the CS method, we show estimated heterogeneous effects for different entry periods: 2007 (Slovenia), 2011 (Slovakia), 2011 (Estonia), 2014 (Latvia), and 2015 (Lithuania).

for euro-area-specific and global symmetric shocks separately. For monetary policy purposes, it is also important how predominance of different types of symmetric shocks—demand and supply side—changes after a country adopts the euro. Based on the method by Callaway and Sant'Anna, we find some evidence of *the euro effect*: the incidence of symmetric shocks in new members would on average increase by 4.4 pp as a consequence of joining the euro area. This is almost entirely driven by global symmetric shocks, while the contribution of euro-area-specific shocks is of much smaller magnitude and statistically insignificant; see Figures 9A and B. Standard D-I-D estimates, in contrast, find no significant *euro effect.* Using the Callaway and Sant'Anna method, we also provide evidence of heterogeneity in the euro effect: compared to our control group, not every country benefits equally from joining the euro area in terms of the incidence of symmetric shocks (Figure 9). While some new member countries that first joined the euro area, Slovakia and Slovenia, seem to have benefited from joining the euro area, the findings are more mixed for the Baltics. We found no gains in terms of incidence of symmetric shocks for Estonia and Latvia, and in Lithuania we documented increased incidence of global shocks, but this is largely offset by decrease in euro-area-specific component; see Figure 9B. Finally, a detailed decomposition of estimated euro effect in Table A.2 suggests that increase in dominance of symmetric shocks has been working through both increased incidence of demand and supply, but demand dominates.

Our empirical analysis is concerned with how incidence of symmetric shocks changes after euro adoption in new member countries that joined the union in later stages of enlargement. A similar formal evaluation of the euro inception in January 1999 on shock synchronization, due to a relatively short pre-euro sample, would be somewhat unreliable.[16] There is, however, evidence in related literature that no significant change in business cycle similarity among member states associated with the EMU can be detected (Giannone, Lenza, and Reichlin 2008). A similar, albeit informal, conclusion

[16]We have included data starting in 1995—that is the earliest starting date possible from the harmonized Eurostat database—as well as extending the data up to 2023:Q3. Our estimates of the relative importance of shocks start only from 1996:Q4, as we lose some initial data due to taking moving averages.

is suggested by Figure 6A (red lines): symmetric shocks seem to be dominant drivers of GDP growth in founding member countries even before euro inception—they account for almost 80 percent of all shocks. Euro inception itself, as suggested by the literature, probably has little additional impact.

Overall, our analysis suggests that the incidence of symmetric shocks has been increasing for all former socialist European countries, irrespective of their euro-area membership, mostly as a part of a general integration with Western Europe and, more broadly, through ongoing globalization processes. We find, however, that in addition to these common factors that predominantly drive the catching-up process, participating in a currency union, on average, additionally speeds up the process of integration. This greater integration is achieved dominantly through larger incidence of symmetric global demand shocks, suggesting more efficient international trade and investment once adopting the euro, as predicted by early OCA endogeneity literature. This has important implications for candidate countries that consider joining the union: the OCA endogeneity should not be advocated unconditionally and should be necessarily evaluated on a country-by-country basis.

4.3 Constructing a New Optimum Currency Area Index for the Euro Area

Cross-country average relative importance of symmetric shocks, as calculated using our framework, is a *shocks-similarity* measure itself, suitable to track OCA properties of the euro area. We argue that dispersion of country-level importance of symmetric shocks also matters. For example, in a case in which the average importance of symmetric shocks is high but heterogeneity across members may have also increased, it may not be sufficient to consider only one of them, first or second moment, in isolation. Indeed, if, for example, high average relative importance of symmetric shocks of 70 percent is attained within a highly heterogeneous environment—the share of symmetric shocks amounts to 90 percent in some countries and only 20 percent in others—common policy will not be optimal for all, with risks of causing political tensions or even possible breakup. We show that a simple *signal-to-noise* ratio of estimated shares of symmetric shocks takes these considerations into account and qualifies as a reliable OCA index of the euro area.

4.3.1 Signal-to-Noise Ratio: A Definition

We construct our OCA measure for the euro area starting from the observation that the common monetary policy will be more successful in stabilizing the euro-area economy if the percentage of symmetric shocks is sufficiently high across member countries. Only in that case will the union-wide monetary policy be well tailored for all member countries. Through the lens of our empirical framework, we additionally argue that the euro area may be *closer to optimal* as a currency area if two conditions are met jointly:

(i) *The cross-country average of the relative importance of symmetric shocks, denoted μ, is high.* A high value of μ reflects that business cycles across member states are predominantly driven by symmetric shocks, ensuring higher chances for common monetary policy to stabilize all euro-area members simultaneously.

(ii) *The cross-country standard deviation of the relative importance of symmetric shocks, denoted σ, is low.* In addition, it is desirable that symmetric shocks be of similar importance for all euro-area countries such that the value of σ is low. This implies that for a given value of μ, the summarizing index should penalize high dispersion of the relative importance of symmetric shocks across countries.

The concept of a simple *signal-to-noise* ratio[17] intuitively embeds these two requirements simultaneously:

$$SNR(t) = \frac{\mu(t)}{\sigma(t)},$$

[17] In electronics, the ratio of desired electronic signals to unwanted noise, often expressed in decibels (dB) is routinely analyzed to evaluate the signal quality. Here, some analogy can be drawn with our application where high average importance of symmetric shocks cannot provide *clear signal* of favorable OCA properties whenever surrounded by a lot of *noise*.

where $\mu(t)$ and $\sigma(t)$ denote the cross-country sample mean and standard deviation of estimated relative contributions of symmetric shocks, denoted $y_1(t), \ldots, y_n(t)$, calculated for a group of n euro-area members:

$$\mu(t) = \frac{1}{n} \sum\nolimits_{i=1}^{n} y_i(t) \tag{5}$$

$$\sigma(t) = \sqrt{\frac{1}{n-1} \sum\nolimits_{i=1}^{n} (y_i(t) - \mu(t))^2}. \tag{6}$$

In this version of the index, equal weights are attached to each country by definition, so we call it the *unweighted OCA index*. We also compute a *weighted OCA index*:

$$SNR^w(t) = \frac{\mu^w(t)}{\sigma^w(t)},$$

where each country enters the formula for the mean and standard deviation first weighted by its GDP:

$$\mu^w(t) = \sum_{i=1}^{n} w_i y_i(t) \tag{7}$$

$$\sigma^w(t) = \sqrt{\frac{\sum_{i=1}^{n} w_i (y_i(t) - \mu^w(t))^2}{1 - \sum w_i^2}}, \tag{8}$$

where $w_i \in [0, 1]$, $\sum w_i = 1$ denote the relative weight of the GDP of country i in the aggregate euro-area GDP. The two measures, $SNR(t)$ and $SNR^w(t)$, have a somewhat different interpretation. When calculating the weighted index $SNR^w(t)$, which accounts for the country sizes, both moments, $\mu^w(t)$ and $\sigma^w(t)$, and the resulting signal-to-noise ratios are by construction dominated by large countries. $SNR^w(t)$ is therefore better at measuring the potential for the common monetary policy to stabilize the overall euro-area economy. On the other hand, economic homogeneity across *all* euro-area members is better reflected in high values for unweighted $\mu(t)$ and low values for $\sigma(t)$.

Signal-to-noise ratios are non-negative numbers and unbounded from above. In our specific case, the relative contributions of symmetric shocks $y_1(t), \ldots, y_n(t)$ are all within the interval $[0, 1]$, implying that the sample means $\mu(t)$ and $\mu^w(t)$ also lie within the same interval. $\sigma(t)$ is bounded by zero from below and, according to Bhatia-Davis inequality (Bhatia and Davis 2000), always bounded from above. For a given average importance of symmetric shocks, irrespective of how $y_1(t), \ldots, y_n(t)$ are distributed, Bhatia-Davis inequality states that

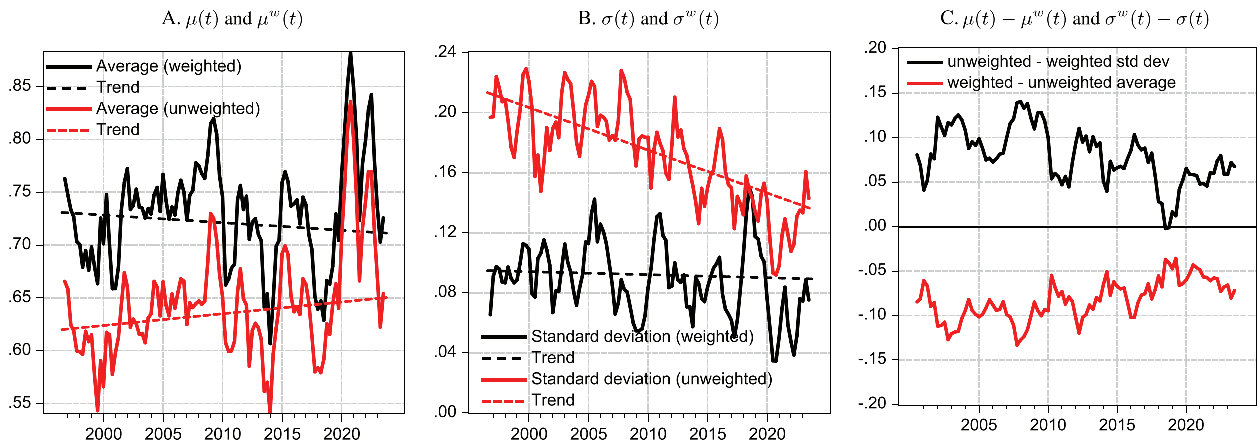
$$\sigma(t) \leq \sqrt{\mu(t)(1 - \mu(t))}.$$

Bhatia-Davis inequality provides an upper bound for the standard deviation $\sigma(t)$ and a lower bound for signal-to-noise ratio $SNR(t)$ for a given estimated $\mu(t)$ and, thus, may help to compare estimated values of OCA indices to some known boundary values.

4.3.2 Signal, Noise, and Signal-to-Noise Ratio

Figure 10 compares aggregate first ($\mu(t)$ and $\mu^w(t)$) and second ($\sigma(t)$ and $\sigma^w(t)$) moments for the weighted and unweighted samples. The weighted average importance of symmetric shocks $\mu^w(t)$ is always greater than the unweighted figure $\mu(t)$, reflecting the fact that the large euro-area members have, on average, had more coherent business cycles with the rest of the euro area than the other countries. The two mean statistics in Figure 10A peak around global crises: the GFC and the COVID crisis. Importantly, in contrast to very similar short-run dynamics of the two mean series, they have different trending properties: unweighted statistics $\mu(t)$ has had a clear upward trend, largely driven by the catching-up process in new member countries, as explained in Section 4.2.4. In contrast, weighted mean, although already at very high level, has been stagnating, or in the case in which the COVID period is excluded, even slightly decreasing over the observed period. As a consequence, the difference between the two mean measures has been decreasing, as illustrated in Figure 10C. Two dispersion statistics in Figure 10B also show different dynamics over the period under analysis. Unweighted standard deviation $\sigma(t)$ is always larger than weighted statistics $\sigma^w(t)$, suggesting that larger member countries deviate less from cross-country average relative importance. However, dynamics of unweighted statistics is dominated by a strong downward trend, mostly driven by the catching-up process in new (and small) member countries. Weighted dispersion, on the other hand,

Figure 10. Cross-Country Average and Standard Deviation of Relative Importance of Symmetric Shocks

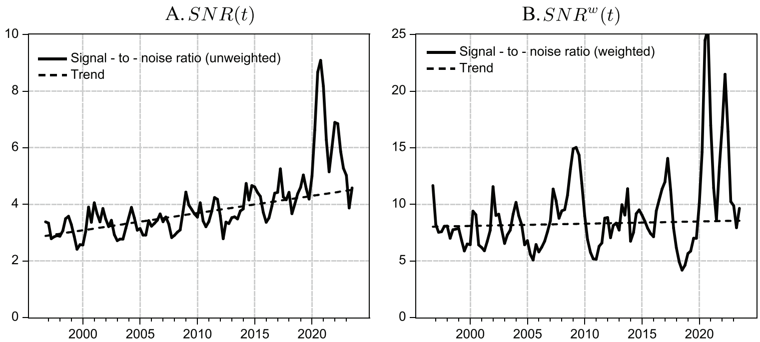


as a result of a relatively high and stable share of symmetric shocks in large members (see Figure 6A for example) is fairly stable over a longer horizon. In the short term, dispersion of weighted standard deviation is affected differently in different crises: it bottoms out during global crises (the GFC and COVID) and peaks during the European debt crisis. More recently, in the period after the European debt crisis, the gap between weighted and unweighted dispersion has been much smaller compared to the pre-crisis period; see Figure 10C. This trend reflects increased synchronization of small and new members with the rest of the euro area. Previously more idiosyncratic business cycles in these countries were important drivers of the relatively high unweighted dispersion throughout the period before the crisis.

OCA indices $SNR(t)$ and $SNR^w(t)$, shown in Figure 11, are then constructed directly as ratios of $\mu(t)$ and $\sigma(t)$ and $\mu^w(t)$ and $\sigma^w(t)$, respectively. The large values for both the weighted (from 5 to 25) and unweighted versions (from 2 to 9) of the proposed indices provide a clear signal of the average importance of symmetric shocks across countries. The optimality of the euro area as a currency union, as measured by the proposed indices, varies over time and, by the nature of their construction, depends on the types of shocks hitting member countries—local, euro-area-specific, or global. The two indices differ in that the weighted index is always above the unweighted version, mostly reflecting relations between weighted and unweighted moments ($\mu^w(t) > \mu(t)$ and second moments ($\sigma(t) > \sigma^w(t)$). Short-run dynamics, on the other hand, of both signal-to-noise ratios is largely driven by variation of second moments $\sigma(t)$ and $\sigma^w(t)$ that is much larger compared to that of cross-country averages; see Figure A.16. Regarding their long-term dynamics, unweighted measure $SNR(t)$ is trending upward, while weighted measure $SNR^w(t)$, already at a much higher level, remains stable in the long run. Overall, constructed OCA indices suggest that the OCA features of the euro area, despite the documented catching-up process of new members, are stagnating in the longer run at levels very similar to those from the pre-euro era.

Our results clearly illustrate that main crises have different mean and standard deviation profiles; see Figure A.15, for example. The European debt crisis was characterized by increased importance of symmetric euro-area shocks and increased cross-country

Figure 11. Signal-to-Noise Ratio

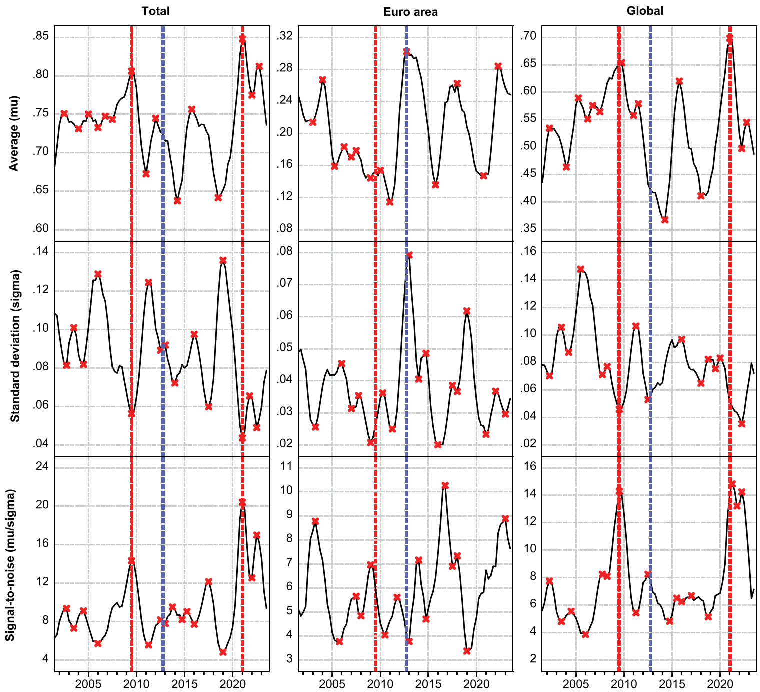


heterogeneity. COVID and the GFC, on the other hand, were global crises, where the importance of global symmetric shocks was elevated, but the dispersion across countries was very low. A useful measure of monetary policy potential should, therefore, take these observations into account. Our indicator is able to capture different types of crises, as it is the *signal* with respect to surrounding *noise*, $\mu(t)/\sigma(t)$, and not necessarily the signal $\mu(t)$ or $\sigma(t)$ alone, that is crucial for stabilizing potential of a common monetary policy. To illustrate that, Figure 12 compares $\mu(t)$, $\sigma(t)$, and ratio $SNR(t)$ for all symmetric shocks (first column), euro-area-specific shocks (middle column), and global shocks (third column). Two global crises—marked with red vertical lines—are characterized by a large share of common global shocks surrounded by low dispersion. Consequently, signal-to-noise ratio, in the third row, increases strongly and provides a clear signal for policy stance. In contrast, the euro-area debt crisis, marked with blue lines, increased overall incidence of symmetric shocks, but increased volatility. As a result, signal-to-noise ratio remained largely unchanged, despite the increase in symmetric shocks.

5. Conclusions

This paper investigates the importance of asymmetric shocks on the euro area and their implications for monetary policy within the currency union. By employing a structural, sign- and zero-restricted, open-economy BVAR model, we are able to differentiate between

Figure 12. Turning Points in Averages, Standard Deviations of Symmetric Shocks and in Signal-to-Noise Ratios



Note: Red vertical lines refer to global crises; blue vertical lines refers to the European debt crisis.

symmetric and asymmetric shocks and assess their relative importance in shaping euro-area business cycle dynamics. Our findings indicate that, while symmetric shocks are the primary drivers of these cycles, the OCA features of the euro area are stagnating in the longer run at levels very similar to those from the pre-euro era.

We introduce a new OCA index underscoring that for a common monetary policy to be effective, there must be a high but not excessively varied importance of symmetric shocks across countries. This index proves particularly valuable in distinguishing between global and localized crises, supporting stability assessments within the euro area.

Our results are also favorable for the OCA endogeneity hypothesis, showing that euro adoption increases the incidence of symmetric shocks, also fostering greater business cycle synchronization among new member states. This challenges the traditional belief that a high degree of pre-adoption coherence is essential for euro membership, suggesting that convergence can continue post-adoption.

The OCA index offers key insights for policymakers by indicating conditions under which common monetary policy is most effective and identifying challenges posed by asymmetric shocks. At the same time, our findings also highlight the necessity of ongoing structural convergence among member economies to ensure the stability of the union. Overall, our research affirms the euro area's viability as a monetary union, whereby the benefits of membership, particularly through post-adoption synchronization, outweigh the costs. Nevertheless, continuous monitoring and policy adjustments remain essential to address asymmetric shocks and sustain long-term stability.

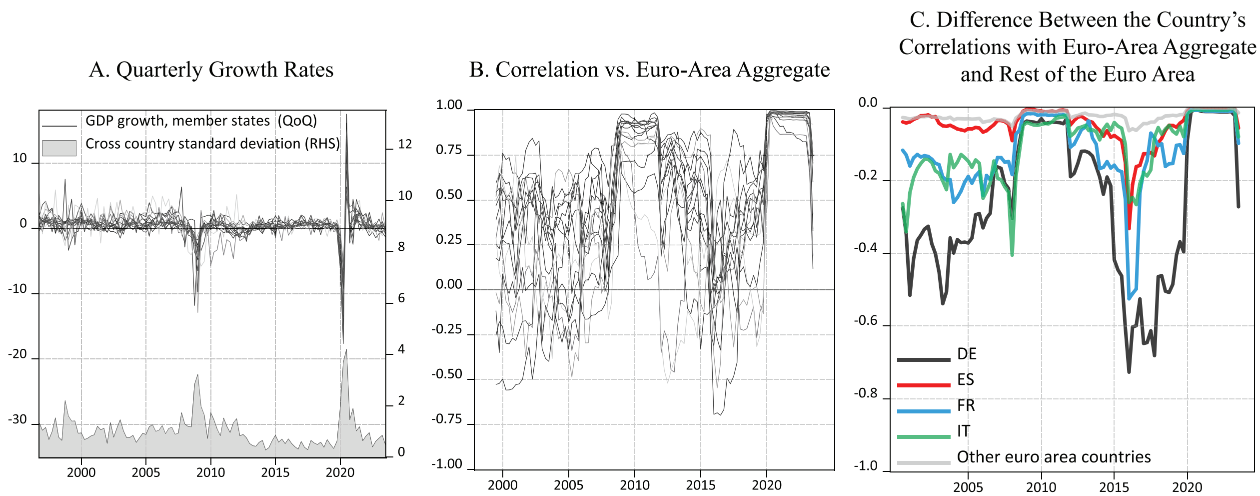
Appendix

A.1 Data

Table A.1. Variable Descriptions

Variable	Definition	Source
Real GDP (Country)	Chained-link volume, million of euros	Eurostat
Real GDP (Rest of the Euro Area)	Euro-area aggregate excl. one member country	Eurostat
Real GDP (World)	Sum of real GDP of Norway, Switzerland, Turkey, Russia, USA, Canada, Mexico, Brazil, Australia, New Zealand, Japan, China, Hong Kong, Korea, and EU but non-euro-area countries	Eurostat, OECD
HICP (Country) HICP (Rest of the Euro Area)	Harmonized index of consumer prices, index-weighted sum of HIPC indices excl. one member country	Eurostat
CPI (World)	Trade-weighted inflation, using data for United States, United Kingdom, China, Switzerland, Poland, Czech Republic, Sweden, Hungary, Japan, Denmark, India	IMF (CPI), Eurostat (Trade Weights)

Figure A.1. GDP Growth: Cross-Country Correlation



A.2 Impulse Response Functions

Figure A.2. Impulse Response Functions for France (median and 68 percent posterior bands)

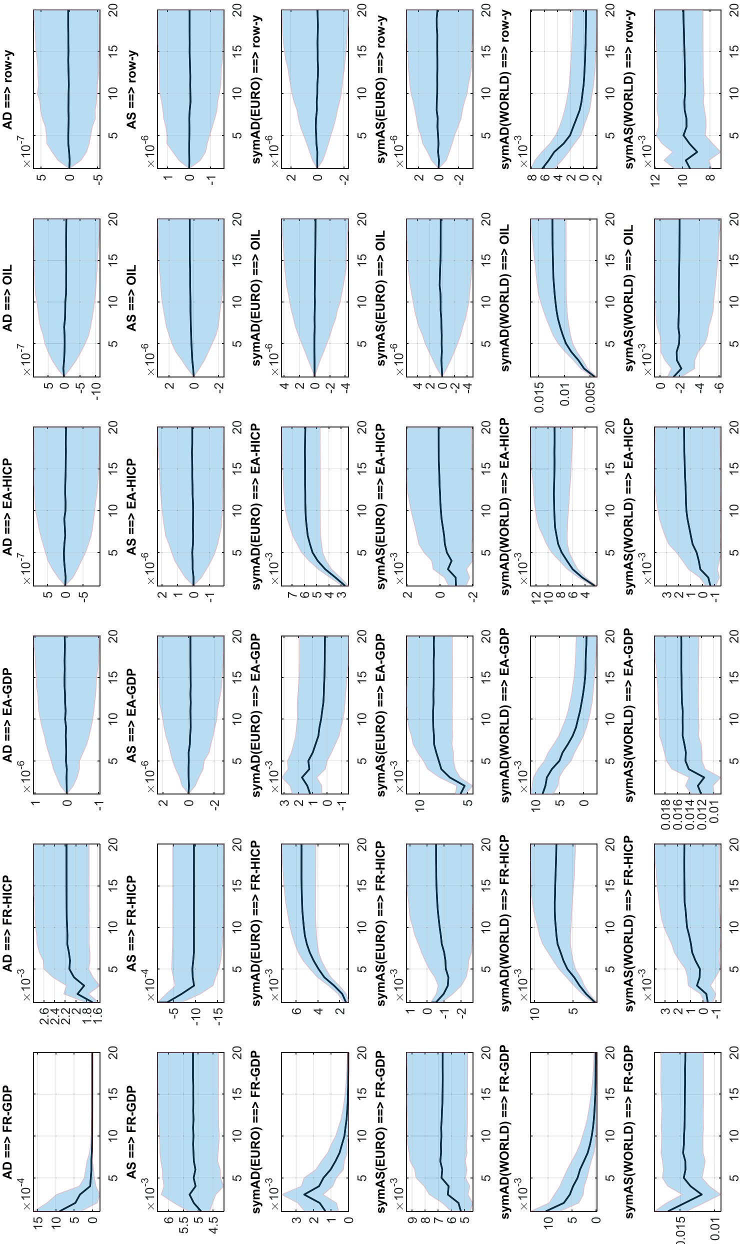


Figure A.3. Impulse Response Functions for Italy (median and 68 percent posterior bands)

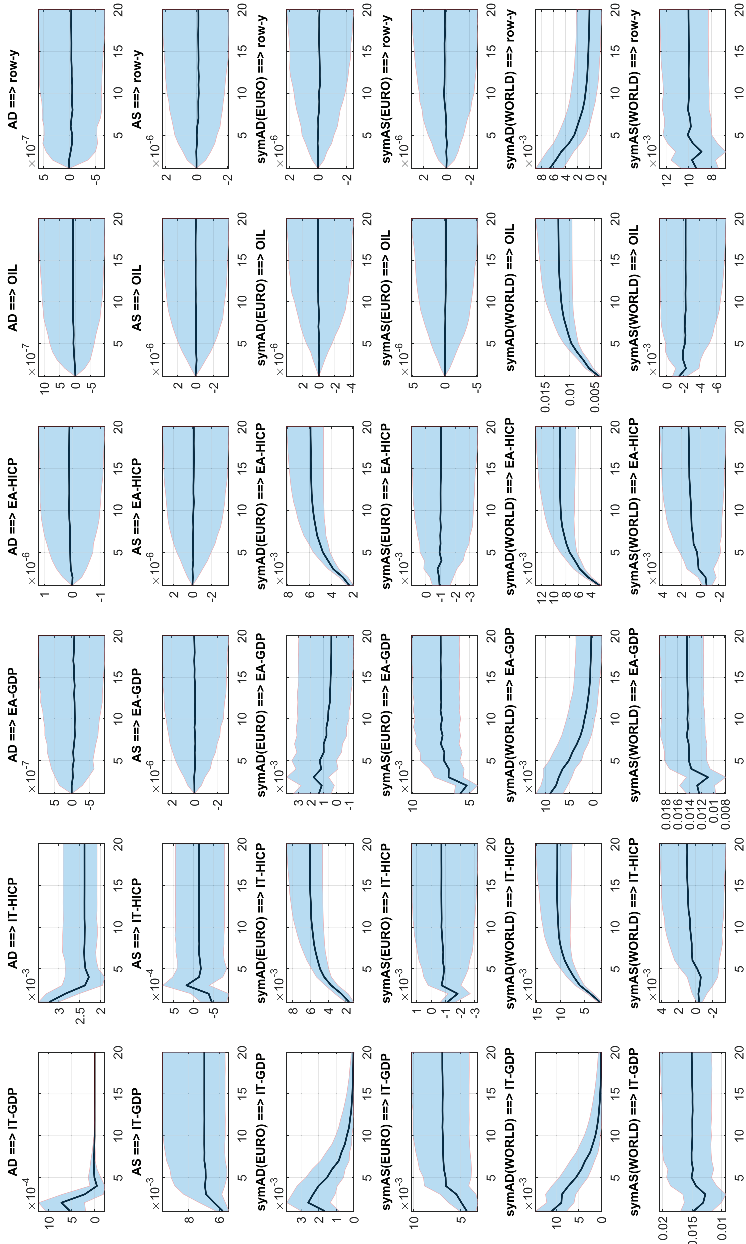


Figure A.4. Impulse Response Functions for Spain (median and 68 percent posterior bands)

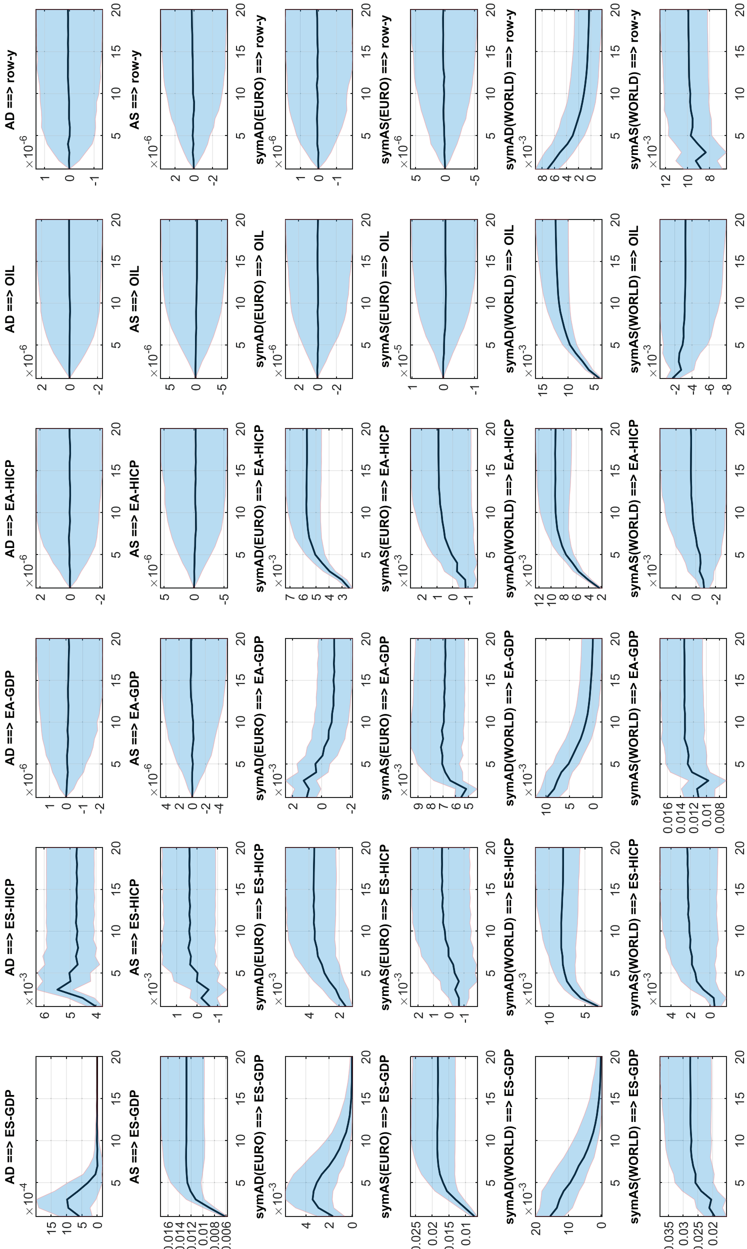
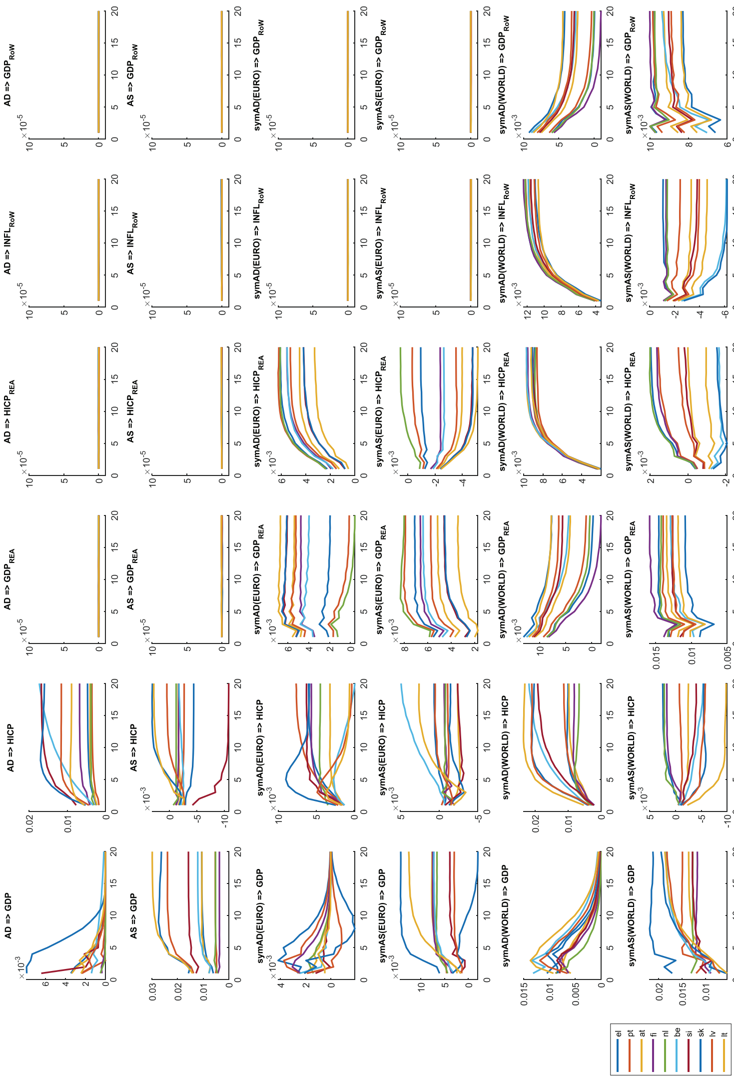


Figure A.5. Impulse Response Functions for Small Countries (medians)



A.3 Historical Shock Decomposition

Figure A.6. Germany (median and 68 percent posterior bands)

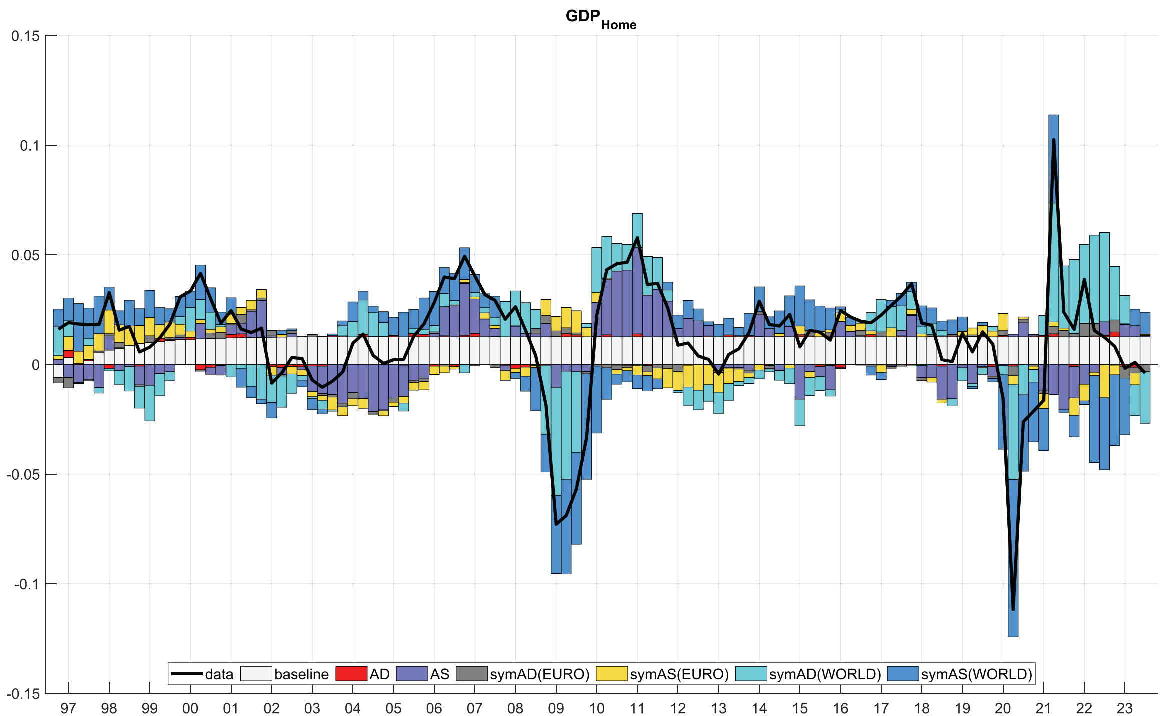


Figure A.7. France (median and 68 percent posterior bands)

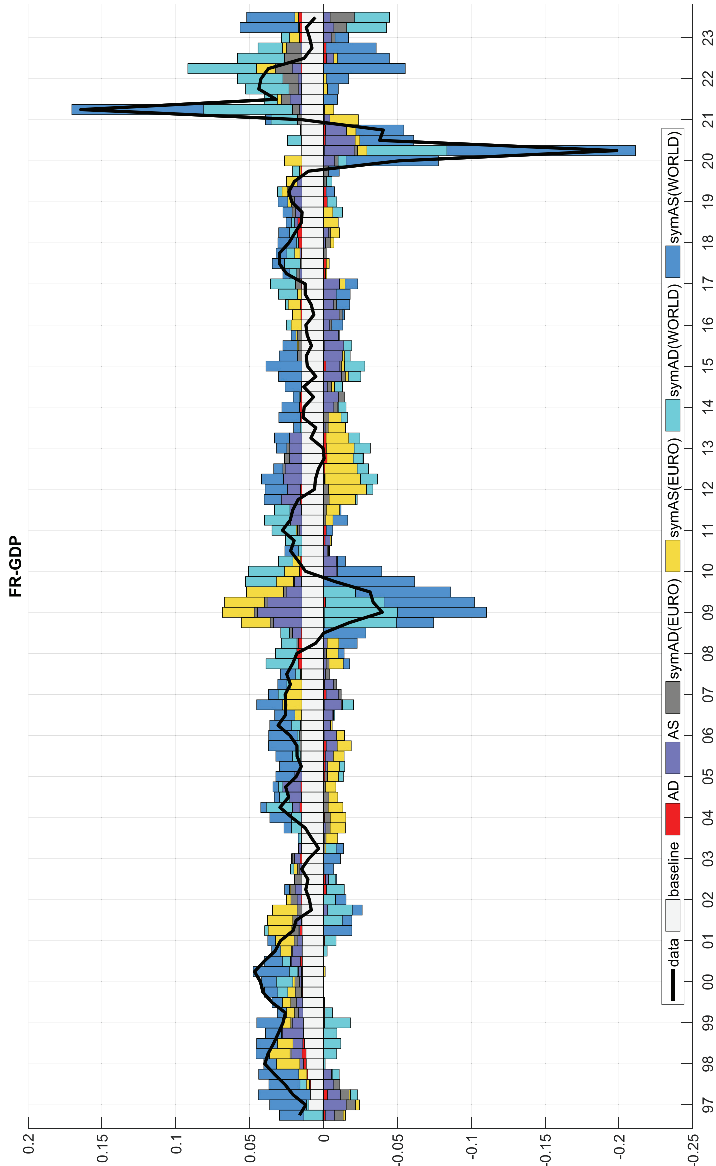


Figure A.8. Italy (median and 68 percent posterior bands)

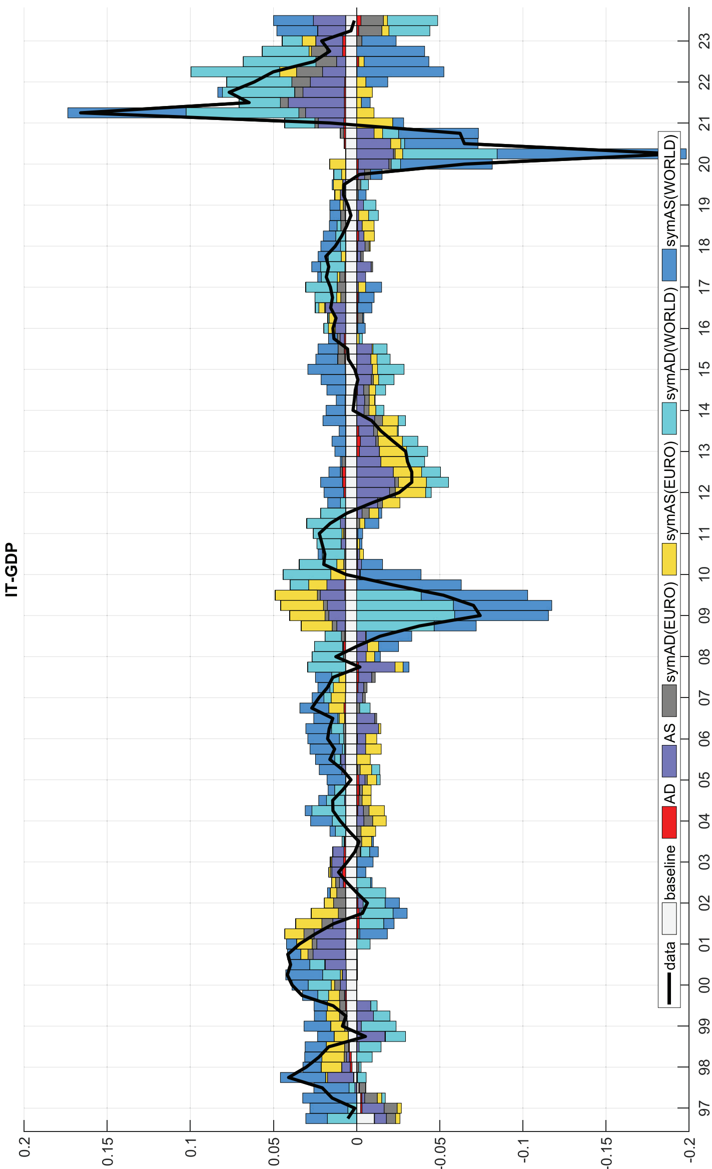
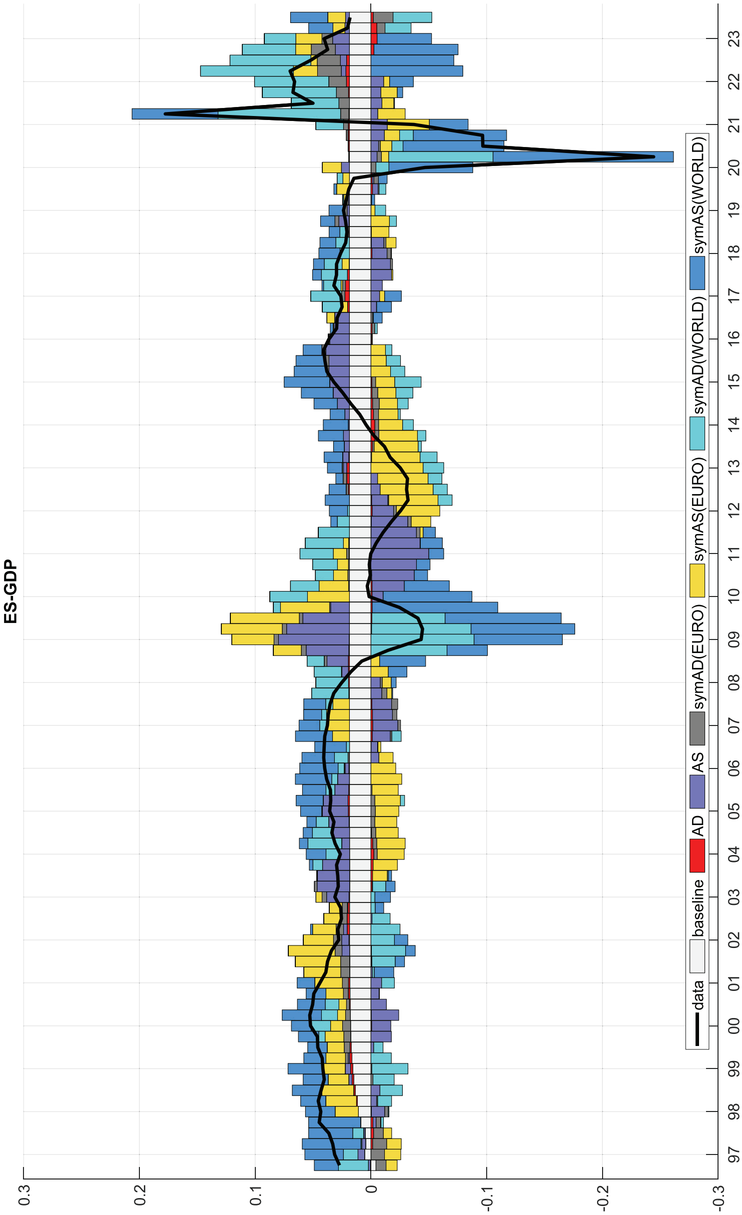


Figure A.9. Spain (median and 68 percent posterior bands)



A.4 Convergence of Markov Chain Monte Carlo Algorithm

Estimated VARs all converge fast, with posterior statistics all converging already after only 100 or 200 admissible models are found. Our results are all based on overall 1,000 admissible draws. We follow Primiceri (2005) to address convergence of the Gibbs sampling algorithm formally and to assess how efficient the algorithm used explores the posterior. Figures A.10 and A.11 plot the 10th-order sample autocorrelation of the saved draws from the posterior of the reduced-form parameters (regression parameters β and covariance matrix Ω). Figure A.10 shows autocorrelation of the elements of β, and in Figure A.11 are elements of the lower triangular part of the error covariance matrix Ω. Both figures point to weakly autocorrelated MCMC draws—estimated autocorrelation is only rarely outside interval $[-0.05, 0.05]$. Figures A.12 and A.13 plot the inefficiency factors for the posterior estimates of the reduced-form parameters when using a 4 percent tapered window for the estimation of the spectral density at frequency zero. The inefficiency factor[18] is inverse of Geweke (1992) relative numerical efficiency and it serves to quantify the relative efficiency loss in the computation from correlated versus independent samples (Chib 2001). Primiceri (2005) suggests that values of the inefficiency factors below or around 20 would be considered satisfactory. In our application these values are less than two, showing a strong convergence of Gibbs sampler.

[18]MCMC draws are realizations of a Markov chain and are, by definition, correlated. When the inefficiency factor is equal to m, we need an MCMC sample that is m times larger compared to an uncorrelated sample to have the same information contained in both.

Figure A.10. Sample Autocorrelation (10th Order) of the Posterior Estimates of the Reduced-Form Parameter Beta

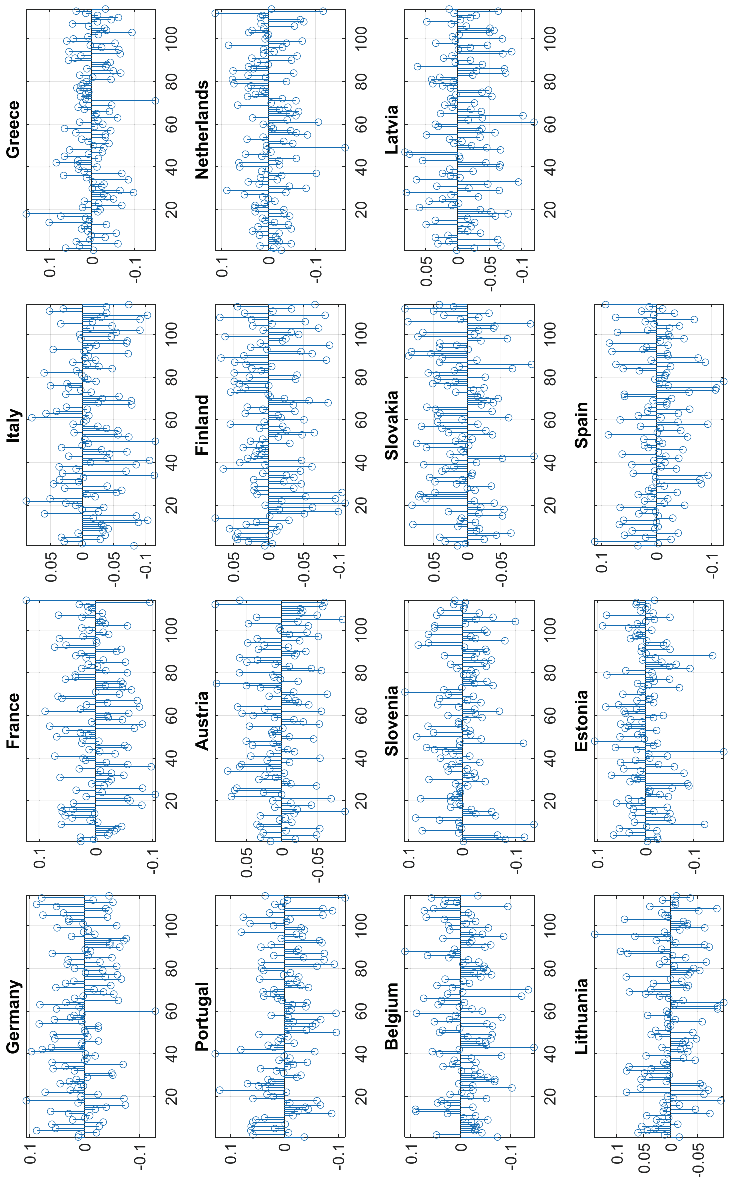


Figure A.11. Sample Autocorrelation (10th Order) of the Posterior Estimates of the Reduced-Form Parameter Omega

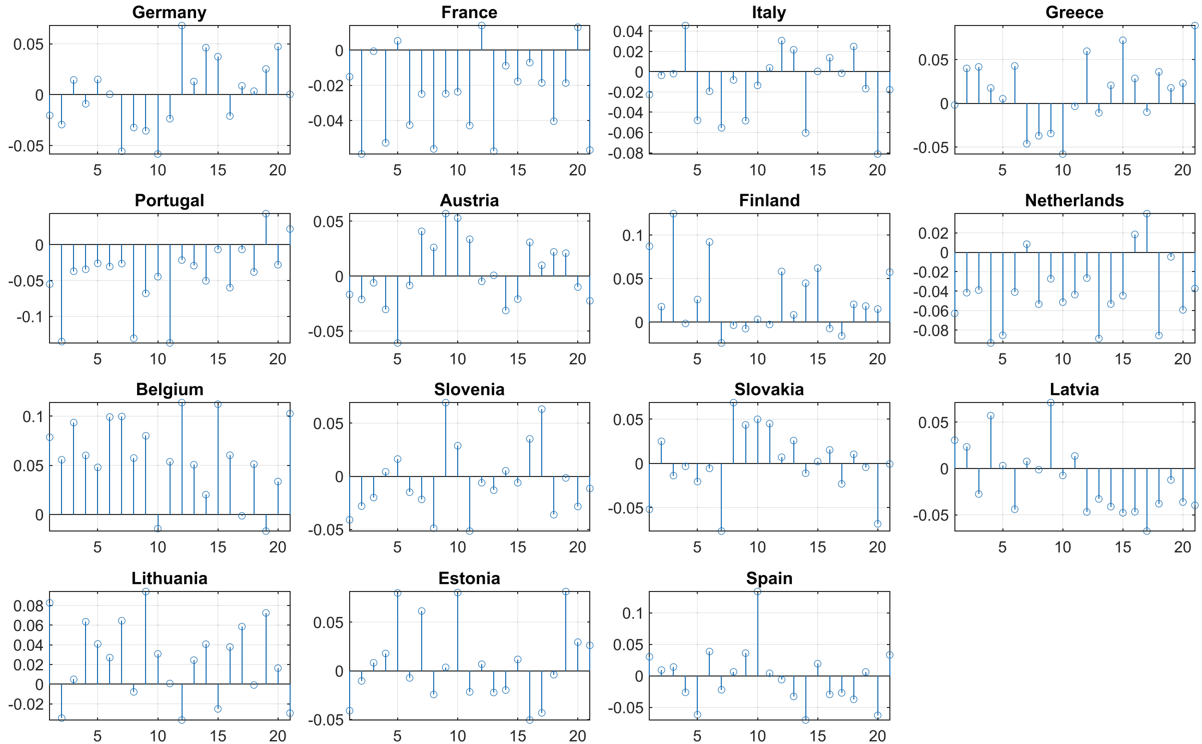


Figure A.12. Inefficiency Factors for the Posterior Estimates of the Reduced-Form Parameter Beta

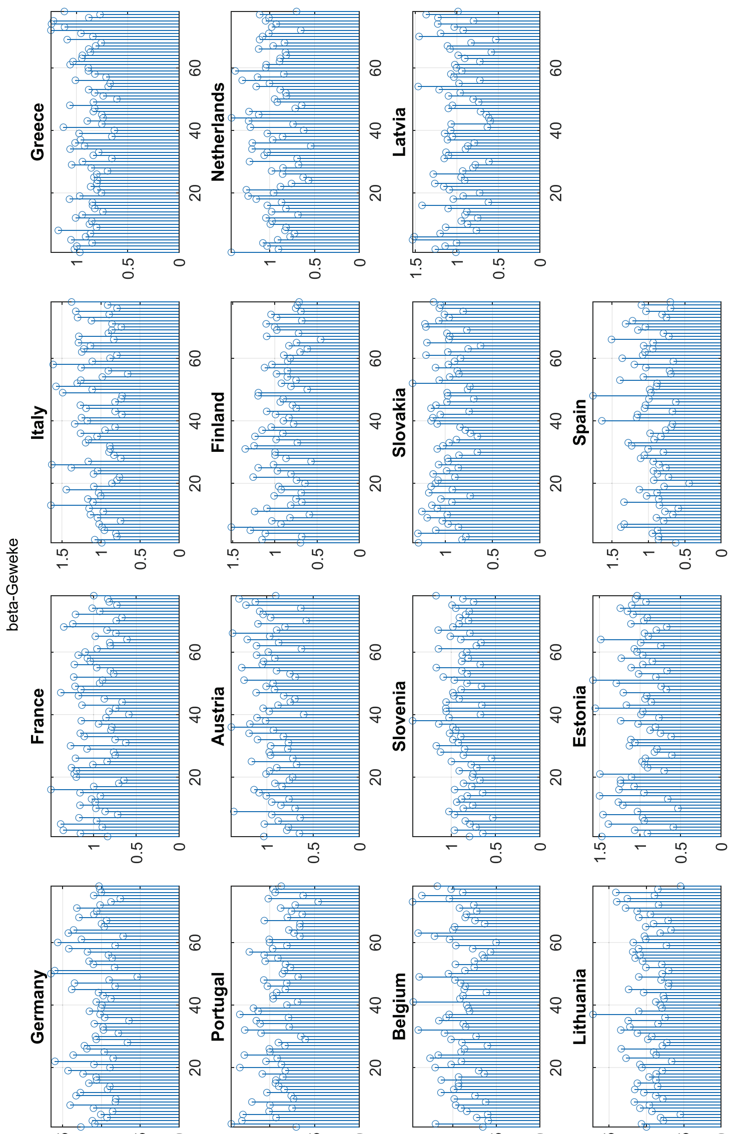


Figure A.13. Inefficiency Factors for the Posterior Estimates of the Reduced-Form Parameter Omega

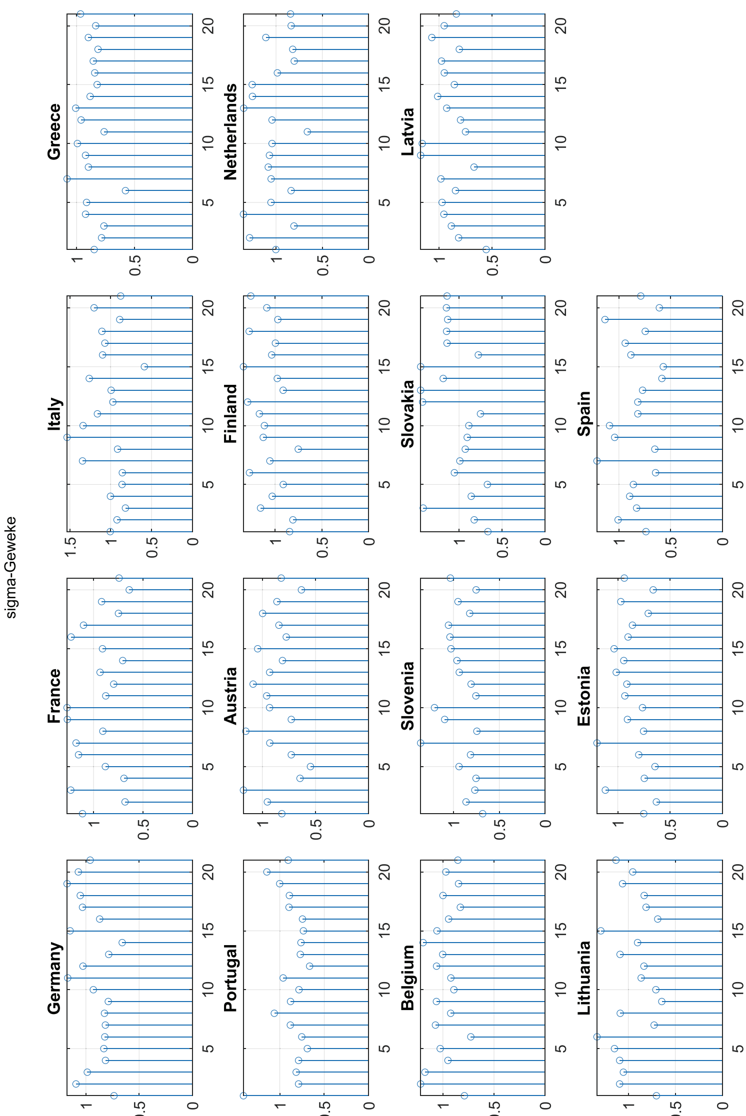


Figure A.14. Output Gap Estimate Based on a BVAR Model: Accumulated Contribution of All Demand Shocks to GDP

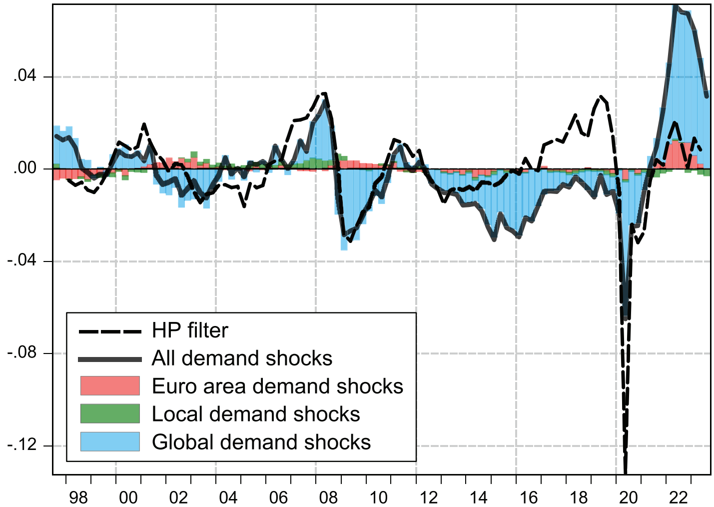


Figure A.15. Relative Importance of Local vs. Euro-Area and Global Symmetric Shocks

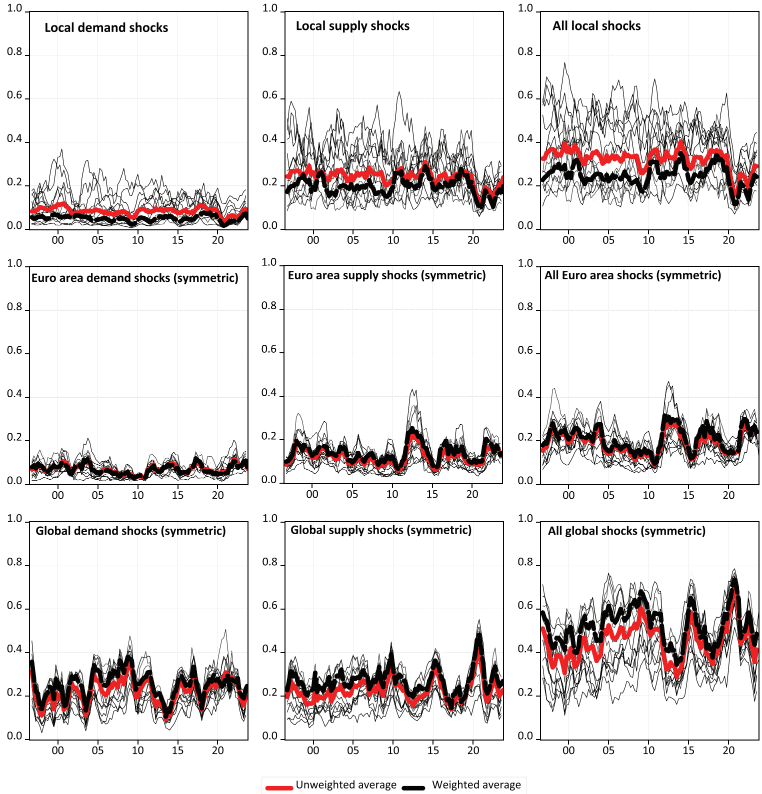


Figure A.16. Decomposition of OCA Index Growth Rates

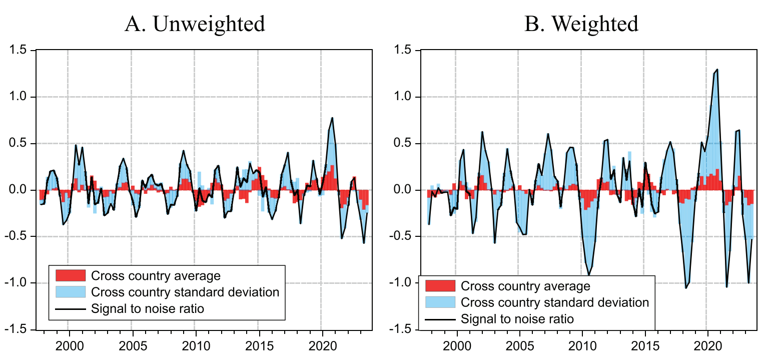


Table A.2. Difference-in-Difference Estimation

	All Shocks (AD and AS)		Aggregate Demand (AD)		Aggregate Supply (AS)	
	Coefficient	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Method	*All Symmetric Shocks*					
Two-Way D-I-D	0.5%	0.86	0.2%	0.91	0.3%	0.84
Callaway and Sant'Anna	4.4%	0.03	2.5%	0.02	1.9%	0.08
	Euro-Area-Specific Symmetric Shocks					
Two-Way D-I-D	–0.8%	0.53	–0.2%	0.84	–0.6%	0.35
Callaway and Sant'Anna	0.7%	0.42	0.5%	0.32	0.2%	0.73
	Global Symmetric Shocks					
Two-Way D-I-D	1.3%	0.46	0.3%	0.68	0.9%	0.38
Callaway and Sant'Anna	3.7%	0.01	2.0%	0.0	1.7%	0.02

Note: AD denotes Aggregate Demand and AS denotes Aggregate Supply. All equations are estimated on 1996:Q3–2022:Q4 for nine countries: Slovenia, Slovakia, Estonia, Latvia, Lithuania, Croatia, Hungary, Poland, and Bulgaria.

References

Alesina, A., R. J. Barro, and S. Tenreyro. 2002. "Optimal Currency Areas." NBER Working Paper No. 9072.

Antolin-Diaz, J., and J. Rubio-Ramírez. 2018. "Narrative Sign Restrictions for SVARs." *American Economic Review* 108 (10): 2802–29.

Arias, J. E., J. F. Rubio-Ramírez, and D. F. Waggoner. 2014. "Inference Based on SVARs Identified with Sign and Zero Restrictions: Theory and Applications." International Finance Discussion Paper No. 1100, Board of Governors of the Federal Reserve System.

———. 2018. "Inference Based on Structural Vector Autoregressions Identified with Sign and Zero Restrictions: Theory and Applications." *Econometrica* 86 (2): 685–720.

Artis, M. J. 2003. "Is There a European Business Cycle?" CESifo Working Paper No. 1053.

Audzei, V., and F. Brazdik. 2018. "Exchange Rate Dynamics and Their Effect on Macroeconomic Volatility in Selected CEE Countries." *Economic Systems* 42 (4): 584–96.

Bayoumi, T., and B. Eichengreen. 1992. "Is There a Conflict Between EC Enlargement and European Monetary Unification?" NBER Working Paper No. 3950.

———. 1993. "One Money or Many? On Analyzing the Prospects for Monetary Unification in Various Parts of the World." Working Paper No. 233213, Center for International and Development Economics Research (CIDER), University of California-Berkeley.

———. 1997. "Ever Closer to Heaven: An Optimum-Currency-Area Index for European Countries." *European Economic Review* 41 (3–5): 761–70.

———. 1998. "Exchange Rate Volatility and Intervention: Implications of the Theory of Optimum Currency Areas." *Journal of International Economics* 45 (2): 191–209.

Beaudry, P., T. J. Carter, and A. Lahiri. 2022. "Looking Through Supply Shocks versus Controlling Inflation Expectations: Understanding the Central Bank Dilemma." Staff Working Paper No. 22-41, Bank of Canada.

Belke, A., C. Domnick, and D. Gros. 2017. "Business Cycle Synchronization in the EMU: Core vs. Periphery." *Open Economies Review* 28 (5): 863–92.

Bhatia, R., and C. Davis. 2000. "A Better Bound on the Variance." *American Mathematical Monthly* 107 (4): 353–57.

Blanchard, O. 2018. "Olivier Blanchard Provides a Brief Reaction to 'Real-Time Estimates of Potential GDP,' by Coibion, Gorodnichenko, and Ulate." Center on Budget and Policy Priorities. https://www.cbpp.org/research/full-employment/olivier-blanchard-provides-a-brief-reaction-to-real-time-estimates-of.

Blanchard, O. J., and D. Quah. 1989. "The Dynamic Effects of Aggregate Demand and Aggregate Supply." *American Economic Review* 79 (4): 655–73.

Bobeica, E., and M. Jarociński. 2019. "Missing Disinflation and Missing Inflation: A VAR Perspective." *International Journal of Central Banking* 15 (1): 199–232.

Callaway, B., and P. H. Sant'Anna. 2021. "Difference-in-Differences with Multiple Time Periods." *Journal of Econometrics* 225 (2): 200–230.

Camacho, M., G. Perez-Quiros, and L. Saiz. 2006. "Are European Business Cycles Close Enough to be Just One?" *Journal of Economic Dynamics and Control* 30 (9–10): 1687–1706.

Camba-Mendez, G., and D. Rodriguez-Palenzuela. 2003. "Assessment Criteria for Output Gap Estimates." *Economic Modelling* 20 (3): 529–62.

Campos, N. F., J. Fidrmuc, and I. Korhonen. 2019. "Business Cycle Synchronisation and Currency Unions: A Review of the Econometric Evidence Using Meta-analysis." *International Review of Financial Analysis* 61 (January): 274–83.

Campos, N. F., and C. Macchiarelli. 2016. "Core and Periphery in the European Monetary Union: Bayoumi and Eichengreen 25 Years Later." *Economics Letters* 147 (October): 127–30.

Canova, F., and G. De Nicolo. 2002. "Monetary Disturbances Matter for Business Fluctuations in the G-7." *Journal of Monetary Economics* 49 (6): 1131–59.

Caporale, G. M., R. De Santis, and A. Girardi. 2015. "Trade Intensity and Output Synchronisation: On the Endogeneity Properties of EMU." *Journal of Financial Stability* 16 (February): 154–63.

Carriero, A., T. E. Clark, and M. Marcellino. 2019. "Large Bayesian Vector Autoregressions with Stochastic Volatility and Non-conjugate Priors." *Journal of Econometrics* 212 (1): 137–54.

Chan, J. C. C. 2019. "Asymmetric Conjugate Priors for Large Bayesian VARs." Working Paper No. 51/2019, Centre for Applied Macroeconomic Analysis (CAMA), Crawford School of Public Policy, The Australian National University.

Chen, M. J., and L. Gornicka. 2020. "Measuring Output Gap: Is It Worth Your Time?" IMF Working Paper No. 20/24.

Chib, S. 2001. "Markov Chain Monte Carlo Methods: Computation and Inference." In *Handbook of Econometrics*, Vol. 5, ed. J. J. Heckman and E. Leamer, 3569–3649. North-Holland.

Coibion, O., Y. Gorodnichenko, and M. Ulate. 2017. "The Cyclical Sensitivity in Estimates of Potential Output." Technical Report, National Bureau of Economic Research.

Comunale, M., and D. Kunovac. 2017. "Exchange Rate Pass-Through in the Euro Area." ECB Working Paper No. 2003.

Corden, W. M. 1972. *Monetary Integration*. Essays in International Finance No. 93. Princeton, NJ: Princeton University Press.

De Grauwe, P. 1996. "Monetary Union and Convergence Economics." *European Economic Review* 40 (3–5): 1091–1101.

———. 2003. "The Euro at Stake? The Monetary Union in an Enlarged Europe." *CESifo Economic Studies* 49 (1): 103–21.

Deskar-Škrbić, M., K. Kotarac, and D. Kunovac. 2020. "The Third Round of Euro Area Enlargement: Are the Candidates Ready?" *Journal of International Money and Finance* 107 (October): Article 102205.

———. 2020. "Twentieth Anniversary of the Euro: Why Are Some Countries Still Not Willing to Join? Economists View." *Comparative Economic Studies* 62 (2): 242–62.

European Commission. 1990. "One Market, One Money. An Evaluation of the Potential Benefits and Costs of Forming an Economic and Monetary Union." *European Economy* 44 (October).

Ferroni, F., and B. Klaus. 2015. "Euro Area Business Cycles in Turbulent Times: Convergence or Decoupling?" *Applied Economics* 47 (34–35): 3791–3815.

Fidrmuc, J., and I. Korhonen. 2003. "Similarity of Supply and Demand Shocks between the Euro Area and the CEECs." *Economic Systems* 27 (3): 313–34.

Forbes, K., I. Hjortsoe, and T. Nenova. 2018. "The Shocks Matter: Improving Our Estimates of Exchange Rate Pass-Through." *Journal of International Economics* 114 (September): 255–75.

Frankel, J. A., and A. K. Rose. 1997. "Is EMU More Justifiable Ex Post Than Ex Ante?" *European Economic Review* 41 (3–5): 753–60.

———. 1998. "The Endogenity of the Optimum Currency Area Criteria." *Economic Journal* 108 (449): 1009–25.

Frydrych, J., and S. Burian. 2017. "OCA Indexes and Convergence Process in Europe." *Scientific Annals of Economics and Business* 64 (2): 187–97.

Furlanetto, F., A. Lepetit, Ø. Robstad, J. Rubio-Ramírez, and P. Ulvedal. 2021. "Estimating Hysteresis Effects." Finance and Economics Discussion Series No. 2021–059.

Geweke, J. 1992. "Evaluating the Accuracy of Sampling-Based Approaches to the Calculations of Posterior Moments." In *Bayesian Statistics*, Vol. 4, ed. J. M. Bernardo, J. O. Berger, A. P. Dawid, and A. F. M. Smith, 641–49. Clarendon Press.

Giannone, D., M. Lenza, and L. Reichlin. 2008. "Business Cycles in the Euro Area." NBER Working Paper No. 14529.

González-Torres, G., J. E. Gumiel, and B. Szörfi. 2023. "Potential Output in Times of Temporary Supply Shocks." *Economic Bulletin* (European Central Bank) 8/2023: Box 3.

Horváth, R., and L. Komárek. 2003. "Optimum Currency Area Indices: Evidence from the 1990s." Technical Report, Department of Economics, University of Warwick.

Inklaar, R., and J. de Haan. 2001. "Is There Really a European Business Cycle? A Comment." *Oxford Economic Papers* 53 (2): 215–20.

International Monetary Fund. 2011. "Staff Report for the 2011 Article IV Consultation for Germany." Technical Report.

Ishiyama, Y. 1975. "Theory of Optimum Currency Areas: A Survey." *IMF Staff Papers* 22 (2): 344–83.

Kadiyala, K. R., and S. Karlsson. 1997. "Numerical Methods for Estimation and Inference in Bayesian VAR-Models." *Journal of Applied Econometrics* 12 (2): 99–132.

Kenen, P. B. 1969. "The Optimum Currency Area: An Eclectic View." In *Monetary Problems of the International Economy,* ed. R. A. Mundell and A. K. Swoboda. University of Chicago Press.

Koop, G., and D. Korobilis. 2010. “Bayesian Multivariate Time Series Methods for Empirical Macroeconomics.” *Foundations and Trends in Econometrics* 3 (4): 267–358.

Kose, M. A., C. Otrok, and C. H. Whiteman. 2003. “International Business Cycles: World, Region, and Country-Specific Factors.” *American Economic Review* 93 (4): 1216–39.

Krugman, P. 1993. “Lessons from Massachusetts for EMU.” In *Adjustment and Growth in the European Monetary Union,* ed. F. Torres and F. Giavazzi, 241–61. Cambridge University Press.

Lindeman, R. H., P. F. Merenda, and R. Z. Gold. 1980. *Introduction to Bivariate and Multivariate Analysis.* Glenview, IL: Scott, Foresman and Company.

Madeira, C., J. Madeira, and P. S. Monteiro. 2023. “The Origins of Monetary Policy Disagreement: The Role of Supply and Demand Shocks.” BIS Working Paper No. 1118.

Masson, P. R., and M. P. Taylor. 1993. *Policy Issues in the Operation of Currency Unions.* Cambridge University Press.

McKinnon, R. 1963. “Optimum Currency Areas.” *American Economic Review* 53: 717–24.

Mink, M., J. P. Jacobs, and J. de Haan. 2012. “Measuring Coherence of Output Gaps with an Application to the Euro Area.” *Oxford Economic Papers* 64 (2): 217–36.

Miranda-Agrippino, S., and G. Ricco. 2018. “Bayesian Vector Autoregressions.” Working Paper No. 756, Bank of England.

Mongelli, F. P. 2002. “New Views on the Optimum Currency Area Theory: What is EMU Telling Us?” ECB Working Paper No. 138.

Muggenthaler, P., J. Schroth, and Y. Sun. 2021. “The Heterogeneous Economic Impact of the Pandemic across Euro Area Countries.” *Economic Bulletin* (European Central Bank) 5/2021: Box 3.

Mundell, R. A. 1961. “A Theory of Optimum Currency Areas.” *American Economic Review* 51 (4): 657–65.

———. 1975. “Uncommon Arguments for Common Currencies.” In *The Economics of Common Currencies,* ed. H. G. Johnson and A. K. Swoboda. London: Allen Unwin Ltd.

Orphanides, A. 2020. “The ECB’s Instruments for Crises and Normal Times: Considerations for the Policy Strategy Review.” Working Paper No. 6233-20, MIT Sloan School of Management.

Peersman, G. 2011. "The Relative Importance of Symmetric and Asymmetric Shocks: The Case of United Kingdom and Euro Area." *Oxford Bulletin of Economics and Statistics* 73 (1): 104–18.

Primiceri, G. E. 2005. "Time Varying Structural Vector Autoregressions and Monetary Policy." *Review of Economic Studies* 72 (3): 821–52.

Rubio-Ramírez, J. F., D. F. Waggoner, and T. Zha. 2010. "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference." *Review of Economic Studies* 77 (2): 665–96.

Sims, C. A., and T. Zha. 1998. "Bayesian Methods for Dynamic Multivariate Models." *International Economic Review* 39 (4): 949–68.

Skorepa, M. 2013. "Troubles in the Euro Area Periphery: The View through the Lens of a Simple Convergence-Sensitive Optimum Currency Area Index." *Finance a Uver* (*Czech Journal of Economics and Finance*) 63 (2): 129–51.

Tenreyro, S., N. Bandera, L. Barnes, M. Chavaz, and L. von dem Berge. 2023. "Monetary Policy in the Face of Supply Shocks: The Role of Inflation Expectations." Paper presented at the ECB Forum on Central Banking, Sintra, Portugal, June 26–28.

Vieira, C., and I. Vieira. 2012. "Assessing the Endogeneity of OCA Conditions in EMU." *The Manchester School* 80 (1): 77–91.

Willett, T. D., O. Permpoon, and C. Wihlborg. 2010. "Endogenous OCA Analysis and the Early Euro Experience." *World Economy* 33 (7): 851–72.