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## Monetary Policy, Divergence, and the Euro

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# Monetary Policy, Divergence, and the Euro

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# Monetary Policy, Divergence, and the Euro

## Abstract

This paper investigates the relationship between economic divergence and expansionary monetary policies within the eurozone based on a new divergence indicator. We study the dynamics between the economic divergence of member states and unconventional monetary policy in a Bayesian SVAR and find a strong positive response of the expansion of the ECB's balance sheet to rising divergence. We find weaker evidence for unconventional monetary policies lowering divergence. We interpret these findings as evidence that expansionary monetary policy aims to absorb shocks leading to divergence. However, it may exacerbate divergence and inflationary pressures in the long-run. This research contributes to the literature on Optimum Currency Areas (OCAs) by highlighting the dynamics between economic disparities and unconventional monetary policy.

JEL-Codes: E520, E580, F150, F450.

Keywords: optimum currency areas, unconventional monetary policy shocks, statistical identification.

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# 1 Introduction

In early 2024, the European Central Bank (ECB) announced that it would implement “changes” to its monetary policy, signaling a strategic adjustment in response to evolving economic conditions (ECB 2024a). Part of this restructuring entailed a scaling down of the ECB’s Pandemic Emergency Purchase Programme (PEPP) and Asset Purchase Programme (APP). While the phasing out of unconventional monetary policy (UMP) may have signaled a shrinking ECB balance sheet, speculation about new financial instruments new green policy goals could potentially offset these tightening measures in the future.

In March 2024, the ECB decided against raising the key rates further, maintaining the rate on the main refinancing operations at 4.5% (ECB 2024b). This decision came in light of revised inflation forecasts, which had been adjusted downward, and a more optimistic outlook on reaching the inflation target. The market promptly anticipated interest rate cuts, a perspective that was supported by statements from ECB President Christine Lagarde, who communicated possible rate cuts in June and and September and stuck with it. In short, if post-pandemic inflation was deemed “transitory”, so too, was 2023’s episode of monetary tightening.

With quantitative tightening remaining hesitant, the question whether inflationary pressures can be considered transitory arises. This paper contends that persisting (possibly hidden) inflationary pressures within the eurozone may be explained by the region’s macroeconomic disparities. The story this paper tells is that structural differences in the eurozone economies have perpetuated a cycle of divergence, compelling the ECB to employ expansionary monetary policies as a means to stabilize the currency union. This dynamic can be traced back to Robert Mundell’s foundational theory of Optimum Currency Areas (Mundell 1961), which emphasizes the role of economic convergence and flexibility within a currency union. The eurozone has struggled with economic disparities—variations in inflation rates, debt

levels, and growth rates have become more pronounced over time. These disparities have led to uneven impacts of monetary policy across member states, necessitating a predominantly expansionary stance by the ECB to mitigate the risks of fragmentation and to support economically and financially unstable countries within the eurozone. This creates a feedback loop where divergence begets expansionary policy, which, without addressing the root causes of economic disparities, only provides temporary relief and potentially exacerbates long-term divergence and instability.

To empirically analyze this dynamic, we first create a composite divergence indicator for the eurozone. The indicator focuses on macroeconomic fundamentals such as inflation rates, wage growth, real growth, and public debt levels, but also on the price-level based real exchange rates and trade balances between Germany and the rest of the eurozone. The choice of the macroeconomic variables reflects those used in the pioneering work of Bayoumi and Eichengreen (1997, Campos and Macchiarelli 2016 for an update) who were among the first to develop an OCA index as well as on subsequent studies on convergence (Frankel and Rose 1998, De Grauwe and Schnabl 2008). We next study the dynamics between our indicator and monetary policy. To do this, we apply a novel Bayesian structural vector autoregressive model (BSVAR) proposed by Anttonen et al. (2024). Their method builds on a recent strain of literature exploiting statistical properties of data to formally identify the plausibility of sign restrictions for modeling economic shocks (Rigobon 2003, Lanne et al. 2017, Puonti 2019).

Besides contributing to the literature on OCAs (see Tavlas 2009, Dellas and Tavlas 2009 for an overview), our paper synthesizes insights from distinct but complementary strands of economic research. First, we draw upon studies showing that the eurozone’s crisis management results in lowest common denominator solutions (Jones et al. 2016), or “failing forward” (Howarth and Quaglia 2021). That an imperfect currency union puts limits on political flexibility and economic effectiveness has been pointed out by Meade (1957), Sci-

ovsky (1958), and Mundell (1961). All issued explicit cautions regarding the adoption of a single currency and the progression of economic integration in Europe. Wilhelm Röpke (1966) compared European economic integration to a convoy of ships, where the pace is set by the slowest vessel. Less metaphorically, Aksoy et al. (2002) have analyzed how asymmetric shocks and divergent propagation of shocks in output and inflation can cause tensions within the ECB concerning the conduct of common monetary policy, affecting the welfare implications of its decisions.

Second, we draw on the literature that tries to assess the dynamic relation between asymmetric shocks and unconventional monetary policy. Of the relatively limited literature that has studied the effects of asymmetric shocks on monetary policies, most authors highlight that the optimal monetary response to asymmetric shocks in a currency union is to remain passive and let the shock be absorbed through fiscal policies instead (Lane 2000, Hefeker and Neugart 2015, Mavrodimitrakis 2023), a point that was already made by Kenen (1969). In the absence of a fiscal union, the central bank may pursue unconventional monetary policy in order to stabilize fiscal imbalances and thereby smooth asymmetries. Cœuré describes unconventional monetary policy as a safeguard of ex-post efficiency (2013).

A larger share of literature has examined the effect of unconventional monetary policy on divergence (see Dominguez-Torres and Hierro 2019 for a survey). Authors studying asymmetries in the transmission of unconventional monetary policies in the euro area across countries find significant heterogeneous effects (Georgiadis 2015, Burriel and Galesi 2018, Almgren et al. 2022). This is against the expectation that unconventional policy measures dampen asymmetries, at least in the short run. A better understanding of the apparent contradiction between those who argue that unconventional monetary policies dampen asymmetries and those who contend that these measures exacerbate them is the primary objective guiding this study.

From a methodological point of view, our approach aligns more closely with literature

that examines the broader dynamics of unconventional monetary policy. This literature mostly uses structural vector autoregressions (Uhlig 2005, El-Shagi et al. 2015, Antolín-Díaz and Rubio-Ramírez 2018). The primary shortcoming of habitual SVARs is their inability to formally assess the plausibility of the imposed economic sign restrictions. Traditional SVAR methods rely heavily on economic assumptions, which may be justifiable for the study of more easily accepted relations, e.g. a demand shock and unconventional monetary policy. In our case, the ambiguous findings in the literature—with unconventional monetary policy possibly both dampening and exacerbating asymmetry—make it difficult to specify meaningful sign restrictions.

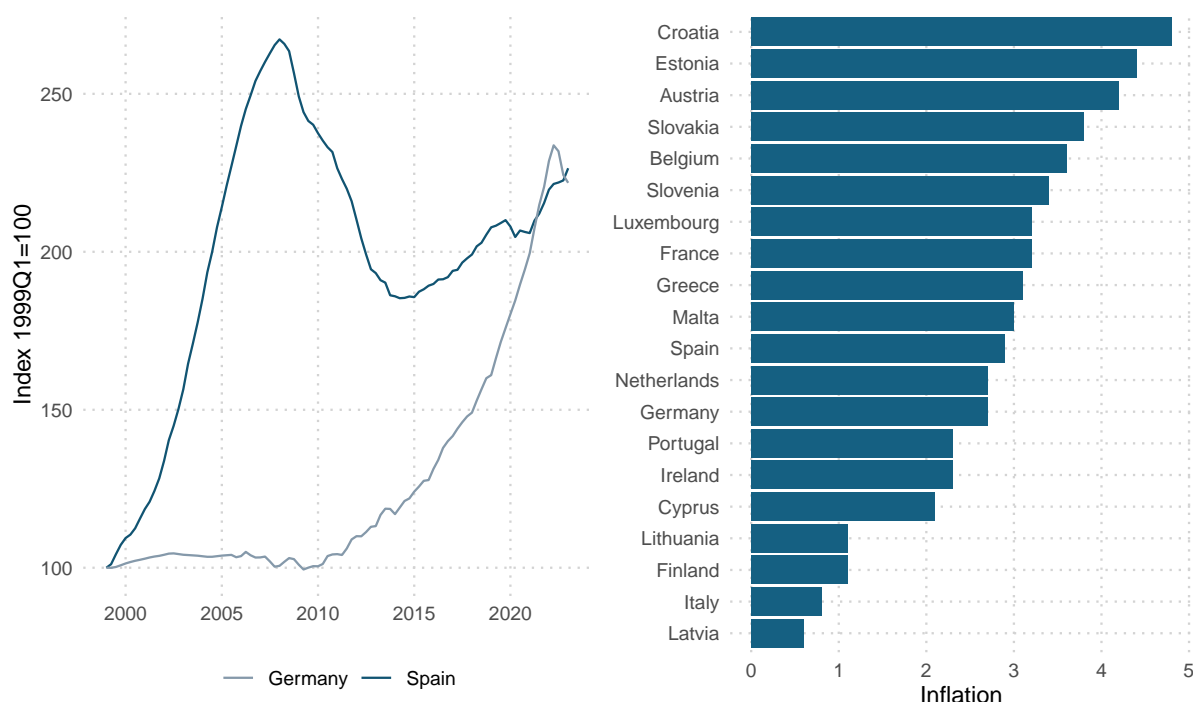
More recently, statistical identification methods have been developed to test the identification of short-run and long-run restrictions in SVAR models. Below, we use the method developed by Anttonen et al. (2024). They employ a structural vector autoregressive model with skewed generalized t-distributions using the non-Gaussianity and potential skewness in the data to achieve identification. This flexibility allows for a more accurate capture of the underlying shock distributions, even when higher moments, such as variance, may not be well-defined. It mitigates risks of misspecification for scenarios such as ours, where prior economic knowledge is ambiguous.

## 2 Divergence in the Eurozone: a New Indicator

There is considerable agreement among scholars that the eurozone does not meet the criteria for an optimal currency area where all members follow the same business cycle (Eichengreen 1992, Krugman 2013). The ECB can only set one key interest rate and has therefore inevitably set the interest rate too high for some countries and too low for others. Economic and institutional asymmetries within the euro area influence the effectiveness of monetary policy. For example, the interest rate level was too low for Spain before and too low for

Germany after the euro crisis, which encouraged exaggerations on the real estate markets at different times (Fig. 1, left). With heterogeneous inflation rates (Fig. 1, right), uniform decisions of interest rate adjustments have heterogeneous effects on the member states. In the absence of a fiscal union, the task of smoothing asymmetric shocks has been either left to individual member states, which have to adjust to recessions through internal devaluation or fiscal tightening or to the central bank, which has had to intervene through unconventional monetary policies. The latter strategy allows fitting the tools to individual member states.

Figure 1: Real Estate Price Index Germany and Spain and Inflation Rates



*Note:* Figure left: Quarterly index of real estate prices in Germany and Spain. The rising prices for Spain before the European financial and debt crisis of 2007/8 are indicative of excessively low borrowing costs in Spain, whereas the rising prices in Germany since 2010 would indicate the same for Germany. Source: Oxford Economics. Figure Right: Y-o-Y inflation rates euro area, Feb 2024. Source: ECB

There is comparatively less agreement for the methods used to assess the (in)effectiveness of a common monetary policy in a currency union. The first wave of OCA literature pioneered by Mundell (1961), McKinnon (1963), and Kenen (1969) emphasized the need for

flexible nominal adjustments, factor mobility, real adjustment, and diversification. Later the focus shifted towards stabilizing exchange rates (Tower and Courtney 1974, Ishiyama 1975). During the 1990s debates on the European Monetary Union, a second wave of OCA literature emerged. Bayoumi and Eichengreen (1997) were among the first to develop indices to determine heterogeneity in a currency union. The index of Bayoumi and Eichengreen uses standard deviations of real growth, export structures, trade relations and economic size. Subsequent studies have modified Bayoumi and Eichengreen’s index to include economic openness (Frankel and Rose 1998, Horvath and Komárek 2002), financial integration (Alesina et al. 2002) and credibility (Chari et al. 2020).

Other studies have based convergence on additional criteria such as inflation dynamics (Cavallero 2011) or fiscal discipline (De Grauwe 1996), characteristics that were motivated by the accession criteria of the EMU. Following Mundell 1961, several studies propose similarity of shocks as an OCA property. The higher the symmetry of shocks across countries, the better these countries are suited for economic integration under a common currency (Alesina and Barro 2002, Belke et al. 2017). Our method is similar to Castañeda and Schwartz (2017), who base their composite index on the standard deviations of macroeconomic variables commonly used in the OCA literature. In this section, we will explain the choice of the components in our indicator and how they relate to previous approaches to assess asymmetries within currency unions.

We follow Bayoumi and Eichengreen (1997) in measuring asymmetries with the cross-sectional standard deviation of the change in output and the wealth level: real growth rates and GDP per capita. The value of the first measure is assumed to be small for country groups in which business cycles are symmetric with outputs moving together. We follow Cavallero (2011) in adding the standard deviations of inflation rates. The importance of inflation convergence between members of a monetary union was first stressed by Fleming (1971). As both an accession and an OCA criterion, price level convergence rests on the similarity of

inflation rates between member states: rising costs relative to other countries that are not offset by productivity gains result in a loss of competitiveness through worsening terms of trade. Consequently, this leads to a reallocation of demand from countries with higher inflation to those with lower inflation, creating external imbalances between economies. Countries with higher inflation then tend to experience current account deficits, while those with lower inflation accrue surpluses. In a recent empirical paper, Garcia-Hiernaux et al. (2023) find evidence for an increase in price level divergence in the eurozone from 2012 onwards.

Following Schnabl and Ziegler (2011) and Dreyer and Schmid (2023), we include the standard deviation of wage growth. International trade theory expects wage convergence within an OCA, as exchange rate volatility as a trade impediment is eliminated, a theory known as factor price equalization. Wage growth convergence remains an important indicator for economic integration. Recent studies highlight that despite the theoretical benefits of labor mobility and wage flexibility, language barriers, cultural differences, and regulatory and administrative hurdles limit the extent to which labor moves freely across borders (Dorn and Zweimüller 2021). Additionally, wage flexibility is often constrained by labor market regulations, collective bargaining agreements, and social protection mechanisms that aim to prevent downward wage spirals but may also slow adjustment processes in the face of monetary policy shocks (Faia and Pezone 2024).

Fiscal sustainability being another accession criteria, we follow De Grauwe (1996) in adding the standard deviation of dept-to-GDP ratios to our index. This view of monetary integration focuses on credibility. For a monetary union to be stable, member states should demonstrate a commitment to low inflation by reassuring other member states of their fiscal discipline. In the Barro-Gordon model (1983), divergent debt-to-GDP ratios can undermine economic stability. Higher debt levels in some member states can lead to higher interest rates, which may incentivize higher-debt countries to favor inflationary policies. As with output, we assume that lower (higher) cross-sectional standard deviations of inflation, wage

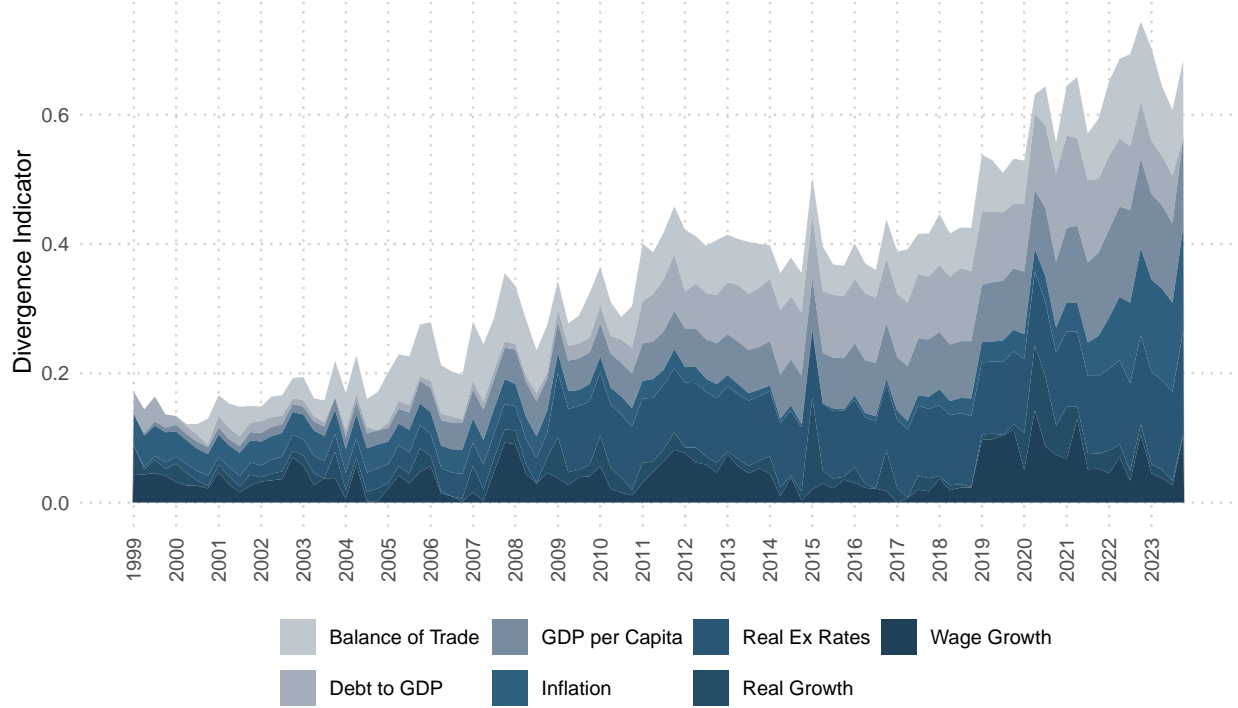
growth and debt-to-GDP ratios are indicative of higher (lower) convergence.

To capture export and trade relations (Bayoumi and Eichengreen 1998), we further add the standard deviations of price level-based real exchange rates and trade deficits versus Germany. The rationale behind focusing on trade imbalances and real exchange rates between Germany and the rest of the eurozone, while other variables are considered between each country, lies in Germany’s economic dominance within the euro area on the one hand and in empirically mimicking the two-country models often adopted in the theoretical literature. The OCA theory holds that exchange rates should stabilize, and trade imbalances should be minimized in a currency union with a high degree of convergence. While evidence for increasing trade of goods exists for the eurozone (Glick and Rose 2016), the trade volume of services is less pronounced (Felbermayr and Steininger 2019). Gains from trade have also been asymmetric, with wage shocks in member states leading to divergent outcomes in trade benefits (Covi 2021).

The values of our indicator—the cross-sectional standard deviations of 1) real growth rates 2) GDP per capita 3) inflation 4) wage growth 5) debt to GDP 6) price level-based real exchange rates versus Germany, and 7) balance of trade versus Germany—are tracked starting from the time they adopted the euro. The countries that joined after 1999, are included in the measurement with their euro adoption, while for the 11 founding members, it starts from the outset. We scale the standard deviations of the individual indicators between 1 and 0, where the lowest observed standard deviation is marked by 0 and the highest is marked by 1. We then calculate an unweighted average value of all standard deviations for each quarter from 1999Q1-2023Q4, i.e. for 25 years and 100 observations. The mathematical formulation of the indicator is described in Appendix B. The resulting composite indicator (Fig. 2) points clearly upwards, signifying growing divergence in the euro-zone. With an average of around 0.3, in 2016 the indicator started to grow faster and peaked in 2023Q3 at slightly above 0.7. These findings are in line with the index of Castañeda and Cendejas

(2022) who also observe an increase in divergence.

Figure 2: Divergence Indicator and its Components



*Note:* Quarterly index of divergence indicator. The indicator measures economic divergence in the euro area based on the unweighted mean standard deviations of seven key macroeconomic variables. Original values have been scaled.

Economic divergence within the eurozone may shape the ECB's monetary policy choices. Unconventional monetary policies, in particular, respond to these differences. The empirical methodology that follows in the next section is designed to capture how policy adjustments respond to and influence divergence.

### 3 Econometric Methodology

Structural vector autoregressions (SVARs) are frequently used to analyze monetary policy. Lanne et al. (2017) demonstrated that SVAR models can be uniquely identified using the

statistical properties inherent in the data. This identification process is statistical rather than economic, but requires additional information for economically interpreting the shocks. Additional information may involve implementing short-term or long-term constraints, which can be effectively tested with statistical identification methods. If these constraints hold, they can be used for further interpretation. However, as noted in the introduction, the literature on unconventional monetary policy often employs sign restrictions as identifying constraints, which are not straightforwardly addressed by conventional methods. We use a Bayesian method developed by Anttonen et al. (2024) to evaluate the likelihood of sign restrictions through their posterior probabilities.

Our empirical results are based on the following SVAR(p) model

$$\mathbf{y}_t = \alpha + \mathbf{A}_1 \mathbf{y}_{t-1} + \dots + \mathbf{A}_p \mathbf{y}_{t-p} + \mathbf{B} \epsilon_t, \quad (1)$$

where  $\mathbf{y}_t$  is an  $n \times 1$  vector of a time series,  $\alpha$  is an intercept term, and  $\mathbf{A}_1 \dots, \mathbf{A}_p$  are  $n \times n$  coefficient matrices.  $\mathbf{B}$  is the  $n \times n$  impact matrix containing the contemporaneous relations of the structural errors  $\epsilon_t$  that is assumed to be nonsingular.

Anttonen et al. (2024), building on Lanne et al. (2017), assume that (i) the error process  $\epsilon_t = (\epsilon_{1t}, \dots, \epsilon_{nt})'$  is a sequence of serially uncorrelated random vectors with each component  $\epsilon_{it}, i = 1, \dots, n$ , having zero mean and unit scale  $\sigma_i$ . The components of  $\epsilon_t = (\epsilon_{1t}, \dots, \epsilon_{nt})'$  are (ii) assumed mutually independent, and at most one of them has a Gaussian marginal distribution. This makes it possible to specify a different distribution for each  $\epsilon_{it}$  even without well-defined second moments. Under these assumptions, the SVAR(p) model above has a moving average representation

$$\mathbf{y}_t = \boldsymbol{\mu} + \sum_{j=1}^{\infty} \boldsymbol{\Psi}_j \mathbf{B} \epsilon_{t-j}, \quad (2)$$

where  $\boldsymbol{\mu}$  is the unconditional expectation of  $\mathbf{y}_t$ ,  $\boldsymbol{\Psi}_0$  is the identity matrix and  $\boldsymbol{\Psi}_j, j =$

$1, 2, \dots$  are obtained recursively as  $\Psi_j = \sum_{l=1}^j \Psi_{j-l} \mathbf{A}_l$ . The  $k$ th column of the matrices  $\Psi_j \mathbf{B} \equiv \Theta_j, j = 0, 1, \dots$  contains the structural shock  $\epsilon_{it}, i = 1, \dots, n$ .

In SVAR models of type (1), the transformation matrix  $\mathbf{B}$  must be rendered unique. The identification problem arises from the possibility of replacing  $\mathbf{B}$  with  $\mathbf{BC}$  and the error term  $\epsilon_t$  with  $\mathbf{C}^{-1}\epsilon_t$ , where  $\mathbf{C}$  is any nonsingular  $n \times n$  matrix. Under Gaussian errors, unique identification of the covariance matrix of  $\epsilon_t$  is typically restricted to a diagonal matrix, so that the diagonal matrix  $\mathbf{C}$  has to be of form  $\mathbf{C} = \mathbf{DO}$  with  $\mathbf{D}$  diagonal and nonsingular and  $\mathbf{O}$  orthogonal. The diagonal elements of  $\mathbf{D}$  are often set to either  $\pm 1$  if the covariance matrix of  $\epsilon_t$  is an identity matrix. Without such normalization, these elements remain unrestricted (but nonzero). To further ensure identifiability, additional constraints such as short-run restrictions may be imposed, restricting certain elements of  $\mathbf{B}$  to zero. A commonly used method includes setting  $\mathbf{B}$  as a lower triangular matrix identified as a Cholesky factor of the covariance matrix of the error term  $\mathbf{B}\epsilon_t$ . This approach, although it solves the identification problem, might impose a recursive structure that could be unrealistic for the variables in  $\mathbf{y}_t$ .

By contrast, Lanne et al. (2017) have shown that under the assumptions (i) and (ii), identification of  $\mathbf{B}$  is unique apart from the permutation and signs of its columns. While this multimodality is not problematic for Bayesian inference, as valid inference only requires a proper posterior, it complicates the analysis of impulse responses, which depend on the correct identification of a specific permutation. In frequentist settings, the parameter space can be restricted a priori, ensuring a single point of likelihood maximization. In the Bayesian framework, the manifestation of the permutation in the posterior sample can be diagnosed by assessing the convergence of the posterior chains. By examining the (split)  $\hat{R}$  convergence statistic and other diagnostic tools, we can detect permutation jumps, i.e. instances where the Markov Chain Monte Carlo (MCMC) algorithm incorrectly alternates between different orderings of the structural shocks. In certain cases, distinct volumes of high posterior probability mass corresponding to different permutations are sufficiently separated that

the estimation algorithm becomes unlikely to jump between them. This simplifies inference by isolating the correct permutation. While assumptions (i) and (ii) guarantee point identification of the parameters of (1), without additional information, the shocks cannot be labeled for economic interpretation. The plausibility of labeling the structural errors as specific shocks, i.e. the unconventional monetary policy shock and shocks leading to more convergence or divergence, by computing the posterior probability of each shock satisfying the relevant narrative restrictions has to be assessed.

The assumption of Gaussian errors in SVAR models is often too restrictive, as it imposes symmetry and finite kurtosis on the errors. Real-world economic data frequently exhibit shocks with skewness and heavy tails, which violate these assumptions. As stated above, Anttonen et al. (2024) address this issue and propose a more flexible approach by estimating the joint posterior distribution of the parameters of the unrestricted SVAR model (1). They specify the probability density function for each structural shock  $\epsilon_{it}, i = 1, \dots, n$ , using a skewed generalized t-distribution, which is given by:

$$f_i(\epsilon_{it}; \boldsymbol{\lambda}_i, \mathbf{p}_i, \mathbf{q}_i) = \frac{\mathbf{p}_i}{2\mathbf{v}_i\mathbf{q}_i^{1/\mathbf{p}_i}B\left(\frac{1}{\mathbf{p}_i}, \mathbf{q}_i\right)} \left[ \frac{|\epsilon_{it} + \mathbf{m}_i|^{\mathbf{p}_i}}{\mathbf{q}_i\mathbf{v}_i^{\mathbf{p}_i}(\boldsymbol{\lambda}_i \text{sign}(\epsilon_{it} + \mathbf{m}_i) + 1)^{\mathbf{p}_i} + 1} \right]^{\frac{1}{\mathbf{p}_i} + \mathbf{q}_i}, \quad (3)$$

where  $B()$  denotes the Beta function. The skewness is controlled by  $\boldsymbol{\lambda}_i$  ( $-1 < \boldsymbol{\lambda}_i < 1$ ), with  $\boldsymbol{\lambda}_i = 0$  indicating symmetry. The parameters  $\mathbf{p}_i > 0$  and  $\mathbf{q}_i > 0$  control the kurtosis, influencing the tail behavior, summarized by the tail exponent  $\alpha_i = \mathbf{p}_i\mathbf{q}_i$ , similar to the degrees of freedom in a Student's t-distribution. When  $\mathbf{q}_i$  tends to infinity, the distribution becomes Gaussian. The scale parameter  $\mathbf{v}_i$  adjusts the spread, while the location parameter  $\mathbf{m}_i$  shifts the distribution. To ensure that the errors  $\epsilon_{it}$  conform to the assumptions (i) and (ii) made above, the parameters in equation (3) can be restricted such that the errors have zero mean and the scale  $\sigma_i$  of  $\epsilon_{it}(i = 1, \dots, n)$  fixed to unity by setting  $\mathbf{v}_i = 1$ . We collect the parameters controlling the skewness and kurtosis of the shocks,  $\boldsymbol{\lambda}_i$ ,  $\mathbf{p}_i$ , and  $\mathbf{q}_i$  for

$i = 1, \dots, n$ , into the vector  $\boldsymbol{\gamma} = (\boldsymbol{\lambda}_1, \mathbf{p}_1, \mathbf{q}_1, \dots, \boldsymbol{\lambda}_n, \mathbf{p}_n, \mathbf{q}_n)'$ .

Due to the complexity of the model described in equations (1) and (3), Anttonen et al. (2024) estimate the parameters using Bayesian methods. In addition to constructing the likelihood function, their approach requires the specification of prior distributions for the parameters. The likelihood function is given by:

$$p(\mathbf{y}|\boldsymbol{\theta}) = |\det(\mathbf{B})|^{-T} \prod_{i=1}^n \prod_{t=1}^T f_i(\boldsymbol{\iota}_i' \mathbf{B}^{-1} \mathbf{u}_t(\boldsymbol{\pi}); \boldsymbol{\lambda}_i, \mathbf{p}_i, \mathbf{q}_i), \quad (4)$$

where  $\boldsymbol{\theta} = (\boldsymbol{\pi}', \boldsymbol{\beta}', \boldsymbol{\gamma}')'$ ,  $\boldsymbol{\pi} = \text{vec}([\alpha, \mathbf{A}'_1 : \dots : \mathbf{A}'_p]')$ , and  $\boldsymbol{\beta} = \text{vec}(\mathbf{B})$ . The vector  $\boldsymbol{\iota}_i$  is the  $i$ th unit vector, and  $\mathbf{u}_t(\boldsymbol{\pi}) = \mathbf{y}_t - \alpha - \mathbf{A}_1 \mathbf{y}_{t-1} - \dots - \mathbf{A}_p \mathbf{y}_{t-p}$ . A truncated normal prior distribution is assumed for the positive parameters  $\mathbf{p}_i$  with a mean of 2 and unit variance, and a log-normal prior distribution is assumed for  $\mathbf{q}_i$ . The support for  $\mathbf{p}_i$  is strictly positive, ranging from 0.01 to 3.99, ensuring a proper prior while setting the mean, median, and mode at 2. The prior distribution for  $\alpha_i = p_i q_i$  has its highest probability for a t-distribution with 2 degrees of freedom ( $\alpha_i = 2$ ). For the parameter  $-1 < \boldsymbol{\lambda}_i < 1$ , a uniform prior over its support is assumed. An improper and noninformative prior is imposed on  $\mathbf{b}$ , the inverse of the impact matrix  $\mathbf{B}$  (i.e.,  $\text{vec}(\mathbf{B}^{-1}) \equiv \mathbf{b}$ ), and on  $\boldsymbol{\pi}$ .

Based on this estimation framework, we investigate the dynamics of unconventional monetary policy and economic divergence, by estimating the parameters of SVAR model (1) with a Differential Evolution Markov Chain algorithm with snooker updater and crossover (DE-MC<sub>z</sub>) as described by Ter Braak and Vrugt (2008). For the empirical specification, we adhere to the framework of Anttonen et al. (2024), keeping their parameter restrictions and prior distributions. Our focus will be on the posterior probabilities of different shock structures and their alignment with unconventional monetary policy and divergence narratives, i.e. the extent to which the identified shocks correspond to specific historically documented dates of monetary policy actions (e.g., contractionary or expansionary phases)

and/or episodes of convergence or divergence and whether these shocks can be interpreted in line with those specific events.

## 4 Estimation Results

Beyond conventional monetary policy, the ECB has implemented several programs over the years with the aim of improving the functioning of specific markets. On May 10, 2010, the Securities Markets Program (SMP) was launched and later replaced by the Outright Monetary Transactions (OMT) program on September 6, 2012, to address the malfunctioning of the securities markets caused by the sovereign debt crisis. In September 2012, the European Stability Mechanism was launched (ESM) to provide loans to member states and banks in financial distress. Subsequently, the Asset Purchase Programme (APP) was announced on January 22, 2015, and formally started in March 2015. The APP included the Public Sector Purchase Programme (PSPP), the Corporate Sector Purchase Programme (CSPP), the Asset-Backed Securities Purchase Programme (ABSPP), and the third Covered Bond Purchase Programme (CBPP3). The APP's goal was to ensure price stability and stimulate economic growth by purchasing private and public sector securities. The APP concluded on July 1, 2023. In response to the COVID-19 crisis, the ECB introduced the Pandemic Emergency Purchase Programme (PEPP) on March 18, 2020, to support the euro area economy through the crisis. PEPP was not further extended on March 31, 2022, even though the ECB still reinvests the principal payments from maturing securities purchased under the program.

In this paper, we are interested in the interaction of unconventional monetary policy shocks and in shocks leading to convergence or divergence. Based on the theoretical and empirical OCA literature discussed in Section 2, we aim to analyze whether 1) the Eurosystem's balance sheet expands in response to increasing economic divergence. A positive long-run

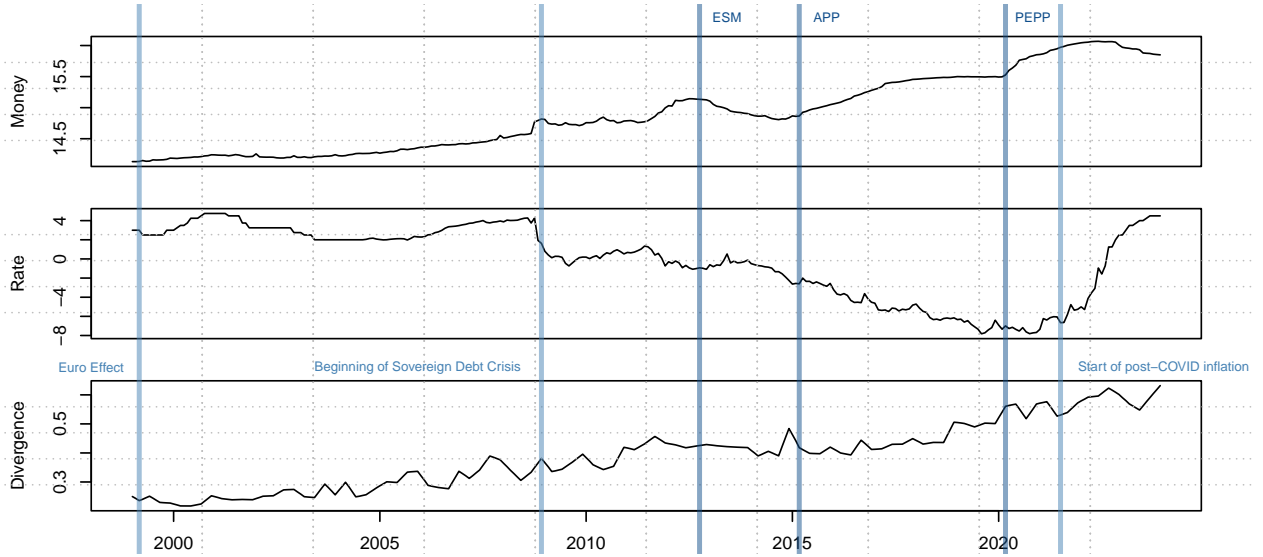
response would imply that the central bank applies unconventional monetary policies to stabilize the currency union. 2) Expansionary monetary policies reduce divergence in the short run. A negative short-run response would imply that unconventional monetary policy helps to mitigate economic differences across countries by providing liquidity and easing financial conditions, though these effects may not be sustained over the longer term. To test whether there is a single shock among the  $n$  statistically identified ones that satisfies the sign restrictions we consider, we employ the Bayesian procedure of Anttonen et al. (2024) discussed in Section 3.

The monthly data (1999:1-2023:12) included in the model are the interpolated outcomes of the divergence indicator, the ECB’s balance sheet in billions of euros, and the interest rate or the shadow rate of Wu and Xia (2020) for the period where the interest rate was at the zero-lower bound. Figure 3 plots all variables of our time-series as well as the shocks we use as narrative signs for statistical identification. All variables except the interest rate are log-transformed. We sample two chains ( $N = 2$ ) from the posterior distribution of the parameters, each consisting of one million draws. After discarding all but the last 150,000 draws from each chain, the chains have clearly converged according to the  $\hat{R}$  convergence statistic (see Appendix C).

The non-Gaussianity of the shocks is supported by the marginal posterior distribution of  $\lambda$ , which includes parameters that describe both the kurtosis and skewness of the shocks. Specifically, the marginal posterior density is notably low in the regions corresponding to Gaussian or near-Gaussian shocks ( $\lambda_i \approx 0, p_i \approx 2, q_i > 0$ ). It should be noted that this methodology does not solely depend on analyzing these marginal densities to determine the non-Gaussian nature of the shocks. If multiple shocks were nearly Gaussian, leading to weak identification, this would be reflected in the form of valid but excessively broad posterior marginal densities and credible intervals.

Even though the SVAR model’s parameters are statistically identified, the structural

Figure 3: Plot of Time Series 1990M1-2023M12



*Note:* Log-transformed (excl. interest rate) time series of the ECB’s balance sheet, interest rate, and economic divergence from 1999M1-2023M12. The light blue events (Euro Effect, Sovereign Debt Crisis, and the start of post-COVID inflation) along with the implementation of unconventional monetary policy programs (ESM, APP, and PEPP) will be tested below as narrative signs for the statistical identification of shocks.

shocks need to be labeled for economic interpretation. Since our goal is to economically interpret the unconventional monetary policy shocks and shocks leading to convergence or divergence, we need to determine which of the identified structural shocks fits either one of these categories. This is typically done informally by examining the impulse response functions of the model. In our case, the impulse response functions of the unrestricted model suggest that the unconventional monetary policy shock is the first one, as it is the only shock that has a marked immediate effect on the balance sheet, whereas the shock leading to convergence/divergence appears to be the third one as it shows an immediate positive effect on divergence (see Figure A.1 in Appendix A). We also observe that our interest rate variable may be interpreted as a conventional monetary policy shock as it displays an immediate positive effect on the interest rate.

To assess these observations in a more rigorous manner, we calculate the posterior

probabilities of each of the shocks satisfying the narrative sign restrictions, i.e. the months in our data that are most likely to correspond to an actual shock. For the balance sheet, we define three expansionary (positive) shocks in October 2012 (beginning of ESM), January 2015 (beginning of APP), and March 2020 (beginning of PEPP). These events mark key interventions by the ECB aimed at providing liquidity and stabilizing the euro area during periods of economic distress. For the divergence indicator, we define two (positive) shocks that increase economic divergence. These include the start of the European debt crisis in October 2009, when peripheral countries faced severe fiscal challenges while others remained relatively stable, see, e.g., Lane (2012), Pisani-Ferry (2014), Frankel (2015) for defining October 2009 as the start of the European debt crisis and, e.g., Jaccard and Smets (2020) for modeling the crisis as an asymmetric shock. We additionally define the end of the COVID-19 lockdowns and the start of inflation in July 2021 as a shock leading to divergence, as this event caused uneven economic recovery across member states. See, e.g., European Central Bank (2021) for an assessment of the heterogeneous effects of pandemic lockdowns easing when inflation exceeded the target in that month. Lastly, we define one (negative) shock leading to convergence in March 1999, assuming that the launch of the euro had a “euro effect” on the area economy by the end of the first quarter (Angeloni et al. 2006).

It may be easier to select precise months for testing the narrative sign restrictions of unconventional monetary policy shocks than for shocks leading to convergence or divergence since the latter may not have agreed-upon dates in the literature. We therefore add two alternative dates: Mario Draghi’s “Whatever it takes” in July 2012 as another (negative) shock leading to convergence and the peak of the post-pandemic inflation in July 2022 as a (positive) shock leading to divergence. We report on the posterior probabilities when adding these dates in Table 3 of Appendix A. We did not find consistently significant results when testing the narrative signs of conventional monetary policy shocks, which is why we refrain from further analysis of the interest rate.

For any shock to be the hypothesized shock, all the posterior probabilities, as well as the joint posterior probability of the shock satisfying all the narrative restrictions, should be high. To confidently label a shock as an unconventional monetary policy or a shock leading to convergence or divergence, it must consistently satisfy the restrictions on all the dates considered.

Table 1: Probabilities of Narrative Sign Restrictions UMP Shocks

	UMP Shock	MP Shock	Convergence/Divergence Shock
October 2012 (ESM)	0.87	0.62	0.49
March 2015 (APP)	0.76	0.45	0.38
March 2020 (PEPP)	0.98	0.11	0.88
<b>Total</b>	0.66	0.03	0.33

*Note:* Fraction of the posterior probabilities satisfying the narrative sign restrictions for every shock. All shocks are assumed to be expansionary (positive). The dates correspond to major unconventional monetary policy measures taken by the ECB.

Table 1 summarizes the results of this assessment for the unconventional monetary policy shocks. The reported posterior probabilities provide a moderate confirmation that the first shock is indeed the unconventional monetary policy shock (provided we are confident about the narrative sign restrictions). The posterior probability for it to satisfy all the narrative sign restrictions is approximately 66%, substantial enough to suggest a reasonable level of confirmation. The results in Table 2 indicate that the shocks leading to convergence or divergence consistently meet the narrative sign restrictions across all observed periods.

The posterior probabilities strongly support that the third shock is almost certainly the convergence/divergence shock, assuming the narrative sign restrictions are accurate, with a posterior probability of 0.86. In contrast, all other shocks show a probability of less than 0. This finding corroborates our initial predictions based on the informal assessment of the impulse response functions. Since shocks that are independent of these events (as we assume they are) have around a 50% chance of satisfying any individual sign restriction a priori,

the likelihood of a shock satisfying all restrictions purely by chance decreases with fewer observations. While this introduces an element of randomness, the relatively high posterior probabilities for the shocks under consideration make it unlikely that the outcomes are due to chance alone.

Table 2: Probabilities of Narrative Sign Restrictions Divergence/Convergence Shocks

	UMP Shock	MP Shock	Convergence/Divergence Shock
March 1999	0.13	0.00	0.86
October 2009	0.00	0.92	1.00
July 2021	0.30	0.00	1.00
<b>Total</b>	0.00	0.00	0.86

*Note:* Fraction of the posterior probabilities satisfying the narrative sign restrictions for every shock. All shocks are assumed to be expansionary (positive). The dates correspond to the launch of the Euro (convergence shock), the beginning of the Sovereign Debt Crisis (divergence shock), and the end of the COVID-19 lockdown/start of inflation (divergence shock).

We can finally assess our impulse response functions with more confidence (Figures A.2 and A.3 of Appendix A). Our findings confirm that unconventional monetary policy, when implemented in response to economic divergences, may temporarily reduce economic disparities by approximately 5-10% over a two-year period. Note that we conditionally restrict the impulse response to being negative for the first 12 months of the shock. While this does not change the posterior probabilities, it lends statistical significance to the impulse response function. We also observe that a shock leading to divergence may induce a sustained increase in the balance sheet of up to 20% for at least five years. We do not observe a statistically significant impact on the interest rate for either unconventional monetary policy or divergence.

To go back to the ambiguous findings discussed in the introduction, we observe that both perspectives are valid: unconventional monetary policy can temporarily alleviate economic disparities, which corresponds with those who advocate for its use to dampen short-term

divergences. However, the long-term effects supports the literature that recommends a more restrained use of monetary policy. Sustained interventions may create long-term dependencies and imbalances, potentially worsening the disparities they were meant to mitigate. In light of growing heterogeneity across eurozone members, pressure on the ECB to use its balance sheet to address divergence could run the risk of entrenching continuous monetary expansion, making quantitative tightening more difficult to implement.

Further, we test the divergence shock for a 10 year horizon, and confirm our findings, i.e. that a shock leading divergence causes a prolonged expansion of the central bank balance sheet. We also test our model with the Divisia monetary aggregate (Darvas 2015), which weights M3 components based on their relative economic importance. This substitution in our model did not change the outcomes.

## 5 Conclusion

In this study we have examined the dynamics between economic divergence among euro area member states and the use of expansionary monetary policies with a newly developed divergence indicator. Using a Bayesian SVAR model, we find that the European Central Bank’s balance sheet tends to expand in response to growing divergence, although in the long run unconventional monetary policies appear less effective at reducing these disparities. Rather than providing long-term solutions, such policies seem to act as stopgap measures that may be unable to remedy underlying structural issues.

In addressing the broader economic implications of our findings, we conclude that sustained expansionary monetary policies caused by divergence in the euro area may contribute to inflationary pressures. While this paper has primarily focused on the dynamics of economic divergence and monetary policy responses, the link between a persistent increase in

the money supply and rising inflation warrants further exploration. Inflationary pressures, when tied to the ECB's efforts to manage economic disparities, highlight a feedback loop where prolonged monetary expansion designed to stabilize short-term disparities may exacerbate long-term price instabilities. Future research could provide deeper insights into how continuous reliance on expansionary policies might be contained to prevent long-term inflationary effects, in particular inflation in markets segments that may not be captured by the CPI.

## References

- Aksoy, Y., P. De Grauwe, and H. Dewachter (2002). Do Asymmetries Matter for European monetary policy? *European Economic Review* 46(3), 443–469.
- Alesina, A. and R. J. Barro (2002). Currency Unions. *The Quarterly Journal of Economics* 117(2), 409–436.
- Alesina, A., R. J. Barro, and S. Tenreyro (2002). Optimal Currency Areas. *NBER Macroeconomics Annual* 17, 301–345.
- Almgren, M., J.-E. Gallegos, J. Kramer, and R. Lima (2022, October). Monetary Policy and Liquidity Constraints: Evidence from the Euro Area. *American Economic Journal: Macroeconomics* 14(4), 309–40.
- Angeloni, I., L. Aucremanne, and M. Ciccarelli (2006). Price Setting and Inflation Persistence: did EMU matter? *Economic Policy* 21(46), 354–387.
- Antolín-Díaz, J. and J. F. Rubio-Ramírez (2018). Narrative Sign Restrictions for SVARs. *American Economic Review* 108(10), 2802–29.
- Anttonen, J., M. Lanne, and J. Luoto (2024). Statistically Identified Structural VAR Model with Potentially Skewed and Fat-Tailed Errors. *Journal of Applied Econometrics* 39(3), 422–437.
- Barro, R. J. and D. B. Gordon (1983). Rules, Discretion and Reputation in a Model of Monetary Policy. *Journal of Monetary Economics* 12(1), 101–121.
- Bayoumi, T. and B. Eichengreen (1997). Ever Closer to Heaven? An Optimum-Currency-Area Index for European countries. *European Economic Review* 41(3), 761–770.
- Bayoumi, T. and B. Eichengreen (1998). Exchange Rate Volatility and Intervention: Implications of the Theory of Optimum Currency Areas. *Journal of International Economics* 45(2), 191–209.
- Belke, A., C. Domnick, and D. Gros (2017). Business Cycle Synchronization in the EMU: Core vs. Periphery. *Open Economies Review* 28, 863–892.
- Burriel, P. and A. Galesi (2018). Uncovering the Heterogeneous Effects of ECB Unconventional Monetary Policies Across Euro Area Countries. *European Economic Review* 101, 210–229.
- Campos, N. F. and C. Macchiarelli (2016). Core and Periphery in the European Monetary Union: Bayoumi and Eichengreen 25 years later. *Economics Letters* 147, 127–130.
- Castañeda, J. E. and J. L. Cendejas (2022). Macroeconomic Asymmetry in the Eurozone Before and After the Global Financial Crisis: An Appraisal of the Role of the ECB. *Journal of Policy Modeling* 44(1), 184–202.

- Castañeda, J. E. and P. Schwartz (2017). How Functional is the Eurozone? An Index of European Economic Integration Through the Single Currency. *Economic Affairs* 37(3), 365–372.
- Cavallero, A. (2011). The Convergence of Inflation Rates in the EU-12 Area: A Distribution Dynamics Approach. *Journal of Macroeconomics* 33(2), 341–357.
- Chari, V., A. Dovis, and P. J. Kehoe (2020). Rethinking Optimal Currency Areas. *Journal of Monetary Economics* 111, 80–94.
- Cœuré, B. (2013). Outright Monetary Transactions, One Year On. Speech presented at “The ECB and its OMT Programme”, organised by Centre for Economic Policy Research, German Institute for Economic Research and KfW Bankengruppe Berlin, 2 September 2013.
- Covi, G. (2021). Trade Imbalances Within the Euro Area: Two Regions, Two Demand Regimes. *Empirica* 48(1), 181–221.
- Darvas, Z. (2015). Does Money Matter in the Euro Area? Evidence from a New Divisia Index. *Economics Letters* 133, 123–126.
- De Grauwe, P. (1996). The Economics of Convergence: Towards Monetary Union in Europe. *Weltwirtschaftliches Archiv* 132(1), 1–27.
- De Grauwe, P. and G. Schnabl (2008). Exchange Rate Stability, Inflation, and Growth in (South) Eastern and Central Europe. *Review of Development Economics* 12(3), 530–549.
- Dellas, H. and G. S. Tavlas (2009). An Optimum-Currency-Area Odyssey. *Journal of International Money and Finance* 28(7), 1117–1137.
- Dominguez-Torres, H. and L. A. Hierro (2019). The Regional Effects of Monetary Policy: A Survey of the Empirical Literature. *Journal of Economic Surveys* 33(2), 604–638.
- Dorn, D. and J. Zweimüller (2021). Migration and Labor Market Integration in Europe. *Journal of Economic Perspectives* 35(2), 49–76.
- Dreyer, J. K. and P. A. Schmid (2023). *Optimal Currency Areas and the Euro, Volume II: Capital and Labor Mobility*. Springer Nature.
- ECB (2024a). Changes to the Operational Framework for Implementing Monetary Policy. *Statement by the Governing Council, March 13, 2024*.
- ECB (2024b). Monetary Policy Decisions. *Press Release, March 7, 2024*.
- Eichengreen, B. (1992). Is Europe an Optimum Currency Area? In S. Borner and H. Grubel (Eds.), *The European Community After 1992: Perspectives from the Outside*, pp. 138–161. London: Palgrave Macmillan UK.
- El-Shagi, M., S. Giesen, and L. J. Kelly (2015). The Quantity Theory Revisted: A New Structural Approach. *Macroeconomic Dynamics* 19(1), 58–78.

- European Central Bank (2021). Annual report. *Economic Bulletin Issue 5*.
- Faia, E. and V. Pezone (2024). The Cost of Wage Rigidity. *The Review of Economic Studies* 91(1), 301–339.
- Felbermayr, G. and M. Steininger (2019). Revisiting the Euro’s Trade Cost and Welfare Effects. *Jahrbücher für Nationalökonomie und Statistik* 239(5-6), 917–956.
- Fleming, J. M. (1971). On Exchange Rate Unification. *Economic Journal* 81(323), 467–88.
- Frankel, J. (2015). The Euro Crisis: Where to from here? *Journal of Policy Modeling* 37(3), 428–444. When Will the Crisis End in the Eurozone and Emerging Markets?
- Frankel, J. A. and A. K. Rose (1998). The Endogeneity of the Optimum Currency Area Criteria. *The Economic Journal* 108(449), 1009–1025.
- Garcia-Hiernaux, A., M. T. Gonzalez-Perez, and D. E. Guerrero (2023). Eurozone Prices: A Tale of Convergence and Divergence. *Economic Modelling* 126, 106418.
- Georgiadis, G. (2015). Examining Asymmetries in the Transmission of Monetary Policy in the Euro Area: Evidence from a Mixed Cross-Section Global VAR model. *European Economic Review* 75, 195–215.
- Glick, R. and A. K. Rose (2016). Currency Unions and Trade: A Post-Emu Reassessment. *European Economic Review* 87, 78–91.
- Hefeker, C. and M. Neugart (2015). Fiscal Transfers in a Monetary Union with Exit Option. *Review of International Economics* 23(3), 489–508.
- Horvath, R. and L. Komárek (2002). Optimum Currency Area Theory: An Approach for Thinking About Monetary Integration. *The Warwick Economics Research Paper Series (TWERPS)* 647.
- Howarth, D. and L. Quaglia (2021). Failing Forward in Economic and Monetary Union: Explaining Weak Eurozone Financial Support Mechanisms. *Journal of European Public Policy* 28(10), 1555–1572.
- Ishiyama, Y. (1975). The Theory of Optimum Currency Areas: A Survey. *Staff Papers-International Monetary Fund*, 344–383.
- Jaccard, I. and F. Smets (2020). Structural Asymmetries and Financial Imbalances in the Eurozone. *Review of Economic Dynamics* 36, 73–102.
- Jones, E., R. D. Kelemen, and S. Meunier (2016). Failing Forward? The Euro Crisis and the Incomplete Nature of European Integration. *Comparative Political Studies* 49(7), 1010–1034.
- Kenen, P. (1969). The Theory of Optimum Currency Areas: an Eclectic View. In R. A. Mundell and A. K. Swoboda (Eds.), *Monetary Problems of the International Economy*, pp. 41–60. University of Chicago Press.

- Krugman, P. (2013). Revenge of the optimum currency area. *NBER Macroeconomics Annual* 27(1), 439–448.
- Lane, P. R. (2000). Asymmetric shocks and monetary policy in a currency union. *The Scandinavian Journal of Economics* 102(4), 585–604.
- Lane, P. R. (2012). The European Sovereign Debt Crisis. *The Journal of Economic Perspectives* 26(3), 49–67.
- Lanne, M., M. Meitz, and P. Saikkonen (2017). Identification and Estimation of Non-Gaussian Structural Vector Autoregressions. *Journal of Econometrics* 196(2), 288–304.
- Mavrodimitrakis, C. (2023). The Policy Mix in a Monetary Union: Who Bears the Burden of Asymmetric Shocks’ Stabilisation? *International Journal of Finance & Economics*.
- McKinnon, R. I. (1963). Optimum Currency Areas. *The American Economic Review* 53(4), 717–725.
- Meade, J. E. (1957). The Balance-of-Payments Problem of a European Free-Trade Area. *Economic Journal* 67(267), 379–396.
- Mundell, R. (1961). A Theory of Optimal Currency Areas. *American Economic Review* 51(4), 657–665.
- Pisani-Ferry, J. (2014). Euro Crisis Timeline. In *The Euro Crisis and Its Aftermath*. Oxford University Press.
- Puonti, P. (2019). Data-Driven Structural BVAR Analysis of Unconventional Monetary Policy. *Journal of Macroeconomics* 61, 103131.
- Rigobon, R. (2003). Identification Through Heteroskedasticity. *The Review of Economics and Statistics* 85(4), 777–792.
- Röpke, W. (1966). European Economic Integration and its Problems. *Modern Age Quarterly Review, Summer*, 231–44.
- Schnabl, G. and C. Ziegler (2011). Exchange Rate and Wage Policies in Central and Eastern Europe. *Journal of Policy Modeling* 33(3), 347–360.
- Scitovsky, T. (1958). *Economic Theory and Western European Integration*. Stanford University Press.
- Tavlas, G. S. (2009). Optimum-Currency-Area Paradoxes. *Review of International Economics* 17(3), 536–551.
- Ter Braak, C. J. and J. A. Vrugt (2008). Differential Evolution Markov Chain with Snooker Updater and Fewer Chains. *Statistics and Computing* 18, 435–446.
- Tower, E. and M. M. Courtney (1974). Exchange Rate Flexibility and Macro-Economic Stability. *The Review of Economics and Statistics* 56(2), 215–224.

- Uhlig, H. (2005). What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure. *Journal of Monetary Economics* 52(2), 381–419.
- Wu, J. C. and F. D. Xia (2020). Negative interest rate policy and the yield curve. *Journal of Applied Econometrics* 35(6), 653–672.

## Appendix A: Additional Tables and Figures

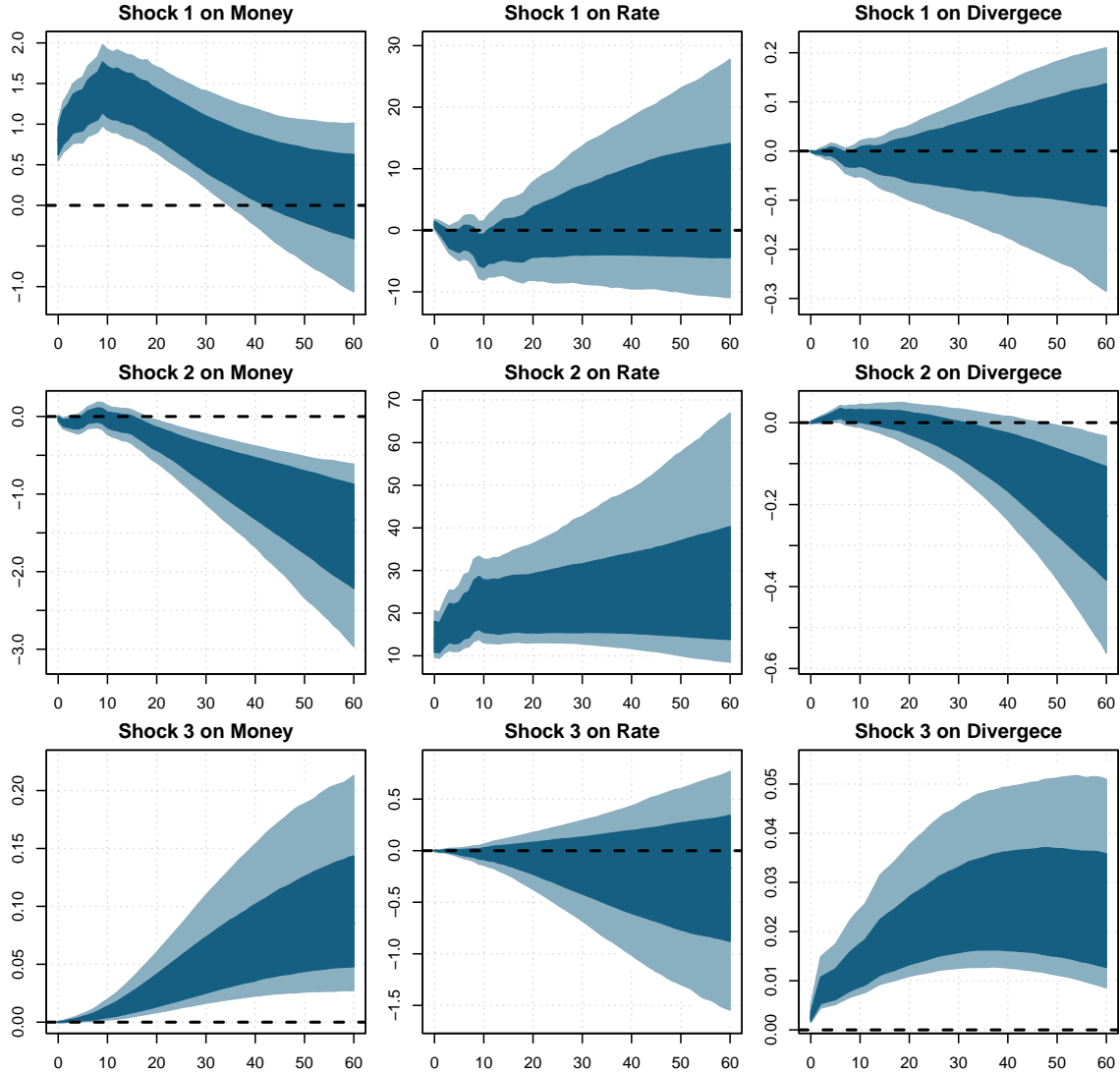


Figure A.1: 68% and 90% point-wise sets of impulse responses to all identified shocks. The y-axis is defined in percentage points for the monetary aggregates and divergence and in basis points for the interest rate. The impulse response on the top row corresponds to an unconventional monetary policy shock, the middle row to a conventional monetary policy shock, and the bottom to a convergence/divergence shock. The size of the shocks is set to unity, which is also the scale of the shock. This corresponds to a shock of a “typical” size. A positive UMP shock leads to an immediate 0.6% increase of the balance sheet. A positive (contractionary) monetary policy shock induces an immediate increase of around 10 basis points in the interest rate. A positive divergence shock leads to a small but persistent increase in divergence.

Table 3: Probabilities of Narrative Sign Restrictions Convergence/Divergence Shocks

	UMP Shock	MP Shock	Convergence/Divergence Shock
October 2009	0.00	0.92	1.00
July 2012	1.00	1.00	0.97
July 2021	0.30	0.00	1.00
October 2022	0.77	0.16	1.00
<b>Total</b>	0.00	0.00	0.97

*Note:* Fraction of the posterior probabilities satisfying the narrative sign restrictions for every shock. The dates correspond to those of 2 except for the “euro effect” which we removed because the literature seems to agree that the convergence process was largely when the euro was launched. However, we add Mario Draghi’s “Whatever it Takes” speech on July 2012, which is often cited as having had a converging effect (negative shock) and the peak of the post-pandemic inflation (positive shock) on October 2022.

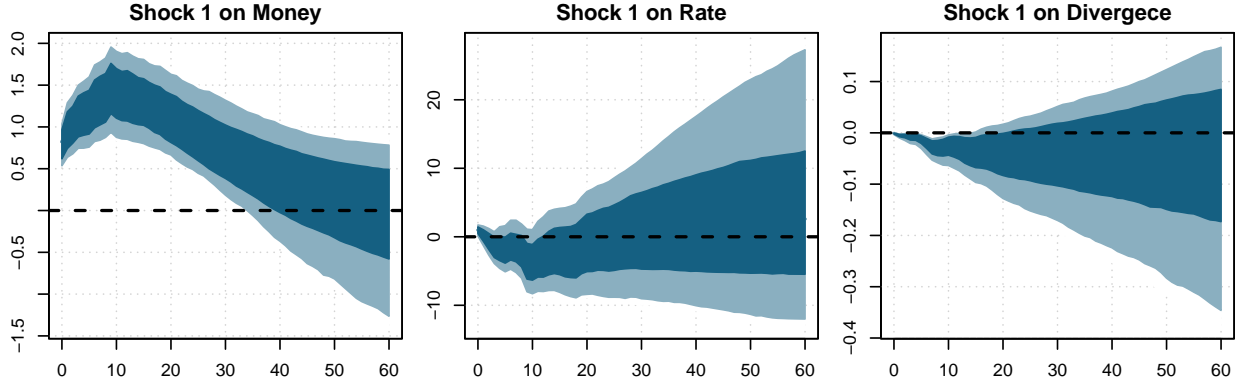


Figure A.2: Impulse responses of a positive unconventional monetary policy shock conditional on the response of the divergence indicator being negative in the first 12 months. The shaded areas are the 68% and 90% point-wise posterior intervals. The y-axis is defined in percentage points for the balance sheet and divergence and in basis points for the interest rate. The size of the shock is set to unity, which is also the scale of the shock. This corresponds to a shock of a “typical” size. An UMP shock (increased balance sheet) induces a small decrease in divergence of 0.5-1% for about two years.

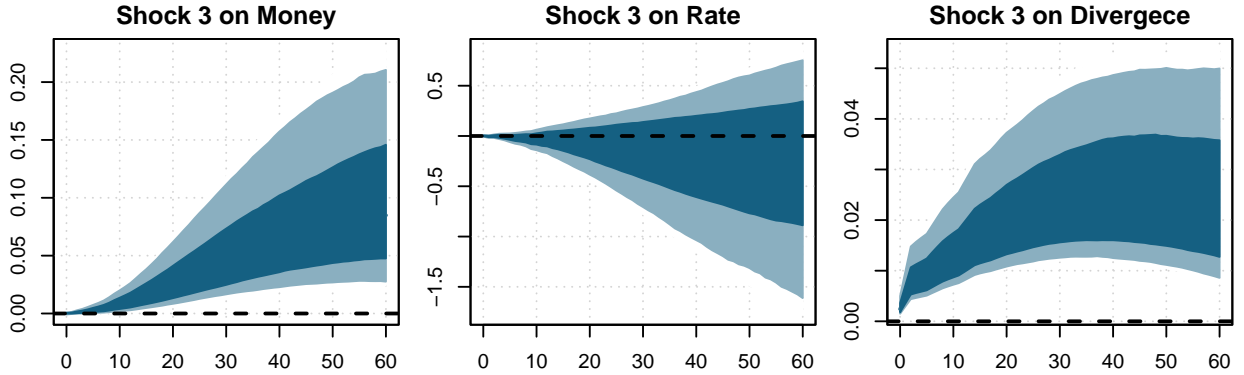


Figure A.3: Impulse responses of a (positive) divergence shock. The shaded areas are the 68% and 90% point-wise posterior intervals. The y-axis is defined in percentage points for the balance sheet and divergence and in basis points for the interest rate. The size of the shock is set to unity, which is also the scale of the shock. This corresponds to a shock of a “typical” size. An increase in divergence induces an persistent increase in the balance sheet of up to 20%.

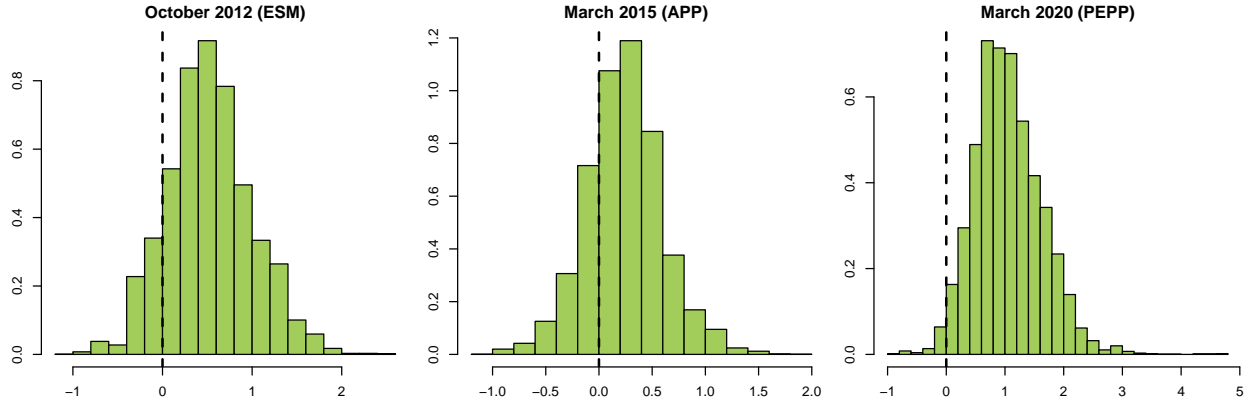


Figure A.4: Marginal posterior distributions of the statistically identified unconventional monetary policy shocks. None of the shocks display a 100% percent probability of satisfying the narrative sign restrictions.

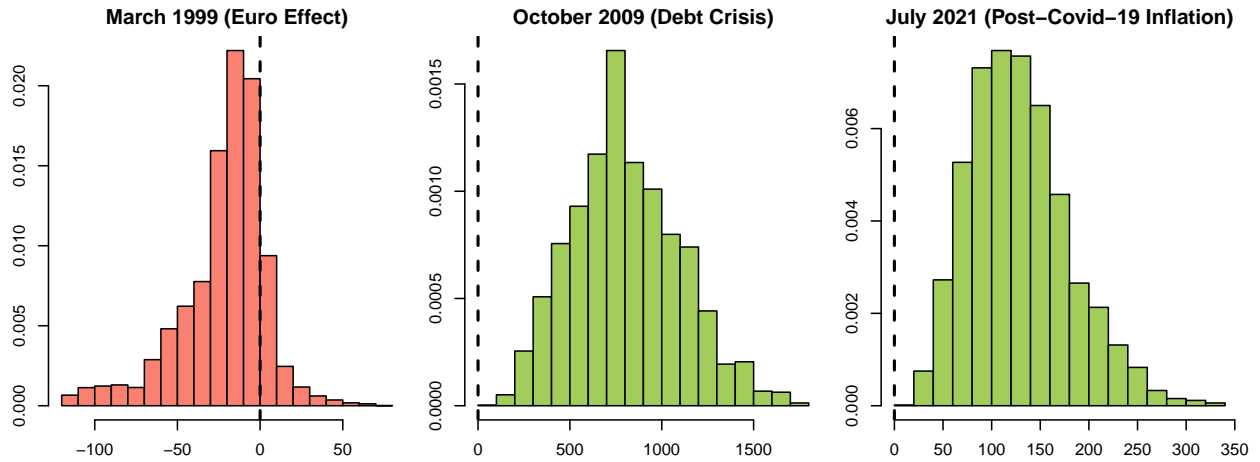


Figure A.5: Marginal posterior distributions of the statistically identified (negative) convergence shocks in red and (positive) divergence shocks in green. Only the “euro effect” does not display a 100% percent probability of satisfying the narrative sign restrictions. Note that we do find a 100% probability for January 2002, when the euro became official legal tender. However, most studies agree that convergence was already achieved prior to the launch of the euro, see also Table 3.

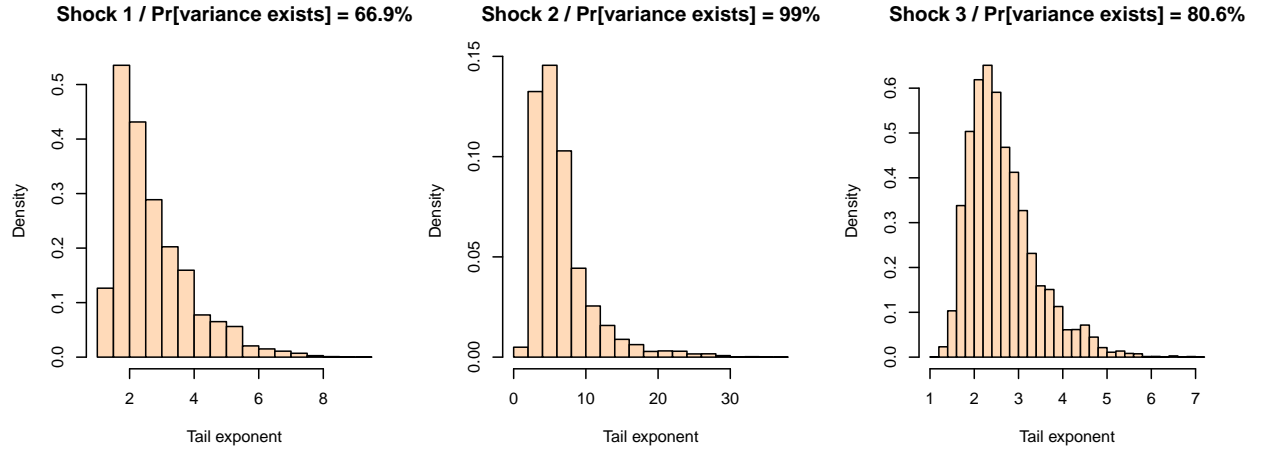


Figure A.6: Marginal posterior distributions of the tail exponent,  $\alpha_i = p_i q_i$ , for all identified shocks. The tail exponent of a sgt-distributed shock is analogous to the degrees of freedom of a  $t$ -distributed shock. Higher values imply thinner tails, e.g. for Gaussian shock  $p_i = 2, q_i \rightarrow \infty, \alpha_i \rightarrow \infty$ ) and lower values imply fatter tails. Only moments up to  $\alpha_i$  exist, i.e. are finite. Hence  $\text{PR}[\text{Variance of the } i\text{th shock is finite}] = \text{Pr}[\alpha_i > 2]$ .

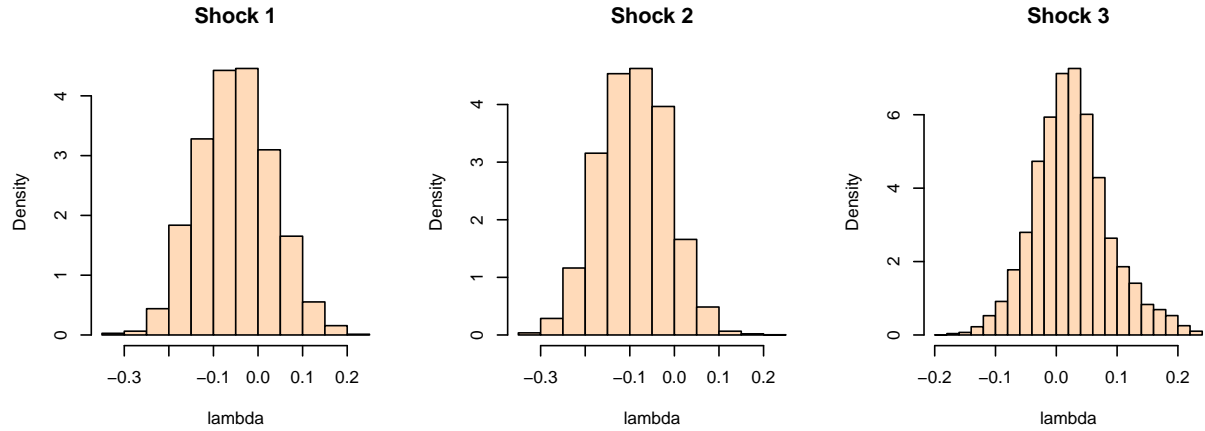


Figure A.7: Marginal posterior distributions of the impact effects for all identified shocks (see Figure A.1. with  $h = 0$ ).

## Appendix B: Constructing a Divergence Indicator

For each quarter, we compute the standard deviation  $\sigma_{x,q}$  of each indicator across all euro area countries from the point of accession

$$\sigma_{x,q} = \sqrt{\frac{1}{N_q} \sum_{i=1}^N (x_{i,q} - \bar{x}_q)^2},$$

where  $x_{i,q}$  is the value of the indicator for country  $i$  in quarter  $q$ , and  $\bar{x}_q$  is the mean value of the indicator across all countries in quarter  $q$ . We then scale each calculated standard deviation to a range between 0 and 1 for the entire period from 1999Q1 to 2023Q4

$$s_{x,q} = \frac{\sigma_{x,q} - \min_q(\sigma_x)}{\max_q(\sigma_x) - \min_q(\sigma_x)}.$$

Lastly, we calculate the composite divergence indicator  $D_q$  for each quarter by taking the unweighted average of the scaled standard deviations of all indicators

$$D_q = \frac{1}{k} \sum_{j=1}^k s_{j,q},$$

where  $s_{j,q}$  represents the scaled standard deviation for the  $j$ -th indicator in quarter  $q$  and  $k$  is the total number of indicators being considered for the divergence calculation.

## Appendix C: Convergence Diagnostic

We use the R-package of Anttonen et al. (2024) which is available via GitHub (<https://github.com/jetroant/rbsvar>). The estimation of the model in Section 4 required 20 million posterior evaluations (two chains and ten inner iterations per step) with 129 parameters. The number of burn-in draws (the draws to be discarded before accepting draws from the chain as the posterior sample) were chosen so that for the final chains of sufficient length (in our case 150,000 posterior draws with 10 inner iterations totaling at 1 million draws per chain), the  $\hat{R}$  convergence statistic of Gelman et al. (2013) did not exceed the threshold of 1.10 for any of the 129 parameters in the model. Figure C.1a depicts the distribution of the marginal  $\hat{R}$  convergence statistics. Figure C.1b suggests, even far fewer draws would have provided us with acceptable performance. We checked our results for sensitivity to the length of the burn-in sample and found the results essentially identical whether 600,000 or 850,000 burn-in samples were drawn.

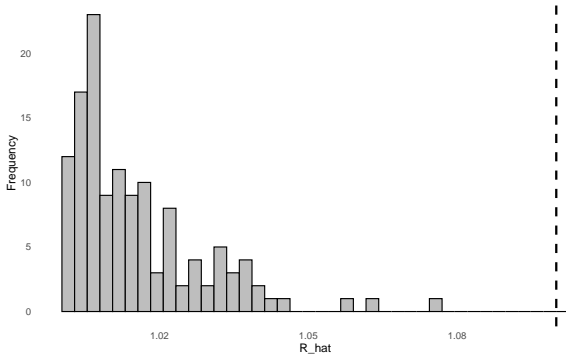


Figure C.1a: Distribution of marginal  $\hat{R}$  convergence statistics of Gelman et al. (2013) for 129 parameters of the model. The number of burn-in draws were chosen such that none of the marginal  $\hat{R}$  convergence statistics exceeded the threshold of 1.10.

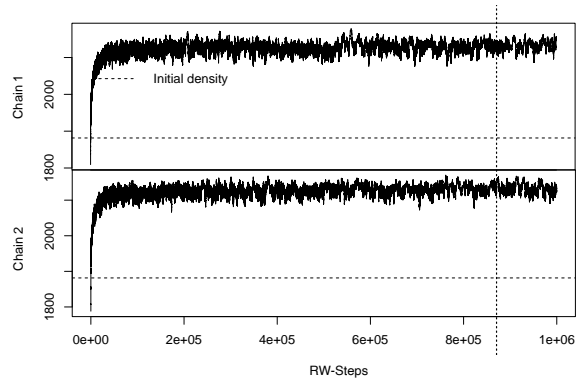


Figure C.1b: Unnormalized posterior densities for two MCMC chains used to estimate the model in Section 4. To make sure the chains have converged, 850,000 burn-in steps were taken, before the actual posterior sample consisting of 150,000 draws per chain. The vertical dashed line marks the spot where burn-in sample ends and the posterior sample begins.

Figure C.2 provides further insights into the behavior of the chains and the shape of the

posterior distribution. It displays the trace plots and marginal posteriors for four random parameters, enhancing our understanding of the chains' mixing properties and the posterior distribution's shape. Each subplot's upper panel shows the marginal trace plot for a given parameter, while the lower panel presents the marginal posterior distribution of the same parameter. Informal visual inspection suggests that the chains appear stationary, mix well, and exhibit smooth and well-behaved marginal posterior distributions. This observation supports our earlier conclusions of well-converged chains based on the  $\hat{R}$  convergence statistic. Additionally, some marginal posterior distributions exhibit notable non-Gaussian characteristics.

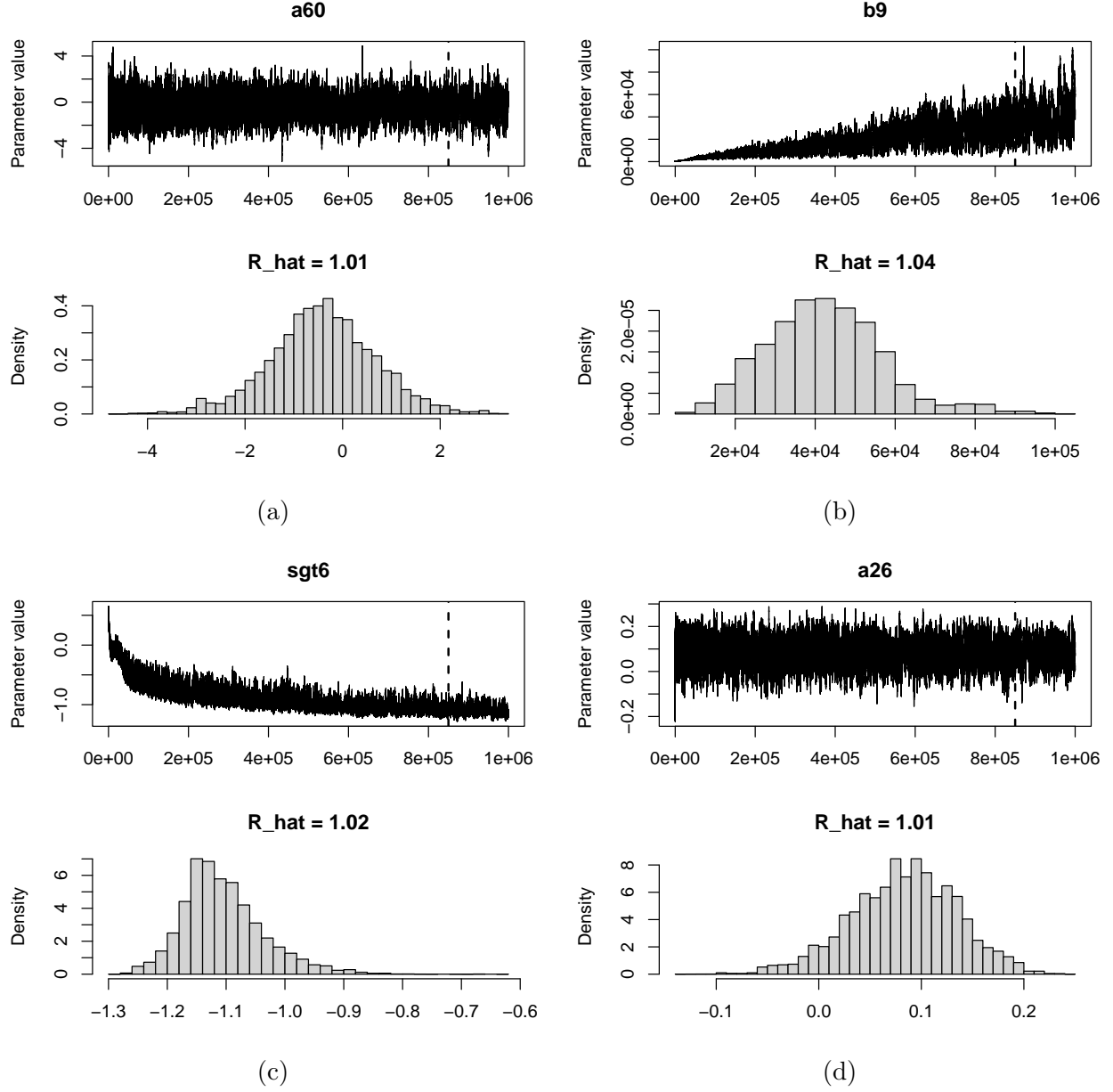


Figure C.2: (a) Trace plot and marginal posterior distribution for the 60th component of  $\text{vec}((A_1, \dots, A_{12})')$ , (b) the 6th component of  $\text{vec}(B^{-1})$ , (c)  $\lambda_6$  characterizing skewness of the sixth sgt-distributed shock, (d) the 26th component of  $\text{vec}((A_1, \dots, A_{12})')$ .