Assessing Synchronicity by Exploiting the Resurrection of the Phillips Curve*

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* Opinions expressed by the authors do not necessarily reflect the official viewpoint of the Oesterreichische Nationalbank or the Eurosystem.

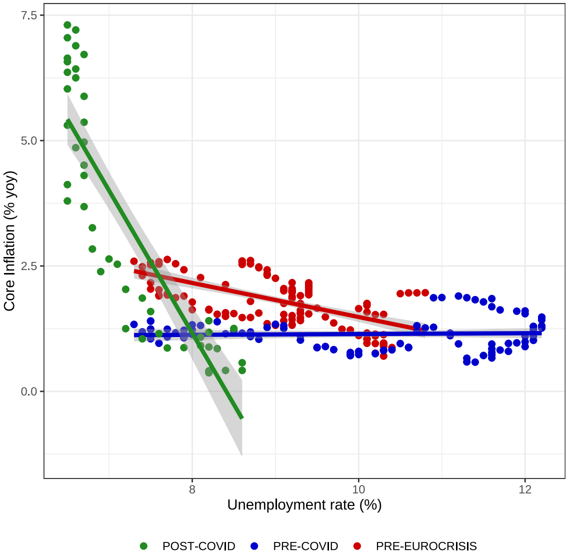
Introduction

- Homogeneity of economic performance across countries is vital in a monetary union and hence for the successful conduct of monetary policy.
- Euro area is still subject to expansion with exposure to global and local shocks.
- Plenty of research on overall business cycle convergence emerged during the early years of the euro area and global shock episodes (GFC/Eurocrisis).
- Recent shocks (Covid, supply chain pressure, geopolitical turmoil) put synchronicity and convergence issues back to the agenda.
- Recent research on Central, Eastern, and Southeastern European (CESEE) region is scarce (Gächter et al., 2013; Stanišić, 2013; Kolasa, 2013; Głodowska and Pera, 2019), despite being EU/euro area candidates.
- Importance of taking *structural* factors of the economies into account to assess shock absorption and thus monetary policy transmission.

The Phillips curve

- One underlying aspect important for monetary policy $\Rightarrow$ linkage between inflation and unemployment, namely the Phillips curve (Phillips, 1958).
- Evidence over the zero lower bound episode suggests that this relationship became muted, implying a flat curve.
- However, the last few years in the aftermath of the Covid-19 pandemic, the negative relationship seemed to have returned (Hazell et al., 2022) $\Rightarrow$ *Resurrection* of the Phillips curve.
- Thus, Phillips curve slopes may be subject to changes over time and not constant $\Rightarrow$ potentially reflecting (in a reduced form way) structural changes.
- The importance of the reduced-form PC for the policymaker:
  - Lower bound estimation of the slope.
  - Predictive power of economic slack for inflation (Eser et al., 2020).

Preliminary evidence for a time-varying Phillips curve relationship in the euro area



Contribution

- Assessing business cycle convergence for a subset of CESEE countries towards the euro area until the recent end (December 2023).
- Expanding standard measures of convergence providing a multi-faceted picture of convergence.
- Analysing *second moments* of business cycles: comparing cycle's time-varying standard deviations with the euro area.
- Estimating **reduced-form** Phillips curves with a time-varying slope coefficient and comparing CESEE results to the euro area:

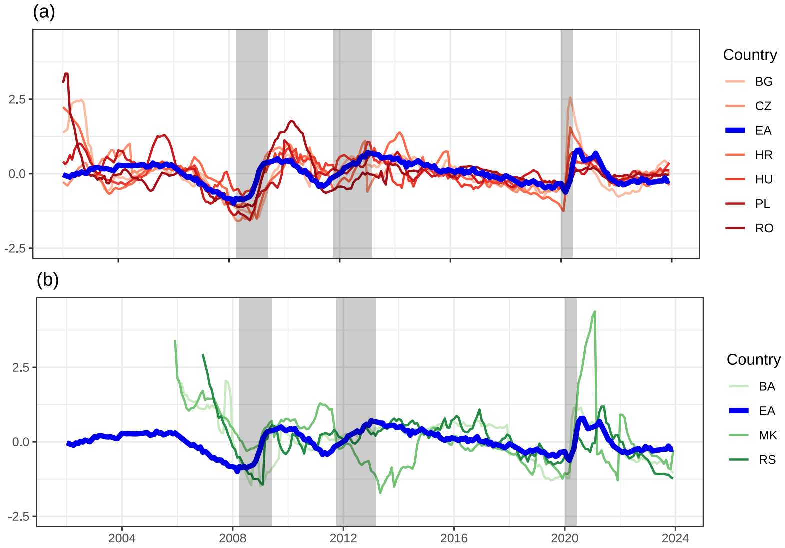
Data and obtaining the business cycles

- Sample consists of *euro area*, *euro area candidate countries* (Czech Republic, Bulgaria, *Croatia*, Hungary, Poland and Romania) and *EU candidate countries* (Bosnia and Herzegovina, North Macedonia, and Serbia).
- Monthly data ranging from 2002M1 to 2023M12.[1]
- Given data availability and structural country idiosyncrasies, we extract the business cycle from unemployment rates.
- For each country, we extract the latent trend component with the Kalman filter (Kalman, 1960).
- The business cycle is then obtained as the difference of the observed unemployment rate and the estimated trend component.

[1] Due to data limitations for Bosnia and Herzegovina, North Macedonia and Serbia, their samples start in 2006M1, 2005M12 and 2006M12, respectively.

CESEE business cycles relative to the euro area (dark blue)

▸ Full set of plots



Assessing alignment through four distinct measures I

- **Synchronicity**: Equal to unity, if both economies are in the same business cycle phase (Mink et al., 2007). A moving average is reported.

$$s_{ij,t} = \frac{c_{i,t}\, c_{j,t}}{|c_{i,t}\, c_{j,t}|}$$

- **Rolling correlation**: Measures strength and direction of two cycles over the moving window.

$$r_t = \frac{\sum_{t-w-1}^{t} (c_{i,t} - \bar{c}_i)(c_{j,t} - \bar{c}_j)}{\sqrt{\sum_{t-w-1}^{t} (c_{i,t} - \bar{c}_i)^2 \sum_{t-w-1}^{t} (c_{j,t} - \bar{c}_j)^2}}$$

- In line with estimates for the business cycle duration of the euro area, we define a moving window of 53 months for both measures. $\Rightarrow$ The value at time t corresponds to the average measure of the preceding 53 months.

Assessing alignment through four distinct measures II

- **Euclidean distance**: Measures the absolute distance between two cycles for each point in time.

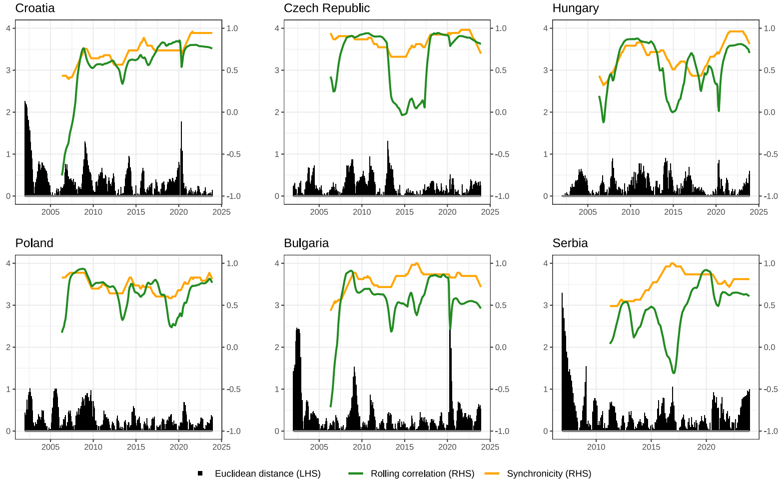
$$d_t = \sqrt{(c_{i,t} - c_{j,t})^2}$$

- **Time-varying standard deviation**: Measures business cycle volatility.

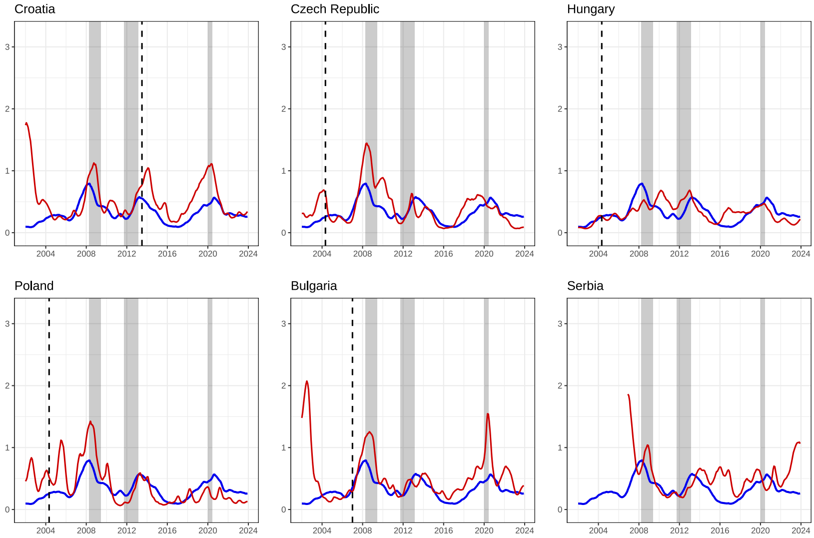
$$c_t = \nu_t, \quad \nu_t \sim \mathcal{N}(0, \omega_t^2)$$
$$h_t = \log \omega_t = \rho_h h_{t-1} + u_{h,t}$$
$$u_{h,t} \sim \mathcal{N}(0, \sigma_h^2), \quad h_0 \sim \mathcal{N}\left(0, \frac{\sigma_h^2}{1-\rho_h^2}\right)$$

▸ Details on the SV model

Business cycle synchronicity with the euro area



Time-varying standard deviation of the EA (blue) and the respective country (red)



Summary of the first results: Synchronicity Measures

- At the end of the sample, the convergence measures are close to or at the highest level.
- Euro candidates are more closely aligned than EU candidates.
- ”Drops” of the rolling correlation and synchronicity measures around 2015 hint at heterogeneities during the Eurocrisis.
- Absolute differences have declined over time for almost all countries.
- Volatility in CESEE shows a similar pattern to the EA, albeit with a slightly stronger magnitude.

Digging deeper: Phillips curve estimation across countries

- After assessing overall synchronicity measures of CESEE countries with the euro area, we want to focus on the underlying relationship of inflation and economic slack.
- Estimation of country-wise reduced form Phillips curves using a time-varying parameter (TVP) regression model.
- We rely on the previously obtained cyclical unemployment rate as a measure of economic slack.
- Analysis of the time-varying slope coefficient of the Phillips curves in CESEE and the euro area.
- Similar slope coefficients of the PC could be an indicator of close overall economic alignment and similar shock absorption capacity.

Model specification

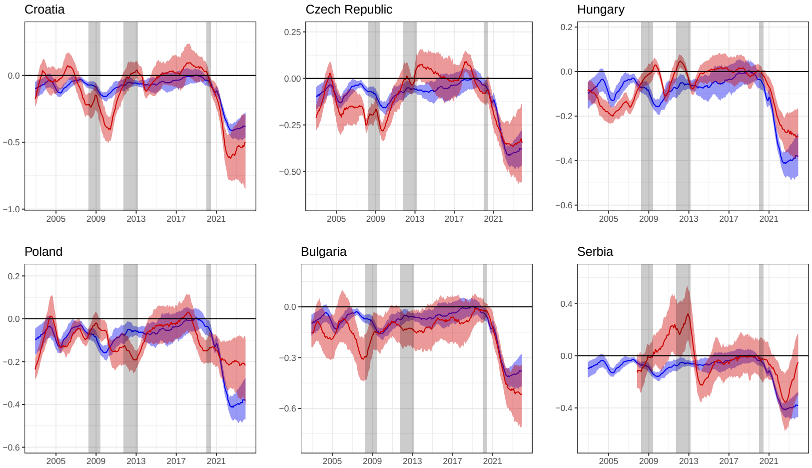
- Time-varying parameter regression of core inflation ($\texttt{CORE}$)

$$\texttt{CORE}_t = \texttt{SLACK}_t \beta_t + \boldsymbol{x}_t \gamma_t + \varepsilon_t$$

  on our measure of the business cycle, $\texttt{SLACK}$.

- The set of controls in $\boldsymbol{x}_t$ consists of
  - $\texttt{L\_INFL}$: the 12-month average of inflation, lagged by one period to proxy expectations (Forbes et al., 2021),
  - $\texttt{GECON}$: the Global Economic Conditions indicator to proxy global conditions (Baumeister et al., 2022),
  - $\texttt{GSCPI}$: the Global Supply Chain Pressure Index, to proxy supply side distortions,
  - $\texttt{OIL}$: the price of Brent crude oil, and
  - $\texttt{COMMODITY}$: a Real Commodity Price Factor (Baumeister and Guérin, 2021).

Phillips curve slopes' of respective countries (red) and the euro area (blue)



Concluding Remarks

- Our augmented set of convergence measures indicates an increasing economic convergence of the CESEE region towards the euro area.

- The assessment of the Phillips curve showed three distinct results
  - In the years leading up to the Covid-19 pandemic, the relationship between inflation and unemployment was notably weak across most economies, reflecting a ”flattening” of the Phillips curve.
  - Following the Covid-19 pandemic, the inflation-unemployment relationship appears to have re-emerged in both the euro area and the CESEE region.
  - The economic slack coefficients for CESEE countries now exhibit similar patterns to those in the euro area towards the end of the sample period.

- Countries preparing to join the euro area demonstrate closely aligned economic behavior with the euro area since their EU accession.

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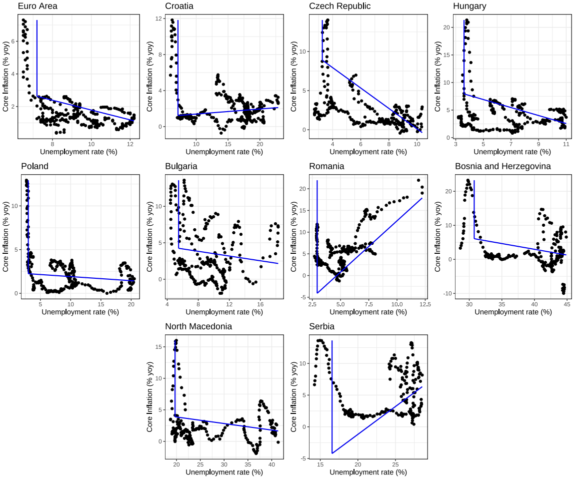
APP: Core inflation and the unemployment rate



Notes: Following Benigno and Eggertsson (2024), this figure shows percentage year on year change in core inflation and the unemployment rate. The black dots represent observed values. For each country, the blue vertical line corresponds to the 10th percentile of the unemployment rate and the slanted blue line is estimated via OLS on the remaining data points. The sample stretches from 2002:M1 to 2023:M12 for most countries. The samples for Bosnia and Herzegovina, North Macedonia and Serbia, start in 2006:M1, 2005:12 and 2006:12, respectively.

APP: Kalman filter: A univariate state space model

- Measurement equation:

$$y_t = z\beta_t + \nu_t, \quad \nu_t \sim \mathcal{N}(0, r), \quad t = 1, \ldots, T, \tag{1}$$

  where y_t is a scalar time series, ν_t is a Gaussian error term with constant variance, r, and z links the latent states, β_t, to the measurement.

- State equation:

$$\beta_t = h\beta_{t-1} + \eta_t, \quad \eta_t \sim \mathcal{N}(0, q), \tag{2}$$

  where h is the state transition coefficient and η_t is a Gaussian error term with constant variance, q.

APP: Kalman filter: Prediction and updating

- Prediction step:

$$\hat{\beta}_{t|t-1} = h\hat{\beta}_{t-1} \tag{3}$$
$$P_{t|t-1} = h^2 P_{t-1} + q \tag{4}$$

- Updating step:

$$\hat{\beta}_t = \hat{\beta}_{t|t-1} + K_t \tilde{y}_t \tag{5}$$
$$P_t = P_{t|t-1} - K_t z P_{t|t-1} \tag{6}$$

- Helper equations:

The measurement residual:	$\tilde{y}_t = y_t - z\hat{\beta}_{t|t-1}$
The innovation covariance matrix:	$S_t = z^2 P_{t|t-1} + r$
The Kalman gain:	$K_t = P_{t|t-1} z S_t^{-1}$

APP: Kalman filter: Kalman gain

- Determines the weight given to the new measurement when updating the estimate of the system's state.
- The Kalman gain balances the uncertainty in the prediction with the uncertainty in the measurement
- High (low) measurement noise will decrease (increase) the Kalman gain and high (low) uncertainty of the predicted state implies a small (large) Kalman gain

APP: Kalman filter: Prior settings

- For estimation, we set $z = h = 1$. This implies a direct measurement of the state and a random walk law of motion
- Importance of the variances r and q: Values reflect a trade-off between the responsiveness and smoothness of the Kalman filter estimate.
- We specify an inverse Gamma prior on the variances:

$$r^{-1} \sim \mathcal{G}\left(a_r, b_r\right) \quad \text{and} \quad q^{-1} \sim \mathcal{G}\left(a_q, b_q\right), \tag{7}$$

where $a_r = 1 + \frac{T}{2}$, $b_r = 10^2 + \frac{1}{2}\sum_{t=1}^{T} \tilde{y}_t{}^2$, $a_q = 10^2 + \frac{T}{2}$ and $b_q = 1 + \frac{1}{2}\sum_{t=1}^{T}(\beta_t - \beta_{t-1})^2$

APP: Obtaining the cycles: Prior setup

- Importance of the variances r and q: Their values reflect a trade-off between responsiveness and smoothness of the Kalman filter estimate.
- We specify an inverse Gamma prior for both variances:

$$r^{-1} \sim \mathcal{G}\big(a_r, b_r\big) \quad \text{and} \quad q^{-1} \sim \mathcal{G}\big(a_q, b_q\big), \tag{8}$$

  where $a_r = \frac{T}{2}$, $b_r = 10^2 + \frac{1}{2}\sum_{t=1}^{T} \tilde{y}_t^{\,2}$, $a_q = 10^2 + \frac{T}{2}$ and $b_q = \frac{1}{2} + \frac{1}{2}\sum_{t=1}^{T}(\beta_t - \beta_{t-1})^2$.
- These priors imply that the implied posterior medians of the gamma distributions are approximately at a $10:1$ ratio between the measurement and the state equation.

$\Rightarrow$ Our estimate of the business cycle is the difference between the unemployment rate and the Kalman filter trend estimate

Obtaining the cycles: Alternatives and robustness

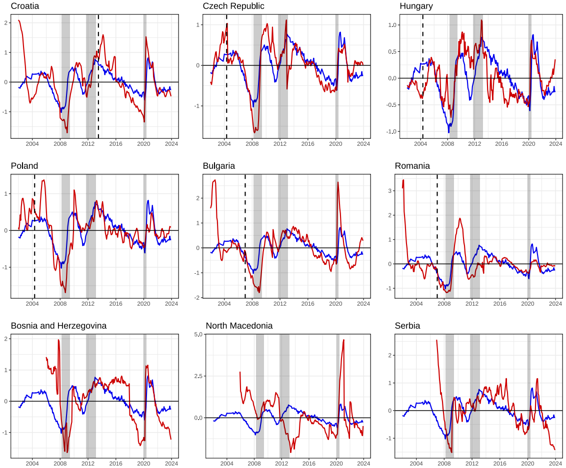
- Alternative methods such as the Hodrick-Prescott (HP) filter or the Hamilton filter come with significant drawbacks:
  - **HP filter:** Arbitrary smoothing parameter and end point bias (Hamilton, 2018).
  - **Hamilton filter:** Issues related to sample size (i.e., loss of approximately 15% of observations). Filter puts less emphasis on shorter cycles and more emphasis on longer cycles (Schüler, 2021).
- Our measurement of the business cycle explains roughly $70 - 90\%$ of the variance across countries.
- HP filter estimates explain roughly $75 - 95\%$ of the variance, which is likely higher due to the bias of the HP filter. Full table

APP: Variance of the unemployment rate explained by the Kalman filter and HP filter trend estimates across countries.

	`Kalman filter`	`HP filter`
Euro area	0.74	0.89
Bosnia and Herzegovina	0.86	0.97
North Macedonia	0.87	0.97
Czech Republic	0.82	0.91
Bulgaria	0.76	0.93
Croatia	0.88	0.95
Hungary	0.84	0.96
Poland	0.91	0.97
Romania	0.70	0.85
Serbia	0.85	0.97

Notes: `Kalman filter` refers to the R^2 of the Kalman filter trend estimate. `HP filter` refers to the R^2 of the HP filter trend estimate.

APP: CESEE business cycles (red) relative to Euro area (blue)



Notes: The figure shows the business cycle of the euro area (blue) and the respective country (red), which is the difference between the observed value of the unemployment rate and its Kalman filtered trend component. The dashed black line denotes the date of joining the European Union and the shaded grey areas corresponds to recessions as defined by the Euro Area Business Cycle Network (EABCN) The vertical axis shows the deviation from the trend in percentage points and the horizontal axis measures the time in months.

APP: Business cycle duration

- We rely on the algorithm proposed by Harding and Pagan (2002) to identify business cycle turning points and calculate the cycle duration for each country.
- Harding and Pagan (2003) show that this algorithm produced business cycle dates that closely align to the NBER business cycle dates.

Table: Business cycle duration in months as a sum of the average recession length and the average expansion length. ▸ Full table of BC durations

Region/Country	Duration
Euro area	53.00
CESEE average	39.21

⇒ Results in line with prior research on emerging market business cycle durations (Rand and Tarp, 2002).

APP: CESEE business cycle durations

Region/Country	Duration
Euro area	53.00
CESEE average	39.21
Croatia	46.60
Czech Republic	44.00
Hungary	35.81
Poland	31.11
Bulgaria	30.66
Romania	30.86
Bosnia and Herzegovina	39.50
North Macedonia	37.17
Serbia	57.17

Notes: `Duration` refers to the average business cycle duration in months as a sum of the average recession length and the average expansion length.

APP: A stochastic volatility model

- To address questions about the volatility of cycles, we follow Kastner (2019) and model the cyclical component of each country, c_j, in a stochastic volatility (SV) framework given by

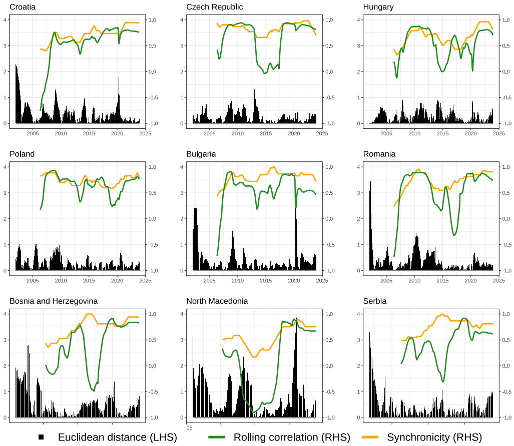
$$c_t = \nu_t, \quad \nu_t \sim \mathcal{N}(0, \omega_t^2), \tag{9}$$

  where ν_t is a Gaussian shock with zero mean and time-varying variance ω_t^2.
- We assume that ω_t follows a flexible stochastic volatility process:

$$h_t = \log \omega_t = \rho_h h_{t-1} + u_{h,t}, \quad u_{h,t} \sim \mathcal{N}(0, \sigma_h^2), \quad h_0 \sim \mathcal{N}\left(0, \frac{\sigma_h^2}{1-\rho_h^2}\right), \tag{10}$$

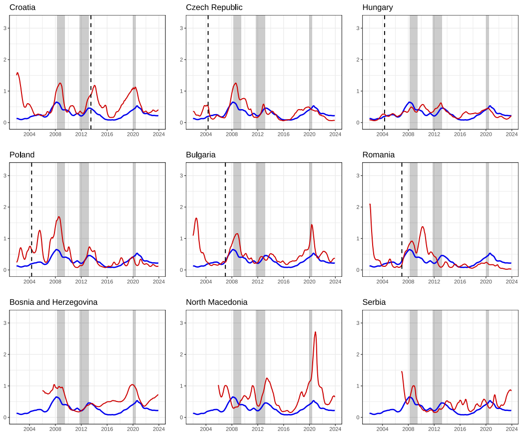
  with the logarithm of $h_t = \log \omega_t$ being assumed to evolve according to a stationary autoregressive process of order one. ρ_h denotes the persistence parameter, σ_h^2 the error variance, and h_0 the initial state of the log-volatility process.

APP: Business cycle convergence with the euro area



Notes: This figure shows country-wise relations to the euro area business cycle over time. Results for the rolling mean of the synchronicity measure are depicted in orange (right hand side), while the rolling correlation is reported in green (right hand side). The black bars show the Euclidean distance of the two corresponding cycles (left hand side). The rolling mean of the synchronicity measure and the rolling correlation are subject to a rolling window of $w = 53$ months.

APP: Time-varying standard deviation of the euro area (blue) and the respective country (red)



Notes: This figure shows estimates for the time-varying standard deviation of the business cycles of the respective countries (red) and the euro area (blue) following 10. The dashed black line denotes the date of joining the European Union and the shaded grey areas corresponds to recessions as defined by the Euro Area Business Cycle Network (EABCN). The vertical axis shows the time-varying standard error and the horizontal axis measures the time in months.

APP: A Time-varying parameter regression model I

- The standard TVP regression model is given by

$$y_t = \boldsymbol{x}_t \boldsymbol{\beta}_t + \epsilon_t, \quad \epsilon_t \sim \mathcal{N}(0, \sigma^2), \tag{11}$$

  where y_t contains our dependent variable of interest, $\boldsymbol{x}_t$ contains a set of K predictors.
- The states in $\boldsymbol{\beta}_t$ evolve according to a random walk denoted by

$$\boldsymbol{\beta}_t = \boldsymbol{\beta}_{t-1} + \boldsymbol{\eta}_t, \quad \boldsymbol{\eta}_t \sim \mathcal{N}(0, \boldsymbol{\Omega}), \tag{12}$$

  with $\boldsymbol{\Omega} = \text{diag}(\omega_1, \ldots, \omega_K)$. Since $\boldsymbol{\Omega}$ is a diagonal matrix, the innovations are conditionally independent.

APP: A Time-varying parameter regression model II

- We follow Frühwirth-Schnatter and Wagner (2010) and exploit the non-centered specification of our regression model:

$$y_t = \boldsymbol{x}_t \beta_0 + \boldsymbol{x}_t \sqrt{\boldsymbol{\Omega}}\, \tilde{\beta}_t + \epsilon_t. \tag{13}$$

- The respective state equation reads as follows

$$\tilde{\boldsymbol{\beta}}_t = \tilde{\boldsymbol{\beta}}_{t-1} + \mathbf{v}_t, \quad \mathbf{v}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{I}_K). \tag{14}$$

- We treat the square root of the state innovation variances in $\boldsymbol{\Omega}$ as additional regression coefficients.

APP: A Time-varying parameter regression model III

- Uninformative prior on the constant part:

$$\beta_0 \sim \mathcal{N}(0, \boldsymbol{I}) \tag{15}$$

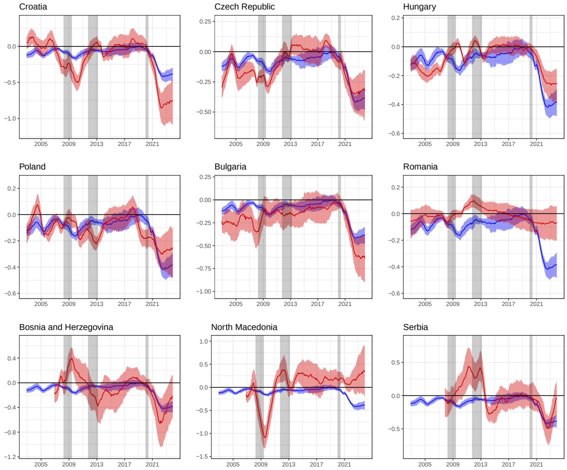
- Hierarchical Normal-Gamma prior on the standard deviations of the innovations is given by

$$\sqrt{\omega_j}|\xi_j^2, \phi \sim \mathcal{N}\left(0, \frac{2}{\phi}\xi_j^2\right), \quad \xi_j^2 \sim \mathcal{G}(a_\xi, a_\xi), \quad \phi \sim \mathcal{G}(c_\xi, d_\xi), \tag{16}$$

  where the set of hyperparameters, $\theta = (a_\xi, c_\xi, d_\xi)$ The parameter ϕ acts as a global scaling parameter, while ξ_j^2 governs local shrinkage.

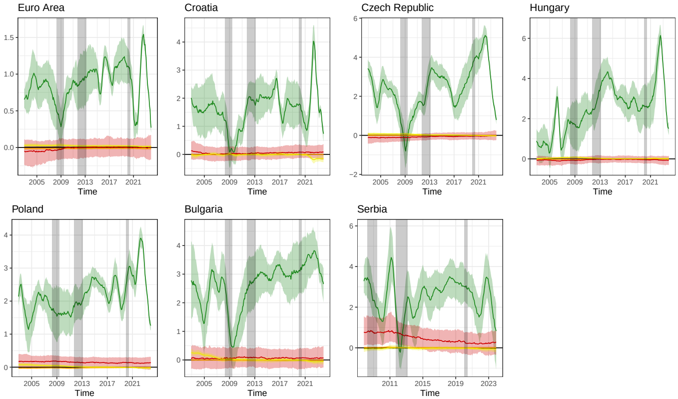
- For estimation, we set $a_\xi = 0.1$, $c_\xi = 0.01 + a_\xi K$, and $d_\xi = 0.01 + a_\xi \sum_{k=1}^{K} \frac{\sqrt{\omega_k}}{2}$

APP: Slack coefficient of respective countries (red) and the euro area (blue)



Notes: Time-varying estimate of the slack coefficient across the sample countries. For each plot, the blue line represents the euro area and the red line represents the respective country. Shaded areas correspond to the 68% credible interval.

APP: Other coefficients of respective countries



Notes: Time-varying estimate of the other coefficients across the sample countries. Solid line corresponds to the posterior median, shaded areas correspond to the 68% credible interval.