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EURO AREA BUSINESS CYCLE: THE EVOLUTION OF EXTRA-REGIONAL AND INTRA-REGIONAL DYNAMICS

Key points

- *The Global Financial Crisis and the subsequent macroeconomic imbalances that emerged across euro area countries have raised the question of whether there has been a meaningful change in business cycle dynamics in the region. To date, however, empirical findings on the characteristics of the euro area business cycle have reached different conclusions, and studies on post-crisis experience appear limited.*

- *The objective of this paper is to provide a comprehensive empirical investigation of the evolution of the euro area business cycle over the period 1990-2017, highlighting business cycle patterns at both the extra- and intra-regional levels.*

- *Based on a dynamic factor model with rich hierarchical structure, our results provide evidence of a distinct euro area cycle with limited exposure to external factors. Nevertheless, within the region, member countries' cycles are not well-synchronised--with two intra-regional cycles emerging in the post-crisis period, (one among core countries like Germany and France and the other linking Italy, Spain and Portugal).*

- *A key implication of this study is that intra-regional cyclical heterogeneity is likely to represent a constraint to monetary policy-makers at the ECB*[1]*. In particular, the constraint of using a single monetary policy to address country-specific conditions appears to be more profound at times when effective policy actions are most needed, such as in the aftermath of a crisis.*

[1] In a June 2017 speech, ECB board member Cœuré acknowledged that "the euro area does not meet all of the classic requirements of an optimal currency area …" and cyclical heterogeneity across member countries can cause "the appropriate monetary policy stance to vary across the currency union". See Cœuré, B. (2017), "Convergence matters for monetary policy", speech at the Competitiveness Research Network (CompNet) conference on "Innovation, firm size, productivity and imbalances in the age of de-globalization" in Brussels, 30 June.

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I. INTRODUCTION

How has the euro area business cycle evolved overtime? What are the major factors driving business cycles in the region? Are these factors mainly global or are they specific to a particular group of countries in the region? Answering these questions is highly relevant to assessing the effectiveness of monetary policy-making in the euro area. For instance, the extent to which the ECB could stabilise turbulences could become more limited if the region is greatly exposed to external shocks. Understanding the degree of synchronisation across members' cycles is also important, given that cycle symmetry is regarded as one of the key criteria for an optimal currency union (see Mundell (1961) and McKinnon (1963)). Regional central banks like the ECB could face a dilemma in accommodating country-specific macro conditions if countries in the region have very asymmetric cycles.

While a lot has been written on the historical characteristics of the euro area business cycle, the literature is a long way from reaching consensus on the major driving factors of cycle dynamics in the region. For instance, depending on the period examined, the selection of variables used, and the methodologies adopted to construct business cycles and to make inference, some studies identify the emergence of a European cycle in the 1990s (e.g. Canova, Ciccarelli, and Ortega (2008)), while others date this phenomenon back to the 1970s (e.g. Lumsdaine and Prasad (2003)), and some don't find the European cycle at all (e.g. Artis (2003)).

The 2008 Global Financial Crisis (GFC) re-ignited interest in this issue. It is believed the crisis intensified macroeconomic imbalances between Northern euro area countries such as Germany and those in the South, such as Italy and Spain. Despite considerable discussion on the sources of post-crisis divergence[2], there is still limited empirical work on the extent to which the synchronicity of the euro area macro cycle has changed in relation to the crisis. For those who do attempt to study the issue, they tend to focus on a rather restrictive set of large euro area countries (Ferroni and Klaus (2015))[3], rather than analyse the common cycles that could arise at either the global or sub-regional level. In this paper, we show that

[2] Some studies attribute the divergence to the presence of a strong financial accelerator in the aftermath of the crisis. For instance, De Grauwe and Ji (2013) emphasise the role of investors' "animal spirits", which they assign to the inability of euro area member countries to issue debts in their own currency, when explaining a significant part of the surge in the spreads of euro area peripheral countries in 2010-2011. Bayoumi and Eichengreen (2017) show that the highly procyclical nature of private bank lending in the region amplify shock transmissions and deepen contraction in the peripheral countries.

[3] Ferroni and Klaus (2015) look at Germany, France, Italy and Spain in their study.

there are, in fact, distinctive features associated with the extra-regional and intra-regional business cycle dynamics.

To fill in some of the gaps in the literature, this study attempts to shed light on the subject using a more recent dataset (1990-2017) that encompasses a broad range of countries, including major advanced and emerging market economies. As commonly adopted in the literature (see, for example, Kose et al. (2003, 2008), Stock and Watson (2011, 2016)), we examine business cycle dynamics in the euro area through a dynamic factor model.[4] This class of model offers a parsimonious way to deal with a large dataset, in which high-dimensional dynamics across a subset or full set of the data can be modelled as a small number of unobserved factors as is commonly assumed in DSGE modelling (see Fernandez-Villaverde et al. (2007)). Such a modelling approach attenuates the problem of traditional VAR modelling that tends to limit the number of driving variables or shocks that can be analysed. The factor layers of the model can also be conveniently restructured to account for various channels through which common shocks can be transmitted to national business cycles. This enables us to separately assess shocks at the global, regional, sub-regional, and country-specific levels and their respective contributions to fluctuations in macroeconomic aggregates.[5]

In our implementation, we decompose macroeconomic fluctuations in national GDP, consumption and investment into the following factors: (i) global factor, which captures common fluctuations across all variables and all countries in the sample, (ii) three regional factors specific to each group of countries (euro area countries, non-euro-area advanced economies, emerging market economies), (iii) country-specific factors that are common across all variables in a given country, (iv) the idiosyncratic factor that is specific to each macroeconomic variable. By focusing on multiple indicators of real activities we are able to obtain a more robust estimate of the underlying business cycle dynamics.[6]

We begin by showing the trend of the euro area business cycle region-wide since the early 1990s, focusing on its co-movement with the external cycles. We find evidence of a distinct euro area cycle with limited exposure to global factors, collaborating with several other findings (Kose et al. (2012)) that highlight the emergence of regional cycles in the globalisation era back in the

[4] Alternative methodologies include using simple statistics such as bivariate correlation index and semi-structural or structural models like the Global VAR and panel VAR.
[5] That said, the standard factor model specification cannot go further to distinguish truly "global" and "regional" shocks from those that emanate in one country and spill over to all other countries.
[6] The NBER also looks at a variety of indicators for dating turning points in US business cycles.

mid-1980s. We then examine the degree of business cycle synchronicity among individual euro area countries. We find that synchronisation was limited across member countries even before the onset of the 2008 crisis, including the first nine years of the operation of the single monetary union. Since then, the crisis has notably widened the divergence. We also find that it generally takes longer for the so-called peripheral countries—namely, the GIIPS economies (Greece, Ireland, Italy, Portugal, Spain)—to re-converge with the euro area cycle in the post-crisis period than for the core countries such as Germany and France; and that separate intra-regional factors have emerged for these two groups in recent years.

The remaining part of this paper is structured as follows: Section II describes the empirical model and data, section III discusses the empirical results and implications, section IV concludes.

II. EMPIRICAL METHODOLOGY AND DATA

II.A. Model

We apply a four-level dynamic factor model of Moench et al. (2013) to a cross-country panel of macroeconomic time series. Let $b = 1, \ldots, B$ denote the number of regions, $s = 1, \ldots., S$ the number of countries, and $n = 1, \ldots., N$ the total number of macro variables of each country, and t denotes time. In our baseline implementation, our data is partitioned in such a way that an observed series Z_{bsnt}[7] evolves according to a country-specific factor $H_{bst}^{country}$, each country-specific factor is explained by a regional factor G_{bt}^{region} and all regional factors are in turn driven by a common global factor F_t^{global}. This implies the following hierarchical factor structure (from bottom to top):

$$
\begin{aligned}
Z_{bsnt} &= \lambda_{bsn}^{H} H_{bst}^{country} + e_{bsnt}^{Z} \\
H_{bst}^{country} &= \lambda_{bs}^{G} G_{bt}^{region} + e_{bst}^{H} \qquad (1) \\
G_{bt}^{region} &= \lambda_{b}^{F} F_{t}^{global} + e_{bt}^{G}
\end{aligned}
$$

[7] Covariance stationarity approximately holds for our data, which is expressed in terms of the growth rate of the underlying series.

where $\lambda^H_{bsn}, \lambda^G_{bs}$ and λ^F_b denote the factor loadings associated with the country-specific, regional and global factors, respectively; e^Z_{bsnt}, e^H_{bst} and e^G_{bt} are the idiosyncratic component and the orthogonal component of the country-specific and regional factors, respectively.

The hierarchical (bottom-up) factor structure in (1) has some appealing features over a single-equation (top-down) factor representation (e.g. Kose et al. (2008))[8]. By construction, the single equation approach does not explicitly model the transmission of shocks at different factor levels. As a result, such approach only yields components of lower-level factors that are orthogonal to the upper level factors i.e. e^G_{bt}, e^H_{bst} For example, it can only identify parts of the euro area country-specific factors that are uncorrelated to the euro area regional factor and the global factor. The hierarchical structure employed here, however, allows us to estimate *de facto* regional, country-specific factors i.e. G^{region}_{bt}, $H^{country}_{bst}$ which could be useful for the purpose of our inference on synchronicity.

The evolution of each layer of factor and the idiosyncratic component is assumed to follow a stationary, normally distributed autoregressive process[9] of order q[10]:

$$F^{global}_t = \psi^F(L)F^{global}_t + \varepsilon^F_t \qquad \varepsilon^F_t \sim iid\ N\left(0, \sigma^{2^F}\right)$$

$$e^G_{bt} = \psi^G_b(L)e^G_{bt} + \varepsilon^G_{bt} \qquad \varepsilon^G_{bt} \sim iid\ N(0, \sigma^{2^G}_b)$$

$$e^H_{bst} = \psi^H_{bs}(L)e^H_{bst} + \varepsilon^H_{bst} \qquad \varepsilon^H_{bst} \sim iid\ N(0, \sigma^{2^H}_{bs}) \qquad (2)$$

$$e^Z_{bsnt} = \psi^Z_{bsn}(L)e^Z_{bsnt} + \varepsilon^Z_{bsnt} \qquad \varepsilon^Z_{bsnt} \sim iid\ N(0, \sigma^{2^Z}_{bsn})$$

[8] A top-down analogy to the factor structure represented by equation (1) has the form $Z_{bsnt} = \lambda^F_{bsn}F^{global}_t + \lambda^G_{bsn}e^G_{bt} + \lambda^H_{bsn}e^H_{bst} + e^Z_{bsnt}$

[9] Examining macroeconomic series such as GDP and its components suggests that these series tend to be governed by some lag structures. An autoregressive process is therefore appropriate in this context.

[10] In principle, the lag polynomial matrices ψ can be of different order, both across factor levels and units in the same factor layer. For simplicity and parsimony, however, we set them as $AR(1)$. As commonly adopted in the literature (see for example, Moench et al. (2013), Ferroni and Klaus (2015)), such lag structure should suffice to capture most contemporaneous and lagged spillovers across variables and countries in our sample. As a robustness check, we also rerun our model using a lag order of four. We obtain qualitatively similar results.

where $\psi^F, \psi_b^G, \psi_{bs}^H$ and ψ_{bsn}^Z are lag polynomial matrices, the innovations to factor $\varepsilon_t^F, \varepsilon_{bt}^G, \varepsilon_{bst}^H$ and the idiosyncratic error ε_{bsnt}^Z are iid normally distributed.[11].

II.B. Identification and Estimation

We follow the standard literature approach to identify the signs and scales of the unobserved factors and their loadings. For sign identification, we require the factor loading for the global factor to be positive for US GDP growth; the factor loading for the regional factors to be positive for the first country listed for each country group in Appendix A; and country factors are identified by positive loading for GDP growth for each country.[12] Following Sargent and Sims (1977), and Stock and Watson (1989, 1993) for scale identification, we assume that factor innovations $\varepsilon_t^F, \varepsilon_{bt}^G, \varepsilon_{bst}^H$ have fixed variances.

Estimation is via Bayesian procedures, which work efficiently with a large cross-section of data and can easily handle a large number of dynamic factors and parameters. For our estimation, specifically, we apply the MCMC procedure to sample from the conditional posterior distribution of factors and parameters. The distribution of the resulting Markov chain will converge with the posterior joint distribution of interest. See Appendix B for details of the sampling procedure.

II.C. Data

Our dataset is constructed primarily from the OECD's Quarterly National Account and comprises quarterly data over the period 1990 Q2-2017 Q4 for 29 countries[13]. We focus on real GDP, real private consumption, and real fixed capital investment as our measures of economic activities. We compute the quarterly growth rates and demean each series. Countries in our sample are divided into three groups comprising, (i) 11 euro area economies; (ii) 10 other non-euro-area

[11] The assumptions of constant factor loading and constant factor volatility imply that our model does not have the full flexibility to account for potential changes in countries' exposure to common shocks, and the relative importance of shocks overtime. While these assumptions might seem restrictive at first sight, we believe the time-varying features that are lost are rather limited, given the relatively short period i.e. 28 years (1990-2017) that is examined, and the fact that much of the cyclical variation is designed to be captured by the time-varying factors and idiosyncratic term in this class of model.

[12] Generally, this requires the factor loading for each factor to be lower-triangular of order zero with positive elements on its diagonal.

[13] Quarterly data on China's National Account is sourced from the Federal Reserve Bank of Atlanta. Construction of the dataset is based on the methodology laid out by Chang et al. (2016). For other EMEs whose data are not available in quarterly frequency in the early period of the sample, we apply the cubic spine interpolation on annual data from the respective national sources.

advanced economies; (iii) 8 emerging market economies. As stated previously, our primary interest is the euro area business cycle. Countries outside the euro area are used to control for the impact of external factors on the euro area cycle, which will enable us to differentiate between the relative importance of global and regional factors in driving macroeconomic activities in the euro area.

To study how business cycle dynamics have shifted in relation to the 2008 GFC, we divide our sample into two distinct periods: the pre-crisis episode (1990 Q2-2007 Q4) and the post-crisis period (2009 Q3-2017 Q4). As in Bayoumi and Eichengreen (2017), we exclude the crisis observations (2008 Q1-2009 Q2) from our estimation, which would otherwise strongly bias our results towards finding highly correlated shocks everywhere.

III. RESULTS

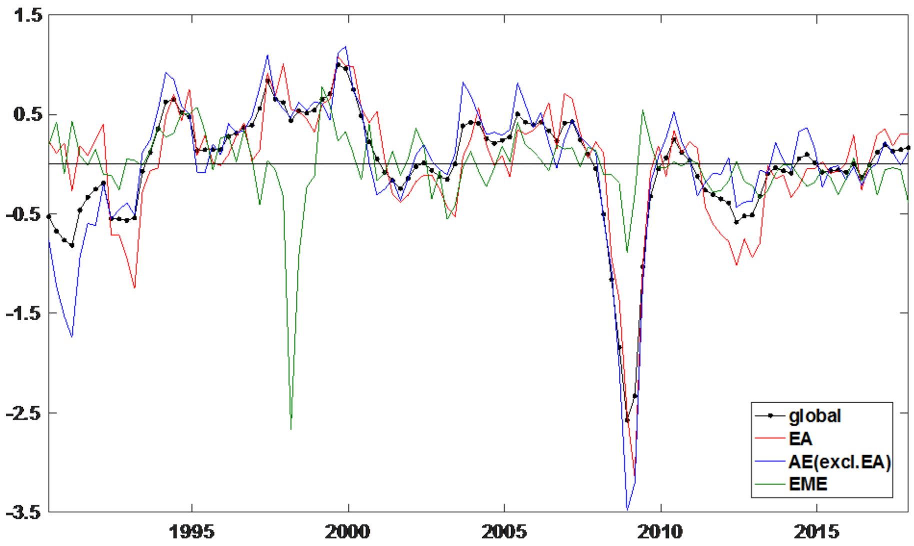
Overall, our estimation results give support to a distinct euro area cycle in which the global factor only accounts for an insignificant share of macroeconomic fluctuations of euro area countries. There are, however, notable asymmetries within the region, further exacerbated by the crisis with more divergence seen among some core and peripheral countries.

III.A. Euro area cycle distinct from the global cycle

First, we examine the relation between the euro area and the external cycles. Figure 1(a) displays the posterior means of factors estimated from the baseline model specification (1)-(2), over the full sample period.[14]

[14] We acknowledge the possibility of the presence of a structural break around the time of the 2008 crisis, but as shown by Bates et al. (2013), structural break (on factor loadings) tends to have little implication in the robustness of the factor estimates.

Figure 1(a). Estimates of the posterior mean of global and regional factors, 1990 Q2-2017 Q2



Notes: We estimate the model with factor structure defined by equation (1) over the full sample period, and plot the mean of the posterior distribution of the global and the three regional factors. The global factor captures all common fluctuations across all countries and macro aggregates (i.e. GDP growth, consumption growth, investment growth) in the sample. The regional factors capture all common fluctuations specific to a country group. EA, AE(excl.EA) and EME refer to euro area economies, non-euro-area advanced economies and emerging market economies, respectively.

Sources: OECD and author's estimation.

As shown in the figure, the euro area factor has tracked the global factor fairly closely since the late 1990s, around the time when the single monetary union regime came into effect[15]. This reflects tight linkages between the region and other advanced economies, apparently suggesting a strong dependence of the euro-area cycle on the external cycles. On the other hand, the euro area cycle appears to be quite distant from the EMEs cycle, with major departures observed in the aftermath of the two great crises: the 1997 Asian Financial Crisis and the 2008 GFC. As our sample comprises disproportionately more advanced economies it might, in a sense, produce a closer tie between the euro area and global factors than otherwise would be the case.[16]

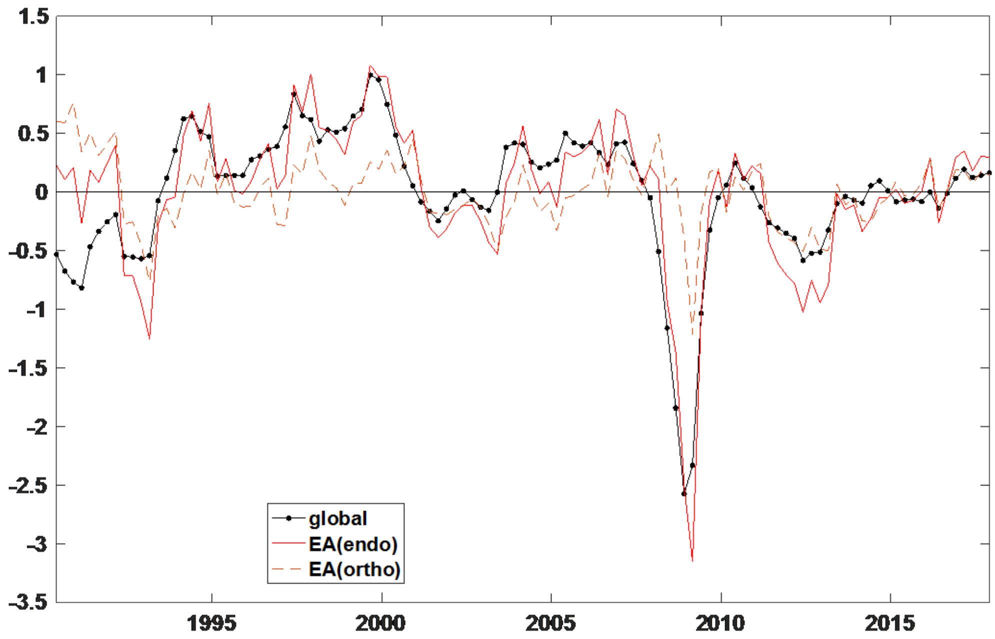
Nevertheless, our results reveal there are substantial euro area-specific dynamics. Figure 1(b) shows that much of the evolution of the euro area factor can

[15] The factor loadings associated with the euro area factor on the global factor are positive for the entire posterior distribution.

[16] There are 21 advanced economies and 8 emerging market economies in our sample.

be accounted for by its own orthogonal component ($e^{G}_{EA.t}$) that evolves independently from the global factor. The orthogonal component moves largely in tandem with the euro area factor.[17]. This points to the presence of a distinct euro area cycle. As will be shown later, the euro area orthogonal factor actually plays a much more important role relative to the global factor in accounting for GDP growth variations for most euro area economies.

Figure 1(b): Estimates of the posterior mean of the global and euro area region factors, 1990 Q2-2017 Q2



Notes: We estimate the model with factor structure defined by equation (1) over the full sample period, and plot the mean of the posterior distribution of the global factor, the euro area factor and its orthogonal component. The euro area regional factor captures all common macro fluctuations across all euro area countries in the sample. The orthogonal component of the euro area regional factor evolves independently from the global factor. EA(endo) and EA(ortho) refer to the euro area regional factor ($G^{regioin}_{EA.t}$) and its orthogonal component ($e^{region}_{EA.t}$), respectively.

Sources: OECD and author's estimation.

So, what are the main driving forces of country-level fluctuations? To measure the relative contribution of different factors to variations of macroeconomic aggregates, we decompose the variance of macroeconomic aggregates attributable to each factor.

[17] To test for the statistical significance of the degree of synchronisation between the euro area factor and its orthogonal component, we perform the Harding and Pagan (2006) test. Our results confirm perfect synchronisation between the two. (See Appendix C for a detailed definition of the null hypothesis, the test procedures and the test results).

Equations (1)-(2) imply the following exogenous process for observed macroeconomic series n:

$$Z_{bsnt} = \Lambda_{bsn}^{global} F_t^{global} + \Lambda_{bsn}^{region} e_{bt}^{region} + \lambda_{bsn}^{country} e_{bst}^{country} + e_{bsnt}^{idio} \qquad (3)$$

where, $\Lambda_{bsn}^{global}=\lambda_{bsn}^{H}\lambda_{bs}^{G}\lambda_{b}^{F}$, $\Lambda_{bsn}^{region}=\lambda_{bsn}^{H}\lambda_{bs}^{G}$

Given independence of the factor components in equation (3) [18], the variance of the observed macroeconomic series n can be written as:

$$var(Z_{bsnt}) = (\Lambda_{bsn}^{global})^2 var(F_t^{global}) + \left(\Lambda_{bsn}^{region}\right)^2 var(e_{bt}^{region}) + \left(\lambda_{bsn}^{country}\right)^2 var(e_{bst}^{country}) + var(e_{bsnt}^{idio}) \qquad (4)$$

and the proportion of the variance of the macroeconomic series that is explained by the global, the regional, the country-specific and the idiosyncratic factors are represented by equations (5a)-(5d), respectively:

$$\frac{(\Lambda_{bsn}^{global})^2 var(F_t^{global})}{var(Z_{bsnt})} \qquad (5a)$$

$$\frac{(\Lambda_{bsn}^{region})^2 var(e_{bt}^{region})}{var(Z_{bsnt})} \qquad (5b)$$

$$\frac{(\lambda_{bsn}^{country})^2 var(e_{bst}^{country})}{var(Z_{bsnt})} \qquad (5c)$$

$$\frac{var(e_{bsnt}^{idio})}{var(Z_{bsnt})} \qquad (5d)$$

Table 1 displays the mean variance shares of euro area countries' GDP growth attributable to the global, euro area region, and country and idiosyncratic factors.

[18] The global factor F_t^{global} is independent of any other factors by construction.

Table 1. Variance decomposition of real GDP growth of individual euro area countries: pre-crisis (1990 Q2-2007 Q4), post-crisis (2009 Q3-2017 Q4)

	Global		Region (euro area)		Country & Idiosyncratic	
	Pre-crisis	Post-crisis	Pre-crisis	Post-crisis	Pre-crisis	Post-crisis
Germany	0.03	0.01	0.18	0.28	0.79	0.71
	(0.00,0.05)	(0.00,0.02)	(0.15,0.21)	(0.20,0.37)	(0.76,0.83)	(0.62,0.79)
Austria	0.01	0.01	0.05	0.25	0.95	0.74
	(0.00,0.01)	(0.00,0.02)	(0.00,0.09)	(0.02,0.59)	(0.89,0.99)	(0.38,0.98)
Belgium	0.06	0.03	0.39	0.64	0.55	0.33
	(0.01,0.11)	(0.00,0.05)	(0.29,0.48)	(0.49,0.79)	(0.46,0.65)	(0.19,0.48)
Spain	0.03	0.00	0.20	0.05	0.77	0.95
	(0.00,0.06)	(0.00,0.00)	(0.12,0.28)	(0.00,0.10)	(0.68,0.86)	(0.90,1.00)
Finland	0.01	0.01	0.06	0.33	0.93	0.66
	(0.00,0.02)	(0.00,0.03)	(0.02,0.10)	(0.08,0.57)	(0.88,0.98)	(0.40,0.92)
France	0.11	0.02	0.77	0.37	0.11	0.61
	(0.02,0.22)	(0.00,0.03)	(0.67,0.87)	(0.09,0.67)	(0.07,0.15)	(0.29,0.90)
Greece	0.00	0.00	0.01	0.07	0.99	0.93
	(0.00,0.00)	(0.00,0.00)	(0.00,0.01)	(0.00,0.15)	(0.99,1.00)	(0.84,1.00)
Ireland	0.00	0.00	0.03	0.02	0.97	0.98
	(0.00,0.01)	(0.00,0.00)	(0.01,0.04)	(0.00,0.04)	(0.95,0.99)	(0.95,1.00)
Italy	0.02	0.03	0.11	0.72	0.87	0.26
	(0.00,0.03)	(0.00,0.05)	(0.04,0.19)	(0.34,0.94)	(0.78,0.95)	(0.05,0.62)
Netherlands	0.05	0.01	0.33	0.13	0.62	0.87
	(0.01,0.09)	(0.00,0.01)	(0.20,0.45)	(0.03,0.19)	(0.49,0.77)	(0.80,0.97)
Portugal	0.04	0.01	0.25	0.28	0.71	0.71
	(0.00,0.08)	(0.00,0.02)	(0.12,0.37)	(0.06,0.52)	(0.58,0.87)	(0.47,0.94)
Average	0.03	0.01	0.21	0.29	0.75	0.70

Notes**:** The results are based on equations (5a)-(5d). Each number denotes the posterior mean share (out of 1) of GDP fluctuations that is explained by the global, euro-area region and country, and idiosyncratic factors. The 68% posterior quartile sets are in parenthesis. Crisis observations i.e. 2008-2009 are excluded from the estimation as they would otherwise bias our results towards finding an exceptionally high importance of the global factor in accounting for macroeconomic fluctuations.

As Table 1 shows, the euro area (region) factor accounts for a significant fraction of business cycle fluctuations among euro area countries in both the pre-crisis and post-crisis periods. On average, the euro area factor explains 21%

and 29% of national GDP growth variations in the pre- and post-crisis periods respectively, though there are important differences across member countries. In general, we find that larger economies are more exposed to the regional cycle. For instance, averaging across both periods, 57% of GDP growth fluctuations in France can be attributed to region-wide factors, whereas the business cycle of smaller economies like Greece is predominantly driven by domestic factors. The euro area factor only accounts for 4% of the volatility of Greece's GDP growth rates, averaging across both periods. In contrast, it appears the euro area is largely disconnected from external cycles during normal times in the absence of big international shocks. The global factor explains as little as 3% (1%) of GDP fluctuations in the pre-crisis (post-crisis) period on average across euro area countries. Again, it is the bigger economies that appear to be more dependent on the global cycle. That said, even for countries like France, the global cycle only accounts for a modest 11% (2%) of output growth fluctuations in the pre-crisis (post-crisis) period, which is less than a third of the corresponding figure for the US[19]. From the monetary policy-making perspective, a distinct euro area cycle that has limited exposure to global factors[20] could, in principle, give the ECB more room to address its mandates, not least because central banks tend to have more capacity to stabilise fluctuations arising from regional or national sources as opposed to those at the global level. On the other hand, a largely independent euro area cycle may imply limited scope for euro area economies to share the benefits of world booms, in line with the observed relatively sluggish recovery of some euro area economies in the aftermath of the GFC.

Taking the euro area as a whole, it appears a major international shock like the GFC has not fundamentally shifted the business cycle dynamics, particularly in making it more connected with the global cycle. Still, it is worth noting some important changes at the country level. For instance, both France and Spain experienced a decline in their association with external cycles. While the former has remained fairly exposed to external development in the post-crisis period, the latter has changed from an externally oriented economy to a largely domestic driven one, with close to a quarter of its GDP growth fluctuations explained by the global and regional cycles prior to the crisis, and a mere 5% after the crisis. At the same time, countries like Italy and Finland have become more driven by the regional factor since the crisis. In fact, as will be shown later, the

[19] The global factor explains 36% and 9% of US output growth variation in the pre- and post-crisis periods, respectively.

[20] This does not rule out the fact that the euro area can be severely affected by one-off big international shocks like the 2008 financial crisis. What it simply implies is that for most of the time macroeconomic fluctuations in the euro area are mainly shaped by regional forces.

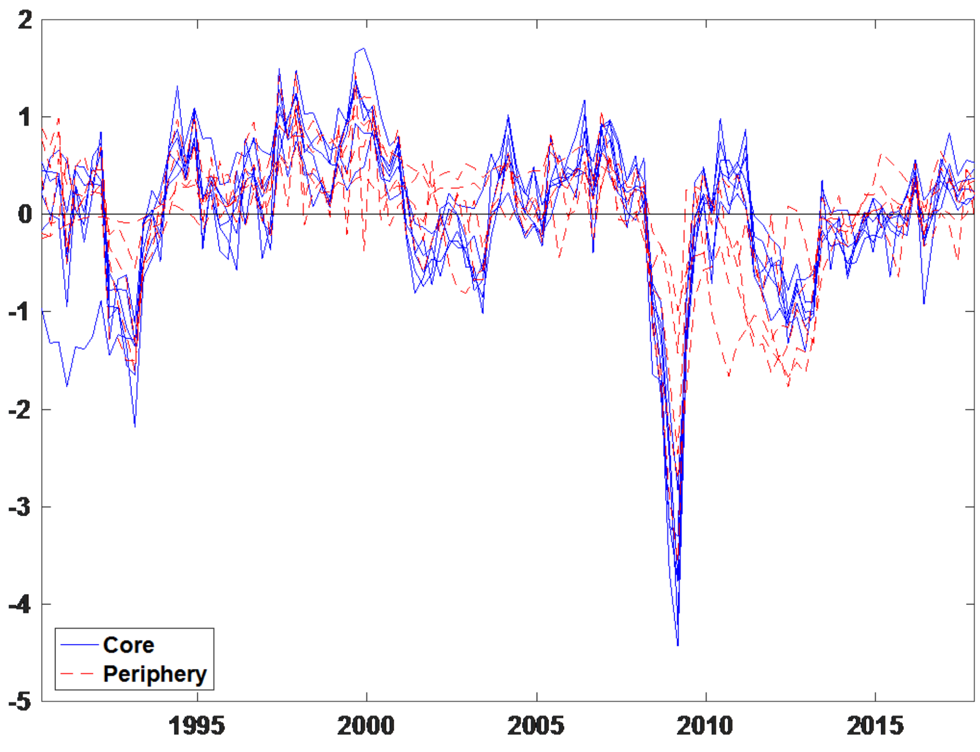
apparent increase in exposure to the common regional cycle for some euro area countries actually reflects their closer linkages with a certain subset of countries in the region.

III. B. Post-crisis divergence between the core and the periphery

We examine the business cycle characteristics of euro area countries from a broad perspective, namely their interactions with the global cycle and the region-wide cycle. So, are there any notable intra-regional business cycle dynamics that are not captured by our previous estimations? And, does the crisis play any part in altering the degree of synchronicity across member countries in the region?

As a preliminary exploration of these issues, Figure 2 presents the estimated posterior mean of the country-specific factors of the 11 euro area countries in our sample. It is notable that some countries have highly synchronised cycles with one another (blue solid line) since the establishment of the euro, whereas cycles of some other countries are more dispersed from the rest of the region (red dotted line), especially in the aftermath of the 2008 crisis.

Figure 2. Estimates of the posterior mean of the core and periphery euro area country factors, 1990 Q2-2017 Q4



Notes: We estimate the model with factor structure defined by equation (1) over the full sample period, and plot the mean of the posterior distribution of the 11 euro area country-specific factors. Country-specific factors capture common fluctuations across macro aggregates (i.e. GDP growth, consumption growth, investment growth) specific to a country. Here, Core refers to Germany, France, Austria, Belgium, the Netherlands and Finland. Periphery refers to Italy, Spain, Greece, Ireland and Portugal.
Sources: OECD and author's estimation.

Figure 2 motivates our decision to model for cycle clustering at the intra-euro area level.[21] In the context of a dynamic factor model, we introduce two factors, one capturing common co-movements among the core countries (Germany, Austria, Belgium, France and the Netherlands), and the other capturing cycle commonality among the GIIPS countries (Greece, Italy, Ireland, Portugal and Spain) at one factor level down from the EA region-wide factor. This implies the following factor structure:

$$\begin{aligned} Z_{bsnt} &= \lambda_{bsn}^{H} H_{bst}^{country} + e_{bsnt}^{idio} \\ H_{bst}^{country} &= \lambda_{bs}^{G} G_{bt}^{subregion} + e_{bst}^{country} \\ G_{bt}^{subregion} &= \lambda_{b}^{F} F_{t}^{region} + e_{bt}^{subregion} \end{aligned} \quad (6)$$

where *b*= {core, GIIPS}

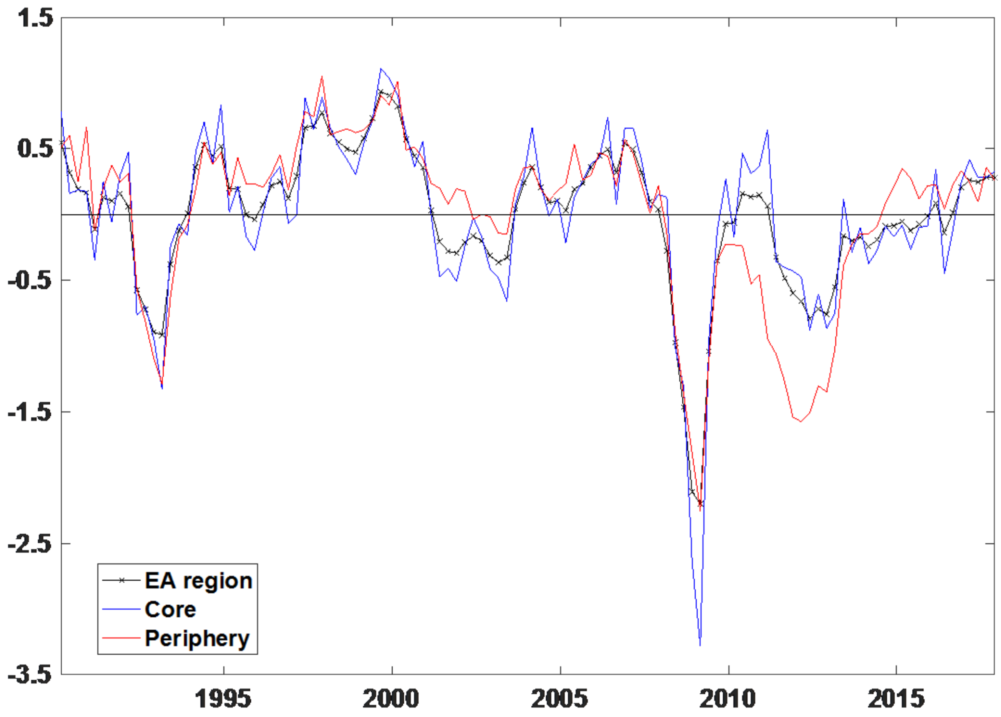
and the 4-level factor model for macro aggregates of euro area countries is now expressed as:

$$Z_{bsnt} = \Lambda_{bsn}^{region} F_{t}^{region} + \Lambda_{bsn}^{subregion} e_{bt}^{subregion} + \lambda_{bsn}^{country} e_{bst}^{country} + e_{bsnt}^{idio} \quad (7)$$

where the euro area- region factor F_t^{region} is now the top-level factor.

[21] Several studies e.g. Giannone et al. (2010), Bayoumi and Eichengreen (2017), Campos and Macciarelli (2018) also carry out their analyses by identifying a core-periphery dichotomy. The former is commonly defined as those with highly correlated shocks and responses to shocks (hence highly synchronised cycles), whereas the latter are said to have weak linkages with one another and with the rest of the euro area.

Figure 3. Estimates of the posterior mean of the euro area regional and sub-regional factors, 1990 Q2-2017 Q4



Notes: We estimate the model with factor structure defined by equation (6) over the full sample period, and plot the mean of the posterior of the euro area regional factor, the core and the periphery sub-regional factors. The euro area regional factor captures all common fluctuations of macro aggregates (i.e. GDP growth, consumption growth, investment growth) across the 11 euro area countries in the sample. The core sub-regional factor represents fluctuations that are common across Germany, Austria, Finland, France and the Netherlands. The periphery sub-regional factor is specific to common fluctuations across Italy, Spain, Greece, Ireland and Portugal.

Sources: OECD and author's estimation.

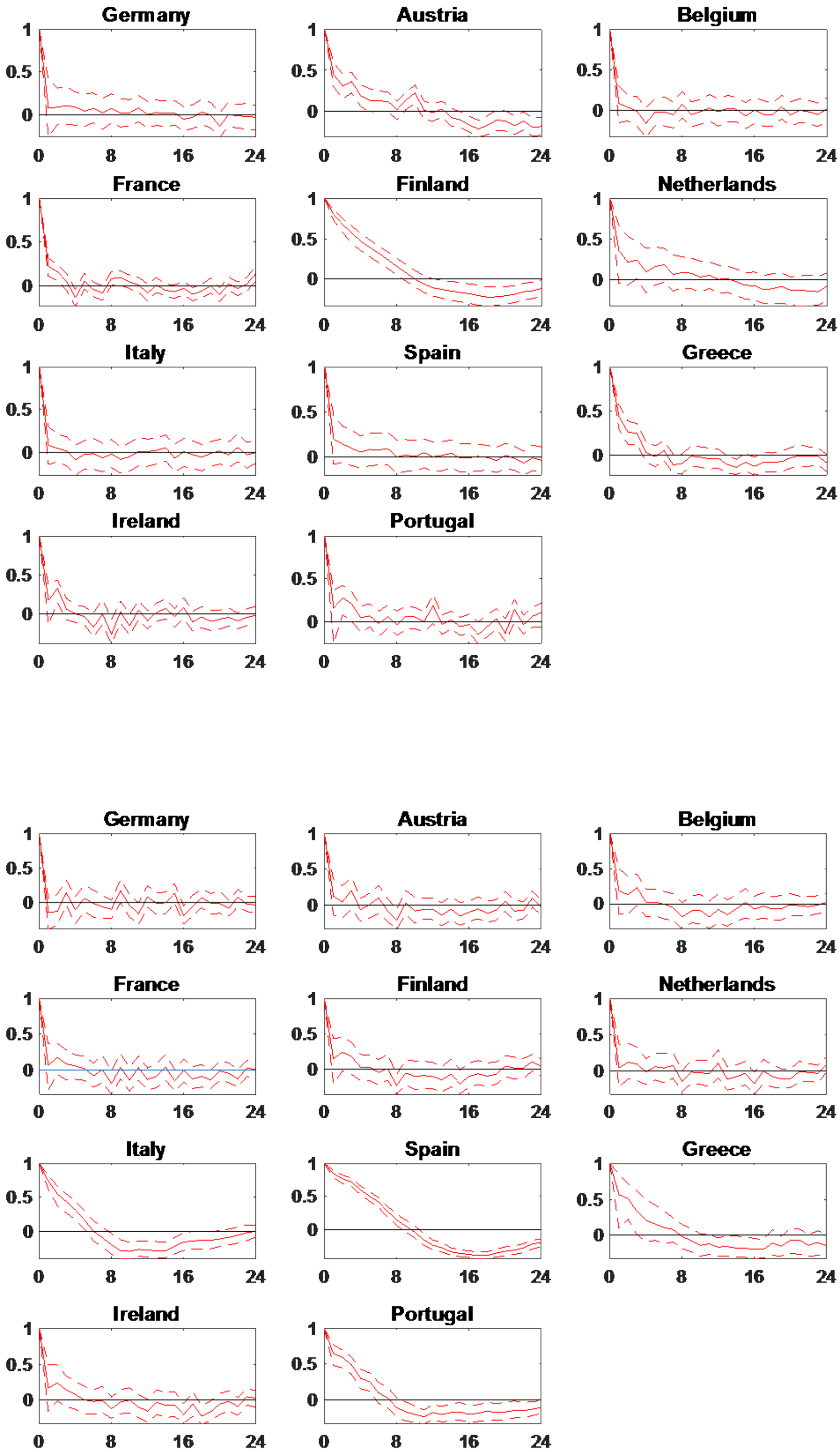
Figure 3 displays the posterior means of the euro area factor and the core and periphery sub-regional factors, estimated from the model with factor structure defined by equation (6). Prior to 2009, the core country and periphery sub-regional factors tracked each other closely, with the exception of a brief period of departure shortly after the 2001 US recession in which core countries were affected more by the negative shock. In particular, the period 2004-2008 marked a time of high synchronisation in the region. The onset of the GFC led to weaker co-movements and greater dispersion in amplitudes across the core and periphery factors. Core countries rebounded promptly and returned to positive growth in 2009 Q3, whereas periphery countries remained in deep recession even when the sovereign debt crisis only hit in late 2011. It is also worth noting that the core-periphery cycle divergence has materialised before the sovereign debt crisis, as highlighted by the two factor plots in Appendix D. Such finding is also confirmed by statistical tests, where we do not reject the null of zero correlation between the core-periphery factors in the pre-Sovereign Debt Crisis period. (See Appendix D for details on test results)

We find evidence of core-periphery cycle decoupling around the time of the GFC, with the periphery cycle turning more country-specific. The question here: is the deviation of the peripheral cycle from the region-wide cycle a one-off event, or is it persistent? To measure convergence, we compute the autocorrelation function of the gap between the country specific cycle and the EA region-wide cycle i.e. $F_{bst}^{country} - F_t^{region}$. Given a one-time deviation, the time for the autocorrelation function to go to zero corresponds to the time required for the euro-area country-cycle to fully converge back to the euro area common cycle.

Figure 3 plots the autocorrelation function over a 24-quarter horizon. In the pre-crisis period, convergence for all euro area countries is fairly rapid, as shown by the mean-reverting nature of their ACFs around zero. Following the crisis, while convergence for core countries remains fast, deviation of most peripheral countries has become more persistent. It could take more than six years for some peripheral countries to fully revert to the common region-wide cycle.

Our finding suggests the post-crisis North-South decoupling could be more than just a one-off turbulence in the event of a big shock, but may instead reflect a shift in business cycle dynamics in a more fundamental way.

Figure 3. Autocorrelation function of the gap between country-specific factors and the euro-area factor: pre-crisis (1990 Q2-2007 Q4); post-crisis (2009 Q3-2017 Q4)



Notes: Pre-crisis period (top panel), post-crisis period (bottom panel). The figure displays the autocorrelation of a one-time deviation of the country-specific factor from the euro area region factor at time 0, over a 24-quarter horizon.

Table 2. Variance decomposition of real GDP: pre-crisis (1990 Q2-2007 Q4), post-crisis (2009 Q3-2017 Q4)

	Region		Sub-region		Country & Idiosyncratic	
	Pre-crisis	Post-crisis	Pre-crisis	Post-crisis	Pre-crisis	Post-crisis
Core						
Germany	0.24	0.23	0.10	0.15	0.65	0.61
	(0.20,0.28)	(0.15,0.33)	(0.09,0.12)	(0.13,0.18)	(0.61,0.70)	(0.51,0.71)
Austria	0.01	0.40	0.00	0.29	0.99	0.31
	(0.00,0.02)	(0.31,0.49)	(0.00,0.01)	(0.18,0.39)	(0.98,1.00)	(0.16,0.47)
Belgium	0.28	0.33	0.12	0.23	0.59	0.43
	(0.22,0.35)	(0.23,0.44)	(0.09,0.15)	(0.16,0.31)	(0.50,0.69)	(0.28,0.58)
Finland	0.04	0.31	0.02	0.22	0.94	0.48
	(0.01,0.07)	(0.22,0.40)	(0.01,0.03)	(0.14,0.30)	(0.90,0.98)	(0.33,0.61)
France	0.63	0.38	0.28	0.27	0.09	0.35
	(0.59,0.67)	(0.29,0.47)	(0.25,0.31)	(0.18,0.36)	(0.08,0.11)	(0.21,0.49)
Netherlands	0.21	0.02	0.09	0.01	0.70	0.97
	(0.11,0.30)	(0.00,0.04)	(0.05,0.13)	(0.00,0.03)	(0.56,0.84)	(0.93,1.00)
Periphery						
Italy	0.22	0.04	0.10	0.70	0.68	0.26
	(0.13,0.30)	(0.00,0.07)	(0.08,0.12)	(0.61,0.79)	(0.60,0.76)	(0.19,0.34)
Spain	0.17	0.02	0.09	0.42	0.74	0.56
	(0.10,0.24)	(0.00,0.03)	(0.05,0.13)	(0.12,0.72)	(0.64,0.84)	(0.25,0.87)
Greece	0.00	0.00	0.00	0.08	1.00	0.91
	(0.00,0.01)	(0.00,0.01)	(0.00,0.00)	(0.01,0.17)	(0.99,1.00)	(0.83,0.99)
Ireland	0.03	0.00	0.01	0.02	0.96	0.98
	(0.01,0.04)	(0.00,0.06)	(0.00,0.02)	(0.01,0.03)	(0.94,0.99)	(0.96,0.99)
Portugal	0.07	0.03	0.05	0.61	0.88	0.36
	(0.01,0.18)	(0.00,0.06)	(0.00,0.11)	(0.49,0.73)	(0.68,0.99)	(0.25,0.46)

Note: Each number denotes the mean share (out of 1) of GDP fluctuations that is explained by the euro-area region, sub-regional factors (core, periphery), country and idiosyncratic factors, estimated using equation (6).

The 68% posterior quartile sets are in parenthesis. Crisis observations i.e. 2008-2009 are excluded from the estimation as they would otherwise bias our results towards finding an exceptionally high importance of the global factor in accounting for macroeconomic fluctuations.

To shed more light on the intra-regional business cycle dynamics, we estimate the variance decomposition of countries' GDP growth. Table 3 presents results based on equation (7). Two key messages emerge from our results. First, the business cycles of the four largest economies in the region (Germany, France, Italy and Spain) have become less synchronised in the post-crisis episode. Specifically, while the euro area region factor can account for a fair amount of the GDP fluctuations of Italy and Spain in the pre-crisis period, linking them with the other big economies, that factor plays virtually no role following the crisis. Second, it appears that two intra-regional cycles have emerged in the post-crisis period - one linking the core countries[22], and one being a major driver of macroeconomic fluctuations in Italy, Spain and Portugal. Apparently, the crisis has led to market realisation of the sovereign debt problems of these GIIPS countries, triggering divergence in financial conditions between the core and the GIIPS countries, which in turn reinforces decoupling in their real cycles. Sub-optimal policy response may also play a role in accounting for the severity of the recession as experienced by some peripheral countries.[23]

It is also worth noting that the degree of cycle symmetry witnessed in the pre-crisis period has been modest at best, with a limited sign of broad-based synchronisation across member countries. For instance, the euro area region factor barely explains output growth fluctuations in Greece, Ireland and Portugal. Despite the fact that the financial convergence process starting in the early 1990s has significantly reduced the gap in real borrowing costs between Northern and Southern countries, the presence of idiosyncratic structural problems among peripheral countries, such as the misallocation of capital (see for example, Gopinath et al. (2017)[24], Reis (2013)), and the lack of reforms in economic institutions (Fernandez-Villaverde et al. (2013)) could explain the lack of North-South cycle synchronisation as in our findings .

[22] The Netherlands has largely decoupled from the other core euro area countries after the crisis. Only 1 % of its output growth variation is attributed to the core sub-regional factor in the post-crisis period.

[23] For instance, Martin and Philippon (2017) show that most countries in the euro area, in particular Greece, could have stabilised their employment if they had followed more conservative fiscal policies during the boom. They also find that early intervention by the central bank to prevent market segmentation would have significantly reduced the recession, and a fiscal devaluation would have enabled countries to reduce some of the job losses.

[24] They show that given financial market imperfection, a low interest rate environment undermines sectoral total factor productivity in peripheral countries by fostering capital re-allocation from small efficient firms to larger relatively unproductive firms.

In sum, our finding that core and periphery cycles diverge in the aftermath of a common shock demonstrates the existence of intrinsic differences among member countries. Specifically, it appears that structurally weaker and more policy-constrained economies, such as Italy and Spain, are more vulnerable to slowdown. For policy-makers, in the longer term, addressing cycle asymmetry at the intra-regional levels can amount to facilitate shock mitigation and better risk-sharing between the more resilient Northern euro area countries and the more crisis-prone Southern countries. With that perspective, the ECB's initiatives to deepen financial market integration (via completion of the capital market and banking union) and to introduce a mechanism for contingent fiscal transfer[25] seem to be the appropriate way forward.

IV. Conclusion

In this study, we provide evidence of a distinct euro area cycle over the past three decades, one that evolves largely independently from external factors. Nevertheless, asymmetries among business cycles of member countries persist: in particular, divergence between some core and peripheral member countries has widened since the 2008 crisis.

A key implication of this study is that cyclical asymmetry in the region, as opposed to external factors, are likely to impose a bigger constraint on the optimal functioning of the ECB's monetary policy. Such constraint could become more binding at times when effective policy actions are most needed, i.e. in the aftermath of a crisis. Looking ahead, it would be desirable to complement the single monetary policy framework with other policy supports that could help members better withstand asynchronous business cycle developments, although the nature of this support will depend on the sources of asynchronicity. Future studies may help uncover such sources, which may include differing degrees of sovereign debt burden and fiscal discipline, financial market and business sentiments, and labour productivity.   .

[25] Farhi and Werning (2017) show that efficient risk-sharing can be implemented by contingent transfer within a fiscal union. They illustrate that the benefits of fiscal union are larger when shocks that affect member states are more asymmetric and persistent, and when member countries are less open.

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Appendix A: List of countries

Group of countries		
Euro area economies	Other advanced economies	Emerging market economies
Germany	United States	China
Austria	Australia	Brazil
Belgium	Canada	Indonesia
Spain	Switzerland	India
Finland	Denmark	South Korea
France	United Kingdom	Mexico
Greece	Japan	Turkey
Ireland	Norway	South Africa
Italy	New Zealand	
Netherlands	Sweden	
Portugal		

Appendix B: Estimation procedure – Gibbs sampling

The joint distribution of factors and the parameters of interest i.e. the factor loading λ and auto-regressive term ψ cannot be derived analytically. But since their conditional distribution can be inferred from the conjugate prior, we could instead apply numerical methods to sample in sequence the conditional distribution. Given stationarity, the resulting Markov chains will converge to the target posterior of the joint distribution. This sampling procedure is known as Gibbs sampling, which takes the following steps:

Let $\Lambda = (\lambda^F, \lambda^G, \lambda^H)$, $\Psi = (\psi^F, \psi^G, \psi^H, \psi^Z)$, $\Sigma = (\Sigma^F, \Sigma^G, \Sigma^H, \Sigma^Z)$. The Gibbs sampling step is as follows:

1. Conditional on Λ, Ψ, Σ, $\{G_{bt}^{region}\}$ and the data Z_{bsnt}, draw $\{H_{bst}^{country}\}$ $\forall\, b\, \forall\, s$
2. Conditional on Λ, Ψ, Σ, $\{F_t^{global}\}$ and $\{H_{bst}^{country}\}$, draw $\{G_{bt}^{region}\}$ $\forall\, b$
3. Conditional on Λ, Ψ, Σ and $\{G_{bt}^{region}\}$, draw $\{F_t^{global}\}$
4. Conditional on $\{F_t^{global}\}$, $\{G_{bt}^{region}\}$ and $\{H_{bst}^{country}\}$, draw Λ, Ψ, Σ
5. Complete one step of Markov chain. Repeat iterations from step 1.

We impose a prior distribution for all factor loadings Λ and auto-regressive coefficients Ψ to be Gaussian with mean zero and variance 10. The posterior distribution for the variance parameters is assumed to follow an inverse chi-squared distribution with v degree of freedom and a scale of d where v and d^2 are set to be 4 and 0.01.We repeat the steps above 100,000 times. We burn the first 50,000 draws, store one of the next 50 draws, leaving us with 1,000 draws for inference.

Appendix C: Test for *strong perfect positive synchronisation* (SPSS) and *strongly non-sycnhronised* (SNS) – the Harding and Pagan (2006) test

Following Harding and Pagan (2002), we define business cycle synchronisation in terms of the similarity of turning point. Specifically, we define a binary indicator S_t which takes the value 1 if the estimated factors are negative for two successive quarters (aligning with the conventional classification that a recession is defined as two successive quarters of negative growth) and 0 otherwise.

$$S_t = \begin{cases} 1, & y_t < 0, y_{t-1} < 0 \\ 0, & otherwise \end{cases}$$

As in Harding and Pagan (2006), for any two cycles S_{xt} and S_{yt}, *strong positive perfect synchronisation* ($SPSS$) and *strongly non-synchronised* (SNS) are defined as follow:

$$SPSS: E(S_{xt}) - E(S_{yt}) = 0$$

$$SNS: E(S_{xt})E(S_{yt}) - E(S_{xt}S_{yt}) = 0$$

In the actual test procedure, the $SPSS$ condition implies testing for the equivalence of the sample means of the two binary cycle indicators; the null hypothesis under the SNS condition corresponds to the two binary indicators having a zero sample correlation coefficient.

Degree of synchronisation between the euro area region factor and its orthogonal component

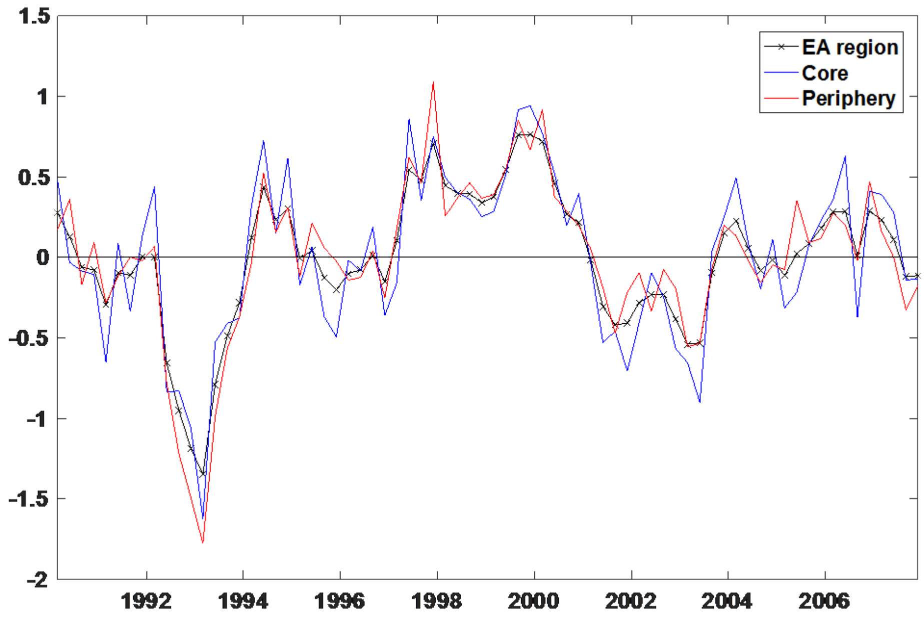
Euro area region factor, orthogonal euro area factor		
Correlation index	SPSS	SNS
0.50 (0.14, 0.78)	0.12 (0.04,0.21)	0.03 (0.00,0.20)

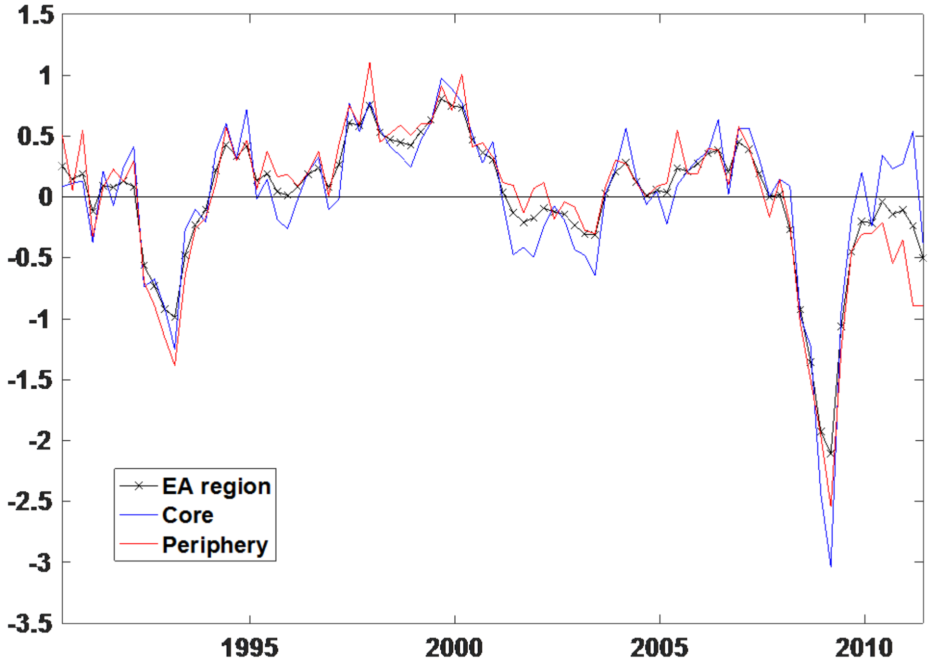
Notes: The ‘Correlation index’ column reports the sample correlation coefficient between the binary cycle indicators associated with each factor. The ‘SPSS’ and ‘SNS’ columns report the *p*-values of the two synchronisation tests. The 90% posterior quartile set are in parenthesis.

Appendix D. Point of divergence: Global Financial Crisis or Sovereign Debt Crisis

The Figure displays the posterior mean estimates of the euro area regional factor, the core and the periphery sub-regional factors, estimated over the pre-GFC period (1990 Q2-2007 Q4) (top panel) and the pre-sovereign debt crisis sample (1990 Q2-2011 Q2) (bottom panel). Prior to the GFC, there was close movement between the core and the periphery sub-regional factors, but a major departure has emerged since then, notability before the onset of the Sovereign Debt Crisis. The Harding and Pagan (2006) test (Table) does not reject the null of *strongly non-synchronised (SNS)* between the core and the periphery sub-regional factor in both the post- GFC and the pre- Sovereign Debt Crisis sub-sample, confirming our proposition that the Global Financial Crisis, rather than the subsequent Sovereign Debt Crisis triggered the divergence between the core and periphery euro area countries.

Estimates of the posterior mean of the euro area regional and sub-regional factors, 1990 Q2-2007 Q4 (top panel), 1990 Q2-2011 Q2 (bottom panel)





Notes: We estimate the model with factor structure defined by equation (6) over the pre-GFC period (1990 Q2-2007 Q4) (top panel) and the pre-Sovereign Debt Crisis period (1990 Q2-2011 Q2). Crisis observations (2008 Q1-2009 Q2) are excluded from the pre-Sovereign Debt Crisis sample. The graphs show the mean of the posterior of the euro area regional factor, the core and the periphery sub-regional factors. The euro area regional factor captures all common fluctuations of macro aggregates (i.e. GDP growth, consumption growth, investment growth) across the 11 euro area countries in the sample. The core sub-regional factor represents fluctuations that are common across Germany, Austria, Finland, France and the Netherlands. The periphery sub-regional factor is specific to common fluctuations across Italy, Spain, Greece, Ireland and Portugal. Sources: OECD and author's estimation.

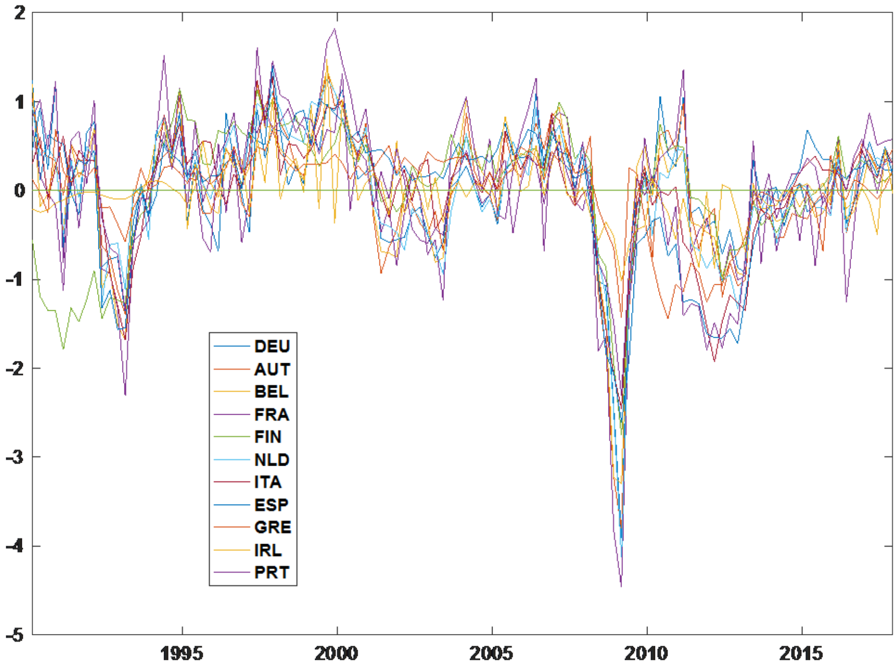
Degree of synchronisation between the euro area core and the periphery sub-regional factors

	core sub-regional factor, peripheral sub-regional factor		
	Correlation index	SPSS	SNS
Pre-GFC	0.48 (0.29,0.65)	0.12 (0.04,0.20)	0.01 (0.00,0.07)
Post-GFC	0.41 (0.16,0.65)	0.11 (0.04,0.20)	0.06 (0.00,0.26)
Pre-SDC	0.34 (0.16,0.52)	0.12 (0.04,0.19)	0.11 (0.00,0.28)

Notes: The 'Correlation index' column reports the sample correlation coefficient between the binary cycle indicators associated with each factor. The 'SPSS' and 'SNS' columns report the *p*-values of the two synchronisation tests as defined by Appendix C. The 90% posterior quartile set are in parenthesis. 'Pre-GFC' and 'Post-GFC' denote the pre- and post- Greawt Financial Crisis sub-samples, corresponding to the period

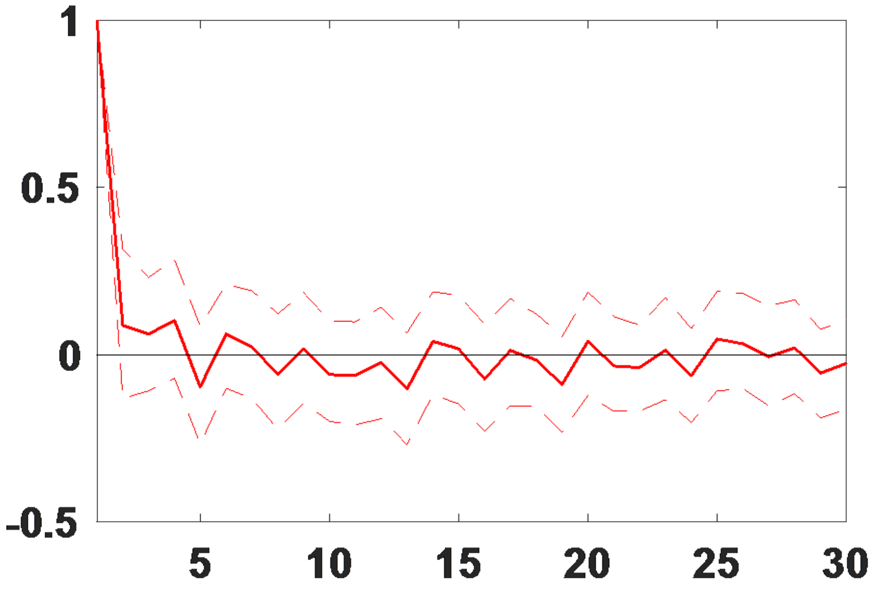
1990 Q2-2007 Q4 and 2009 Q3-2017 Q4 respectively. ‘Pre-SDC’ denotes pre Sovereign Debt Crisis sub-sample (1990 Q1-2011 Q2) with the GFC observations (2008 Q1-2009 Q2) excluded.

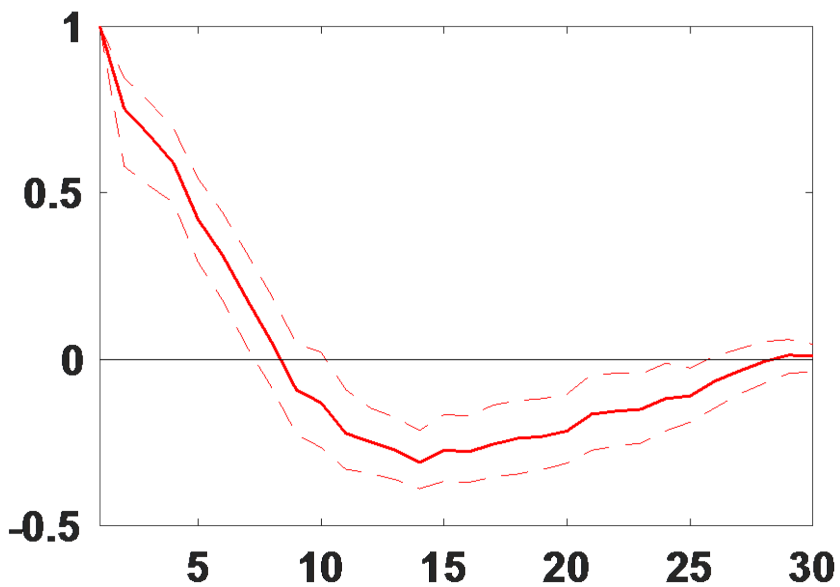
Appendix E1: Evolution of the euro area country-specific factors, 1990 Q2-2017 Q4



Notes: We estimate the model with factor structure defined by equation (6) over the full sample period, and plot the mean of the posterior distribution of the 11 euro area country-specific factors.

Appendix E2: Autocorrelation function of the gap of the euro area periphery factor relative to the core factor, top panel: pre-crisis(1990 Q2-2007 Q4); bottom panel: post-crisis (2009 Q3-2017 Q4)





Notes: Pre-crisis period (top panel), post-crisis period (bottom panel). The figure displays the autocorrelation of a one-time deviation of the periphery sub-regional factor from the core sub-regional factor at time 0, over a 30-quarter horizon.