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Ansgar Belke

Clemens Domnick

Daniel Gros

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Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

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Ansgar Belke, Clemens Domnick, and Daniel Gros[1]

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Abstract

This paper examines business cycle synchronization in the European Monetary Union with a special focus on the core-periphery pattern in the aftermath of the crisis. Using a quarterly index for business cycle synchronization by Cerqueira (2013), our panel data estimates suggest that it is countries belonging to the core that are faced with increased synchronization among themselves after 2007Q4, whereas peripheral countries decreased synchronization with regards to the core, non-EMU countries and among themselves. Correlation coefficients and nonparametric local polynomial regressions corroborate these findings. The usual focus on co-movements and correlations might be misleading, however, since we also find large differences in the amplitude of national cycles. A strong common cycle can thus lead to large differences in cyclical positions even if national cycles are strongly correlated.

JEL Classification: E32, F15, R23

Keywords: Business cycles; core-periphery; EMU; local polynomial regressions; synchronicity; common monetary policy

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1 Ansgar Belke, UDE and Institute for the Study of Labor (IZA), Bonn; Clemens Domnick, UDE; Daniel Gros, Centre for European Policy Studies, Brussels. *– The authors would like to thank Thomas Osowski, Pedro Cerqueira, Daniel Wissmann and participants of the Jean Monnet conference Economic Prospects for the European Union - Challenges for Economic Policy until the End of the Decade in Düsseldorf for helpful comments and suggestions. All remaining errors are our own.* *– All correspondence to: Clemens Domnick, University of Duisburg-Essen, Universitätsstraße 12, 45117 Essen, Germany, e-mail: clemens.domnick@gmail.com*

1. Introduction

"Uniform monetary policy and inflexible exchange rates will create conflicts whenever cyclical conditions differ among the member countries." Martin Feldstein (1997)

The crisis in the European Monetary Union (EMU) brought a sharp economic division between core and peripheral members states to the limelight (European Commission, 2014). Whereas core countries such as Germany had experienced only temporary losses in output, peripheral countries such as Greece or Portugal continue to fight with weak economic activity and a stark rise in unemployment. Analyzing and assessing cross-country heterogeneity among EMU members play a key role for establishing a sustainable governance for the euro area. Hence, the core-periphery paradigma has been subject of much academic work (Blanchard *et al.*, 2015; Wortmann and Stahl, 2016; Cesaroni and De Santis, 2016).

The core-periphery distinction is especially relevant for monetary policy. Diverging economic trajectories pose a significant threat to the stability of the EMU, since the European Central Bank (ECB) can only react with a "one-size-fits-all" interest rate policy to stabilize output movements. The importance of synchronized business cycles for a well-functioning currency union is stressed in the theory of the Optimum Currency Area (OCA), pioneered by the work of Mundell (1961) and McKinnon (1963).[1] Firstly, the more aligned the business cycles of members of a monetary union are, the easier it is for the central bank to conduct stabilization policies (Clarida *et al.*, 1999; Rogoff, 1985). Secondly, a high degree of synchronization between national cycles may reduce the probability of asymmetric shock propagation across EMU members (Altavilla, 2004).

In a string of papers, Eichengreen (1990, 1991, 1993) concludes that the cost of giving up autonomy over monetary policy is especially high if business cycles of member states are only weakly correlated and alternative adjustment mechanisms, such as factor mobility, are not sufficiently available. To put it differently: the higher the synchronization of business cycles among member states is, the lower

[1] See Mongelli (2008) for a theory on the evolution of the OCA idea.

is the cost of abandoning national monetary policy. As a result, business cycle synchronization is considered to be the most important OCA criterion (Gächter *et al.*, 2012).

Based on this reasoning, our paper adds to the vast literature on business cycle synchronization by providing a thorough analysis of how output co-moves among EMU member states. Specifically, we complement the literature by focusing on the relationship between two clusters within the EMU: a group of core countries, namely Germany, France, Austria, Finland and the Netherlands, and a group of peripheral countries, i.e. Portugal, Italy, Ireland, Greece and Spain.[2] Several studies pointed to a division of core and peripheral countries even before the introduction of the Euro (Bayoumi and Eichengreen, 1992; Dickerson *et al.*, 1998).[3] Lehwald (2013) concludes that business cycles for core and peripheral countries diverged after the introduction of the EMU, in line with Papageorgiou *et al.* (2010). Our main research questions are: what are the correlation patterns between the core and the periphery in the EMU, and how has the co-movement of output evolved over time, especially in the crisis period starting in 2007?

The bulk of earlier studies that examined business cycle synchronization relies either on calculating a correlation measure over the entire time period or over non-overlapping subperiods of time (Furceri and Karras, 2008; Gouveia and Correia, 2008). The observed time window is often set arbitrarily and the correlation coefficients are prone to potential outliers biasing the results. We are able to overcome these problems by using a correlation index pioneered by Cerqueira and Martins (2009) that provides us with a correlation measure on a quarterly basis. In our empirical analysis, we start with a comparison of simple correlation coefficients, but continue with both parametric and nonparametric estimations in the spirit of

[2]There exists no exact definition as to which countries belong to the core or to the periphery. With regards to the latter, the literature nearly unanimously includes Portugal, Spain, Ireland and Greece, with Italy being sometimes excluded (Lehwald, 2013). For the former, we follow a geographical definition and include France in the group of core countries, as opposed to studies clustering along country-specific economic policies (Schäfer, 2016).

[3]The distinction between a core and a peripheral set of countries was also found for the other criteria suggested by the OCA theory, see Artis (2003). As Artis and Zhang (2002) point out, there exists a group of Southern peripheral countries, namely Spain, Italy, Portugal, and Greece, for which participating in a currency union would not be strongly advised.

Cerqueira (2013) to detect a potential change in the cross-country core-periphery pattern. While the former are standard and widely used in economics, the nonparametric measures in form of local polynomial regressions (LPR) have the advantage that they are very flexible in their use and do not rely on prior assumptions about a particular functional form regarding the co-movement of economic activity. Thus, our quarterly correlation index and the LPR framework permit us to specifically track the changing relationship over time. Since our empirical investigation covers the time period from 1970Q1 to 2015Q4, we are able to investigate the potential (de)synchronizing effects of both the great financial crisis and the subsequent sovereign debt crisis, an issue that only a limited number of studies have addressed so far (Grigoraş and Stanciu, 2016; Degiannakis *et al.*, 2014). Apart from the synchronization of business cycles, we also study their amplitudes because different amplitudes can lead to diverging cyclical conditions even if the cycles are perfectly correlated.

These aspects relate to the future of the economic governance of the EMU, since the negative effects of strongly diverging business cycles could be minimized by common institutions for risk sharing. De Grauwe and Ji (2016), for instance, argue that risk-sharing efforts to stabilize the business cycles should be strengthened relative to the efforts that have been taken to conduct structural reforms. This is because they show empirically that a large part of the divergence in the Eurozone was the result of business cycle movements whose amplitudes differ across countries.

Our main empirical findings can be summarized as follows: both our panel and LPR estimations suggest that the output co-movement between core and peripheral countries decreased markedly in the wake of the financial crisis. Analyzing the synchronization between core and peripheral economies among themselves, our results point to a rather stark drift among peripheral countries around the financial crisis, which was partly reversed during the sovereign debt crisis. Core economies, on the other hand, enjoyed a rising synchronization of output during both the financial and the subsequent sovereign debt crisis. We observe the same pattern when comparing the alignment of economic activity of our two clusters with countries outside of the EMU: the drop in synchronization is significantly more pronounced for countries belonging to the periphery than to the core. We also find that there are large differences in the amplitudes of national cycles, which seem to be related to the extent to which national economies react to the common cycle. But these differences are not systematically related to the core-periphery divergence in correlations. This suggests that the core-periphery desynchronization is not the only problem for the euro area.

The remainder of this article proceeds as follows: Section 2 gives a brief overview of the related literature, Section 3 discusses our data, Section 4 describes our empirical methods and the estimation results, while Section 5 concludes.

2. Related Literature

The debate about whether and how business cycles are synchronizing in the EMU has been the focus of an intense academic exchange. In this section, we will give a short and necessarily selective review of the vast literature relevant in our context.[4]

Before the start of the EMU, several studies examined whether the economies that planned to form a common currency area in Europe could be considered an optimum currency area. Bayoumi and Eichengreen (1992) use structural vector autoregressions (SVAR) to identify the incidence of supply and demand shocks in Europe. Both types of shocks are estimated to be smaller in magnitude and more intercorrelated for a group of core countries, consisting of Germany, France, Belgium, the Netherlands and Denmark - than for the other European Community (EC) countries, such as Italy, Spain, Portugal, Ireland, Greece and the UK. Overall, "there is also little evidence of convergence in the sense of the core-periphery distinction becoming less pronounced over time" (Bayoumi and Eichengreen, 1992, p. 34). In the same vein, Dickerson *et al.* (1998) find a clear difference in business cycles between a group of core countries (Netherlands, France, Belgium, Luxem-

[4]While we focus on studies that investigate business cycle synchronization at the national level, another strand of the literature focus on co-movement between regions in the EU. See, for instance, Anagnostou *et al.* (2015), Bierbaumer-Polly *et al.* (2016) or Belke and Heine (2006).

bourg, Germany) and the periphery (Greece, Ireland, Italy, Portugal, Denmark, United Kingdom, Spain) prior to the implementation of the EMU.

Christodoulakis *et al.* (1995) tend to have a more optimistic view. According to their empirical framework, countries of the EC react remarkably similar to shocks, even though the nature of the shocks might be rather different. Mostly, these differences were found to be related to institutions (e.g. labour market regulations) or policy variables (such as government consumption). As a result, "observed differences in shocks and business cycles mechanisms will tend to melt down as common institutions and politics start to emerge" (Christodoulakis *et al.*, 1995, p. 16), a view shared by the European Commission (1990) in its seminal study *One Market, One Money*. Moreover, they do not find any evidence for a core-periphery distinction. Others point to the increase of business cycle synchronization in the run-up to the EMU (Angeloni and Dedola, 1999; Fatas, 1997).

Would the introduction of the Euro spur business cycle synchronization among member states? Proponents of the endogeneous OCA analysis, based on the seminal papers of Frankel and Rose (1997, 1998), tended to agree. They argued that differences in the co-movement of aggregate output between future members of the EMU were not as problematic as initially claimed, since member states would meet the necessary OCA criteria better after the introduction of the common currency, i.e. ex post than ex ante. Following this logic, the introduction of the EMU would have led to a marked increase in economic and financial integration that would consequently help to align economic fluctuations among member states. With the benefit of hindsight, the empirical evidence is conflicting, making the notion of whether the introduction of EMU led to higher business cycle synchronization contested.[5]

Studies detecting a positive effect include Furceri and Karras (2008). They use a simple pairwise correlation coefficients of GDP and unemployment and find that all 12 countries in their sample are better synchronized with the common EU-wide cycle after the start of the EMU. The positive effects of EMU on business

[5]For a recent survey about business cycle synchronization in Europe, see de Haan *et al.* (2008). Willett *et al.* (2010) provide an overview of the endogeneous OCA theory and its validity for the first years of the EMU.

cycle synchronization are confirmed, with albeit different statistical methods, by Altavilla (2004), Gogas (2013), Darvas and Szapáry (2008), Gonçalves *et al.* (2009), among others, as well as for different proxies for economic activity such as industrial production (Gayer, 2007) or economic sentiment indicators (Aguiar-Conraria *et al.*, 2013). On the other hand, other studies fail to detect any EMU effect on business cycle synchronization (Camacho *et al.*, 2006; Weyerstrass *et al.*, 2011), or find even a dampening one (Papageorgiou *et al.*, 2010).[6]

Another string of literature suggests rather heterogeneous effects of joining the EMU across member states. Lehwald (2013) uses a dynamic factor model and compares the common European factor for the initial EA-12 before and after the introduction of the EMU. The results suggest that the implementation of the EMU had a dampening effect for the peripheral economies, defined as Spain, Portugal, Greece and Ireland, but spurred the co-movement for the core (i.e. the other 8 economies). Along the same lines, Papageorgiou *et al.* (2010) argue that Europe tended to converge during the period 1992 - 1999, but to diverge from 2000 - 2009 on, leading to an increasing number of clusters within Europe. Konstantakopoulou and Tsionas (2011) use a dynamic analysis based on the autoregressive distributed lag model for the time-span of 1960-2009. Their results point to a core group of countries, such as Germany, the Netherlands, Austria, France and Belgium that are highly synchronized among themselves, while especially Greece and Portugal do not show any synchronization with the other economies, corroborating the results of Gouveia and Correia (2008).[7]

The tumultuous period of the financial crisis and the following sovereign debt crisis brought deep economic imbalances within the EMU to the limelight (Lane, 2012). However, there are only a very limited number of studies focusing on the potential (de)synchronization of economic activity during this period. Degiannakis *et al.* (2014) investigate the time-varying correlation between the EU-12 and its initial members using scalar-BEKK, a widely used model of conditional covariances and correlations, and a multivariate riskmetrics framework. While business

[6]Generally, it is not easy to separate the effects of the introduction of the Euro from other EU-wide initiatives, as pointed out by Willett *et al.* (2010).

[7]However, the core-periphery dualism seems to be less pronounced in Europe than in the United States, according to the estimates of Ferreira-Lopes and Pina (2011).

cycles in the EMU were getting increasingly correlated until 2007, the financial crisis triggered a desynchronization process, most prominently for Greece, Ireland, Portugal and Spain, but also for non-EMU countries such as the United Kingdom or Sweden, supporting the analysis of Gächter *et al.* (2012) who find a decrease in correlation and an increase in the dispersion of synchronization levels due to the financial crisis within the EMU. Grigoraş and Stanciu (2016) compare concordance and correlation measures for a sample of European economies, concluding that the co-movement of economic activity among European economies diverged after the outbreak of the crisis (starting 2009Q1) compared to the Euro adoption period (2002Q1 - 2008Q4). Ferroni and Klaus (2015) use a factor model to determine the business cycle properties of the four largest European economies during the recent European debt crisis. They find that Germany, France and (surprisingly) Italy are well-aligned with the EA cycle, whereas Spain shows an asymmetric behaviour.

Differences in the results can be partly explained by the myriad of empirical methods to determine the level of business cycle synchronization: for instance coherence and concordance measures based on business cycle dating algorithms (Harding and Pagan, 2002, 2006; Artis *et al.*, 2004; Grigoraş and Stanciu, 2016), dynamic factor models (Lee, 2013; Lehwald, 2013; Kose *et al.*, 2003), dynamic correlations (Croux *et al.*, 2001; Fidrmuc and Korhonen, 2010), rolling coefficients (Gayer, 2007), correlation coefficients (Furceri and Karras, 2008) or wavelet analysis (Aguiar-Conraria and Soares, 2011), among others. For our empirical analysis, we employ three different methods to analyze whether business cycles have diverged between the core and the periphery: (i) correlation coefficients as most prominent measure to assess business cycle synchronization in the literature (Bordo and Helbling, 2003), (ii) panel regressions that allow for a more systematic representation and (iii) nonparametric regressions that are specifically useful to track non-linear dynamics over time.

3. Data and Variables

3.1. Data

For our empirical analysis, we use the seasonally adjusted real gross domestic product (GDP) on a quarterly basis from the OECD. Our dataset includes all member states of the euro area-12 (EA-12)[8] plus Norway, Switzerland, Denmark and Sweden as non-EMU members, with data ranging from 1970Q1 to 2015Q4.

We focus on gross domestic product as our main indicator for business cycle movements for two reasons: it is (i) the most comprehensive measure for aggregate economic activity and (ii) the most widely used and accepted measure in the academic literature and in the general public (Haan *et al.*, 2008; Grigoraş and Stanciu, 2016).[9]

3.2. Calculating Business Cycles

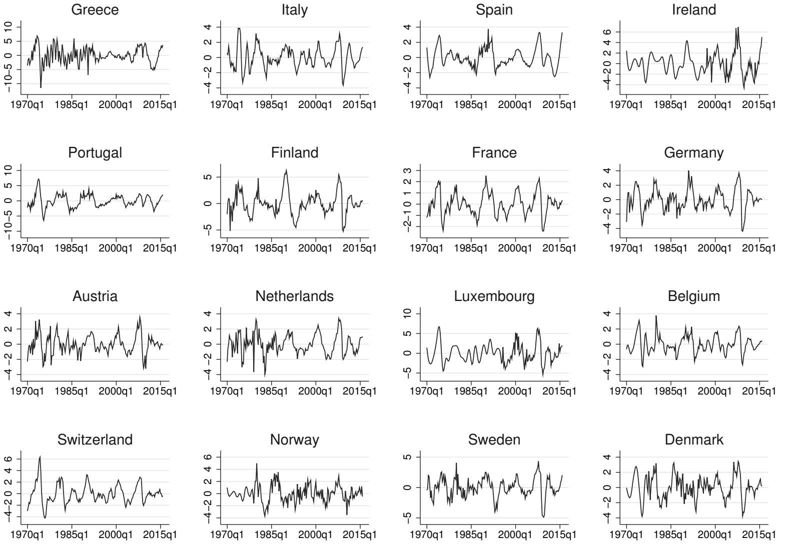
Business cycle refers to the movement of economic activity over time (Burns and Mitchell, 1946). Generally, two different types of cycles can be distinguished: the classical and the growth cycle. In the spirit of Lucas (1977), we focus on the growth cycle, i.e. the evolution of the cyclical component of GDP around its long-term trend instead of the classical cycle that is focused on the fluctuations of aggregate economic activity.[10] The literature proposes several different methods to separate the long-term growth trend from the cyclical component (Weyerstrass *et al.*, 2011). For our study, we employ the Hodrick-Prescott (HP) filter (Hodrick

[8]EA-12 includes the eleven countries that adopted the Euro in 1999 (Austria, Belgium, Germany, Spain, Finland, France, Ireland, Italy, Luxembourg, the Netherlands and Portugal) as well as Greece that joined in 2001.

[9]Alternatively, other potential measures include industrial production (Imbs, 2010) or the unemployment rate (Fatas, 1997). On the upside, these indicators are available at higher frequencies. On the downside, they are not as comprehensive a measure for aggregate activity as GDP, and - in the case of the unemployment rate - depend heavily on country-specific institutions that make cross-country comparisons difficult.

[10]From a theoretical point of view, the output gap seems to be the relevant indicator for central banks to monitor (Gächter and Riedl, 2014). From a technical point, our correlation index, as explained in further detail in Section 3.3, requires covariance-stationary time-series.

Figure 1: Business Cycle Fluctuations over time



Notes: Cyclical component of business cycles, using the Hodrick-Prescott filter with λ=1600.

and Prescott, 1997) to detrend the national real GDP series. Belke and Heine (2006) show that the HP filter produces cyclical components broadly similar to those obtained by the bandpass filter. The HP filter is not without criticism,[11] but due to its simple estimation and implementation it remains widely used in the business cycle literature. The cyclical component corresponds to the output gap, whereas the trend can be interpreted as potential output. We follow the literature and use a smoothing parameter of λ=1600 for quarterly data (Ravn and Uhlig, 2002). We depict the cyclical movement of the core and peripheral countries in Figure 1.

[11]See, for instance, Canova (1998).

3.3. Correlation Index

In the following, we introduce a correlation index developed by Cerqueira and Martins (2009) that gains increasing popularity in business cycle research (Gächter and Riedl, 2014; Bierbaumer-Polly *et al.*, 2016). As opposed to normal correlation coefficients, the correlation index of Cerqueira and Martins (2009) provides a measure of bilateral correlation for higher - in our case quarterly - frequencies and captures time-variability in bilateral business cycle correlations since it distinguishes between specific episodes of higher and lower synchronization, respectively. This correlation index can be applied to any two covariance-stationary time-series g_{it} and g_{jt}:[12]

$$\rho_{ijt} = 1 - \frac{1}{2}\left(\frac{g_{it} - \overline{g_i}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(g_{it} - \overline{g_i})^2}} - \frac{g_{jt} - \overline{g_j}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(g_{jt} - \overline{g_j})^2}}\right)^2 \tag{1}$$

When averaged over time, the correlation index is identical to the conventional linear correlation coefficient ρ_{ij}, i.e. $\rho_{ij}{=}\frac{1}{T}\sum_{t=1}^{T}\rho_{ijt}$. However, the index in equation 1 suffers from an asymmetric range: it is bounded between 3-2T and 1 and thus more dispersed over negative than over positive values. Cerqueira (2013) proposes the following transformation

$$\rho_{ijt}^{nb} = \frac{1}{2}ln\left(\frac{1 + \frac{\rho_{ijt}}{2T-3}}{1 - \rho_{ijt}}\right) \tag{2}$$

which we will use for our subsequent estimations. Another way to examine the co-movement between country pairs are so-called "rolling window" correlation coefficients, an approach widely used in the business cycle literature (Weyerstrass *et al.*, 2011). In contrast to rolling window correlation coefficients, the proposed correlation index provides distinct advantages: first, there is no loss of observations, second, there is no need to set a an arbitrary window-length, and, third, it is easier

[12] Augmented Dickey Fuller tests reject the null hypothesis of a unit root process at conventional significance levels for all series.

to implement in econometric analysis since rolling-window correlations suffer from heavy autocorrelation and hence heavily autocorrelated dependent variables.[13]

4. Empirical Framework and Results

4.1. Pairwise Correlation Coefficients

As a benchmark analysis, we start our empirical investigation with the estimation of simple correlation coefficients which correspond to the average of our (unbounded) correlation index ρ_{ijt} over the same sample period. According to this measure, national cycles between two countries are synchronized if both are positively and statistically correlated with each other. In order to analyze time variation in the synchronization of business cycles, we have divided our data in two non-overlapping time periods and calculate the correlation coefficient for each time period separately: the first period starts in 1999Q1 and lasts until 2007Q4, corresponding to the introduction of the Euro until the beginning of the financial crisis that started in the US, following Bekiros *et al.* (2015), while the second period covers the phase after the financial crisis erupted (2008Q1 - 2015Q4). We present our results in three tables, focusing on (i) individual core countries (Table 1), (ii) individual periphery countries (Table 2) and (iii) countries outside the EMU (Table 3).

As depicted in Table 1, core countries tend to have quite a high correlation between each other as well as with the EA-12[14] and the periphery aggregate in the pre-crisis period. The Netherlands and Finland show the lowest correlation with the periphery and the EA-12, and Austria and Germany the highest, respectively. The correlation between individual core countries and the periphery starts to drop after the start of the financial crisis. The drop is most pronounced for Austria and

[13]For a further discussion, see also Gächter and Riedl (2014) and Degiannakis *et al.* (2014).

[14]Naturally, correlation coefficients between EMU member states and the EA-12 are biased upwards. This bias is more pronounced for countries that have a higher weight in the EA-12 aggregate (Haan *et al.*, 2008).

France, where the correlation coefficient decreased from 0.934 (Austria) and 0.927 (France) to 0.619 and 0.642.

Table 1: Correlation coefficients: core (individual) vs. periphery (aggregate)

	Finland	France	Germany	Austria	Netherlands	Periphery	EA-12
Pre-Crisis							
Finland	1						
France	0.894***	1					
Germany	0.780***	0.859***	1				
Austria	0.852***	0.928***	0.854***	1			
Netherlands	0.838***	0.903***	0.856***	0.902***	1		
Periphery	0.866***	0.927***	0.928***	0.934***	0.864***	1	
EA-12	0.879***	0.953***	0.963***	0.942***	0.914***	0.984***	1
Crisis							
Finland	1						
France	0.942***	1					
Germany	0.971***	0.966***	1				
Austria	0.927***	0.951***	0.948***	1			
Netherlands	0.872***	0.771***	0.827***	0.793***	1		
Periphery	0.719***	0.642***	0.679***	0.619***	0.906***	1	
EA-12	0.946***	0.917***	0.943***	0.895***	0.938***	0.881***	1

Notes: The cyclical component is extracted using the HP filter for the logarithmic real and seasonally adjusted quarterly GDP. The "pre-crisis" period is defined as ranging from 1999Q1 - 2007Q4, the "crisis" period from 2008Q1 - 2015Q4. ***/**/* indicate significance at the 1%/5%/10% level.

For the periphery (see Table 2), the general correlation between these countries with the EA-12 and the core seems less pronounced. Italy and Spain show the highest, Portugal and Greece the lowest correlation with economic activity in the core and the aggregate EA-12. The peripheral economies decreased their degree of synchronization with the euro area and the core in the crisis period, with the exception of Italy, with Spain and Greece showing the most pronounced drop. In general, Greece seems to have a rather low degree of synchronization with other European economies, an observation already pointed out by Gayer (2007): it shows a moderate (positive) but insignificant correlation with the EA-12 but negative (however insignificant) correlation with core countries in the crisis period. Interestingly, Italy enjoyed in both sample periods a very strong co-movement of economic activity with both the core and the EA-12 aggregate.

Table 2: Correlation coefficients: periphery (individual) vs. core (aggregate)

	Italy	Portugal	Greece	Ireland	Spain	Core	EA-12
Pre-Crisis							
Italy	1						
Portugal	0.603***	1					
Greece	0.544***	0.261	1				
Ireland	0.814***	0.613***	0.488***	1			
Spain	0.884***	0.751***	0.600***	0.861***	1		
Core	0.911***	0.801***	0.552***	0.830***	0.958***	1	
EA-12	0.941***	0.772***	0.587***	0.858***	0.969***	0.994***	1
Crisis							
Italy	1						
Portugal	0.677***	1					
Greece	0.0615	0.612***	1				
Ireland	0.727***	0.549***	0.341*	1			
Spain	0.676***	0.822***	0.643***	0.816***	1		
Core	0.917***	0.416**	-0.114	0.658***	0.502***	1	
EA-12	0.967***	0.628***	0.130	0.785***	0.719***	0.958***	1

Notes: The cyclical component is extracted using the HP filter for the logarithmic real and seasonally adjusted quarterly GDP. The "pre-crisis" period is defined as ranging from 1999Q1 - 2007Q4, the "crisis" period from 2008Q1 - 2015Q4. ***/**/* indicate significance at the 1%/5%/10% level.

One way to test whether the membership of the euro area influenced the way the financial crisis had an impact on business cycle co-movements is to examine the correlations also for countries that are outside of the EMU but with economies very much integrated with the euro area. We therefore analyze the correlation patterns for four non-EMU countries: Denmark, Sweden (EU member countries who have opted to stay out of the EMU) as well as Switzerland and Norway (as part of EFTA). Denmark has opted for a fixed exchange rate to the euro and should thus, from a macroeconomic point of view, be regarded as an "informal" member of the core. The other three countries have a flexible exchange rate regime (to a varying degree) with Norway the added specificity of its reliance on oil revenues, which should make its economy less dependent on the euro area cycle. Results are depicted in Table 3. In the pre-crisis period, there is no stark difference between the correlations of the core and the periphery with the non-EMU countries. In both cases, Switzerland had the highest correlation and Norway the lowest. Yet, the co-movement patterns changed after the eruption of the financial crisis. Compared

Table 3: Correlation coefficients: outside EMU countries vs. aggregates

	Denmark	Sweden	Norway	Switzerland	Periphery	Core	EA-12
Pre-Crisis							
Denmark	1						
Sweden	0.903***	1					
Norway	0.692***	0.732***	1				
Switzerland	0.816***	0.812***	0.653***	1			
Periphery	0.831***	0.893***	0.680***	0.929***	1		
Core	0.793***	0.849***	0.639***	0.948***	0.961***	1	
EA-12	0.818***	0.878***	0.667***	0.951***	0.984***	0.994***	1
Crisis							
Denmark	1						
Sweden	0.879***	1					
Norway	0.388**	0.201	1				
Switzerland	0.867***	0.734***	0.448**	1			
Periphery	0.736***	0.773***	0.278	0.671***	1		
Core	0.926***	0.899***	0.379**	0.876***	0.709***	1	
EA-12	0.921***	0.917***	0.368**	0.862***	0.881***	0.958***	1

Notes: The cyclical component is extracted using the HP filter for the logarithmic real and seasonally adjusted quarterly GDP. The "pre-crisis" period is defined as ranging from 1999Q1 - 2007Q4, the "crisis" period from 2008Q1 - 2015Q4. ***/**/* indicate significance at the 1%/5%/10% level.

to the pre-crisis period, all non-EMU countries have less synchronization vis-à-vis the periphery, while correlation with the core stayed more or less at the same level. Norway seems like an exception since output synchronization fell significantly for both the core and the periphery. But this might be due to the high variability of oil prices after 2007/8. All in all it appears that the reaction of these European economies to the crisis was not visibly affected by their non-membership to the euro area. The sovereign debt crisis does not seem to have affected the relatively close correlation between the core countries and these other economies not part of the euro area. It seems that the relatively strong external position of the non-euro countries, similar to the one of the core euro countries, was more important than the fact that they are not part of the EMU.

At the aggregate level, our analysis suggests that correlation between the core and the periphery fell, as one would expect, after the eruption of the financial crisis. The non-EMU countries, with their strong external positions, did not experience risk spreads and showed a lower synchronization with the periphery in the crisis period, but no significant change in the output co-movement with the core countries.

4.2. Panel Regression

In this section, we run variants of the following panel regression to test whether the eruption of the global financial crisis changed the business cycle synchronization on a country-pair level:

$$\rho_{ijt}^{nb} = \beta_0 + \beta_1 Cluster_{ij} \times Crisis_t + \delta_i + \gamma_j + \alpha_{ij} + \omega_t + \epsilon_{ijt} \tag{3}$$

We regress our quarterly correlation index ρ_{ijt}^{nb} (see equation 2) on an interaction term between a crisis dummy that equals 1 starting from 2008Q1 and 0 otherwise and four different country clusters: core, periphery, non-EMU and EA-12. A statistically significant value for the coefficient β_1 in equation 3 indicates a structural shift in the business cycle synchronization among the specific clusters. We include all our EA-12 plus four non-EMU countries (Norway, Sweden, Denmark, Switzerland) and run our regressions from the start of the EMU in 1999Q1 until 2015Q4. Furthermore, we include time, country and bilateral fixed effects to control for unobserved heterogeneity.

Results are depicted in Table 4 for the core and periphery (i) among and between themselves (column 1), (ii) vis-à-vis the EA-12 (column 2) and (iii) relative to the non-EMU countries (column 3), defined as Denmark, Sweden, Norway and Switzerland. Note that we do not include dummies for the crisis and the clusters since they are absorbed by the time and country-pair fixed effects.

Our estimations support our initial findings based on correlation coefficients: the negative interaction coefficient suggests that countries along the core-periphery dimension were less aligned after the eruption of the financial crisis (column 1). This effect is significant at the 1% level. Interestingly, while core countries were growing stronger together as a group, peripheral countries were drifting apart. As a result, the core countries grew stronger together as a block among themselves, the pe-

Table 4: Business cycle synchronization

	(1)	(2)	(3)
Crisis × Core - Core	0.205**		
	(0.0880)		
Crisis × Per. - Per.	-0.252***		
	(0.0880)		
Crisis × Core - Per.	-0.535***		
	(0.0604)		
Crisis × Core - EA-12		-0.00694	
		(0.0516)	
Crisis × Per. - EA-12		-0.405***	
		(0.0516)	
Crisis × Core - non-EMU			0.181***
			(0.0657)
Crisis × Per. - non-EMU			-0.204***
			(0.0657)
Observations	8159	8159	8159
R^2	0.159	0.156	0.151
Time FE	✓	✓	✓
Country FE	✓	✓	✓
Bilateral FE	✓	✓	✓
Sample Mean ρ^{nb}	1.320	1.320	1.320

Notes: Dependent variable is the unbounded quarterly bilateral correlation index by Cerqueira (2013). Clustered standard errors at the country-pair level in parentheses. ***/**/* indicate significance at the 1%/5%/10% level. Specifications (1) - (3) include country, bilateral and time (quarterly) fixed effects. The dummy variable "crisis" equals 1 starting from 2008Q1.

ripheral countries as cluster were less aligned relative to the core, but also relative to themselves. Comparing the core and peripheral countries with country-pairs belonging to the EA-12, a similar picture emerges (column 2). Peripheral countries were significantly less aligned with EA-12 countries during the crisis period, whereas core countries did not have a statistically significant change in the synchronization of economic output. A drop in synchronization is also detected for non-EMU countries with regards to the periphery, which stands in contrast with the increased alignment of the non-EMU countries with the core (column 3). Judging from these results, the period after 2007 initiated a decoupling in the Eurozone, and resulted in a group of core countries that over time increased their synchronization of economic activity, both among themselves and towards neighboring countries that are not part of the euro area. On the other side, the peripheral countries decoupled from the core, non-EMU countries and among themselves.

Concerning the "decoupling" within the periphery, all these countries had periods of high risk premia in common. But the root cause of their difficulties was very different: Ireland and Spain had a real estate boom which burst with the financial crisis. But the economies of these two countries started to recover quickly once the banking problems in the real estate sector had been resolved. Portugal and Greece, by contrast, had more fundamental problems of growth and productivity and have not fully recovered even today.

4.3. Local Polynomial Regressions

Both our correlation coefficients and our panel regression point to a split between the synchronization of peripheral and core business cycles after the eruption of the financial crisis. However, our results may hide some important variability given our time aggregation in two non-overlapping periods. Generally, linear models provide a simple fit to the data, are easy to understand and widely used. However, they are less suited if the data shows nonlinearities. In our case, business cycle synchronization across different country groups is likely to fluctuate over time. Nonparametric methods provide a useful modeling alternative since they are widely used in data analysis to determine unknown trends and do not rely on any specific functional form.[15] We estimate the following model to analyze cross-country business cycle synchronization over time:

$$\rho_{ijt}^{nb} = f(t) + u_{ijt} \tag{4}$$

[15]For an in-depth treatment, see Fan and Gijbels (1996), especially Chapter 3.

Since $f(t)$ is unknown, we use local polynomial regressions as a smoothing approach that makes no assumptions about the functional form of $f(t)$. This approach models the regression locally in the neighborhood around each point of interest t_0 with a window width of h, using a p-order Taylor expansion as approximation of the true function. In the estimation process, a weighting function K (Kernel) determines how observations in the neighborhood of t_0 are weighted. The quality of the fit of the LPR is affected by these three critical parameters. For our estimations, we use an Epanechnikov kernel, a polynomial of order 1 and rely on a rule-of-thumb (ROT) algorithm to automatically determine the optimal bandwidth, following closely the setting of Cerqueira (2013). We present our LPR results with pointwise confidence intervals (95%) (Cameron and Trivedi, 2005). Contrary to our analysis based on correlation coefficients and panel data, we take advantage of the full length of our sample starting in 1970 in order to track changes of synchronization over an extended time horizon, even though our primary interest remains on potential changes in the recent crisis period.

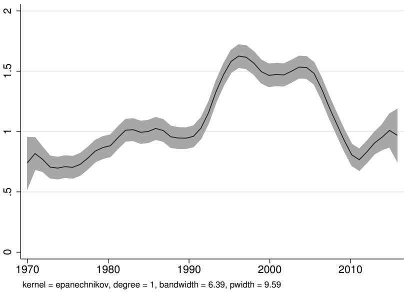
Results for the core and periphery cluster are depicted in Figure 2. Synchronization between core and peripheral countries was rather low during the 1970s until the beginning of the 1990s (see Figure 2a). During the run-up to the EMU, cycles seemed to synchronize rather sharply, in line with other studies that mention the "Maastricht effect" (Papageorgiou *et al.*, 2010; Inklaar *et al.*, 2008; Aguiar-Conraria and Soares, 2011). After the establishment of the currency area, the output co-movements continued to oscillate on a rather high level in the early 2000s. The process of higher synchronization between the two clusters has come to a hold shortly before the beginning of the financial crisis and consequently before the eruption of the sovereign debt crisis, thus corroborating the findings of Ferroni and Klaus (2015) in the case of Spain. Our findings are also in line with Degiannakis *et al.* (2014) who suggest a general reduction in the co-movement of economic output among peripheral economies and the EMU-12 cycle after 2007.[16]

[16] As local polynomial regressions take data before and after t_0 into account, our results anticipate to a certain extent future changes in synchronization. Therefore, as opposed to assigning a certain level of synchronization to a certain date, the LPR results are best interpreted as overall tendencies over a period of time.

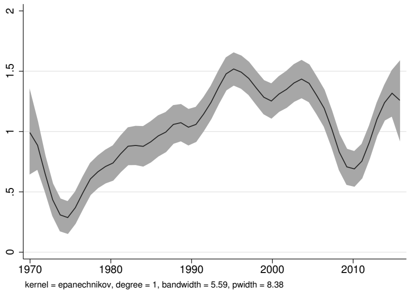
Synchronization starts to slightly increase again after 2010, but remains at a low level.[17]

Figure 2: Local polynomial regressions: core and periphery

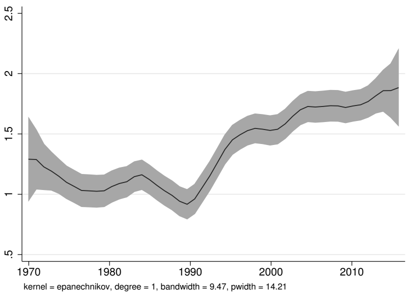
(a) Core - Periphery



(b) Periphery - Periphery



(c) Core - Core



Notes: Local polynomial regressions for core and peripheral countries.

Starting from the mid-1970s, peripheral countries steadily increased synchronization among themselves that peaked around the mid-1990s (see Figure 2b).

[17] In order to check whether our slope is different from a constant, we implement a significance test that is analogous to a simple t-test in a parametric regression setting (Racine, 1997; Racine *et al.*, 2006). For all the nonparametric models presented in this section, the test rejects the notion that our explanatory variable exerts a constant effect at a 1% significance level, i.e. the synchronization between the clusters varies significantly over time.

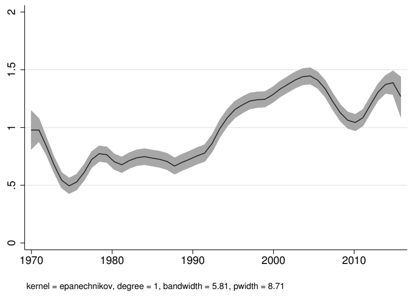
From there on, the alignment of economic activity hovered around a steady level, which on average was however lower than for the core countries. The co-movement of output decreased among peripheral economics during the financial crisis. However, synchronization started to increase from 2010 on, potentially reflecting the subsequent symmetric impact of the sovereign debt crisis on economic activity.

The relationship among core countries shows a slow, but steady upwards trend since the 1990s (see Figure 2c). The first plateau is reached after the rather strong increase in synchronization after the German unification process, and then in the early years of the EMU. Rather interestingly, and opposed to the behaviour of peripheral countries, there seems to exist no real dampening impact of either the financial crisis or the sovereign debt crisis on the alignment of economic activity among core countries. Rather to the contrary, economic synchronization has had a slight upwards tick in the period after 2010.

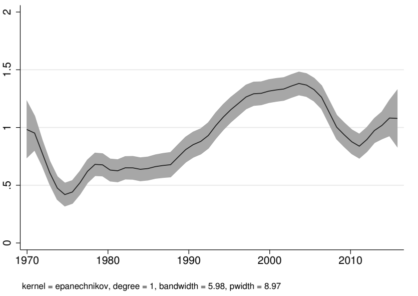
Figure 3 shows the development between the core and periphery vis-à-vis countries outside of the EMU. These economies enjoyed a rather low level of synchronization with all the EA-12 countries up until 1990, but then gradually increased to synchronize up until the mid-2000 (Figure 3a). The onset of the financial crisis triggered a rapid decrease in correlation, corroborating the results of Degiannakis *et al.* (2014) that non-EMU countries decoupled from the EMU-cycle in 2007. However, the synchronization of economic activity between non-EMU and EA-12 countries started to increase again around 2010. Splitting the EA-12 sample in the periphery (Figure 3b) and core clusters (Figure 3c), it becomes obvious that the most recent slowdown in synchronization is particularly driven by the periphery.

Figure 3: Local polynomial regressions: non-EMU countries

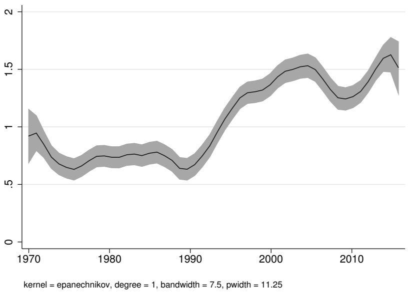
(a) non-EMU - EA-12



(b) non-EMU - Periphery



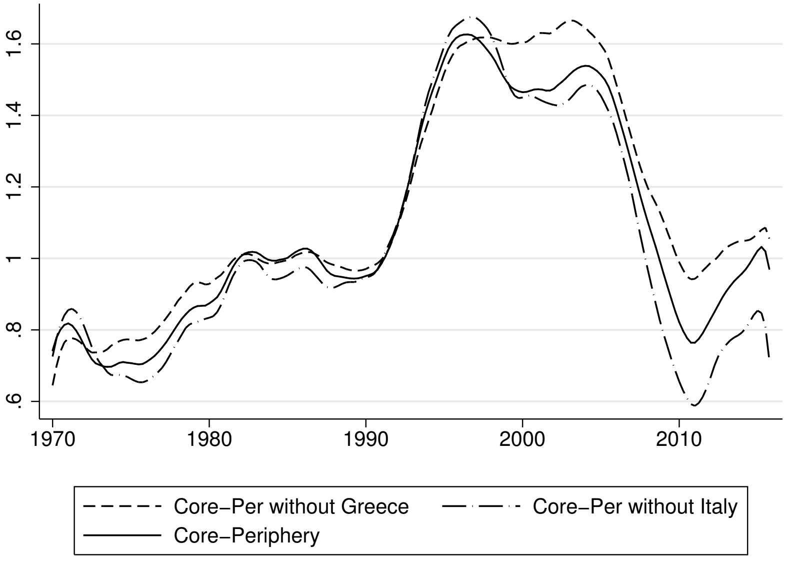
(c) non-EMU - Core



Notes: Local polynomial regressions for non-EMU countries relative to core, peripheral and EA-12 countries.

Overall, our dynamic analysis relying on local polynomial regressions confirms our previous results. Core and peripheral countries uncoupled significantly in the wake of the financial crisis. It also confirms that core countries seem to enjoy a higher (albeit on a very low level) synchronization after the crisis. Turning to the correlation among countries of the periphery, the financial crisis led first to asymmetric behavior, but turned into more synchronization due to a common shock in form of the sovereign debt crisis. Economic activity with non-EMU countries was particularly uncoupled for peripheral countries around the financial crisis, but less so for the core.

Figure 4: Local polynomial regressions: robustness check



Notes: Local polynomial regression between core and peripheral countries without Italy and Greece, respectively.

As a robustness check, we provide our local polynomial regression estimations with a different set of countries for the periphery cluster. Our analysis in Section 4.1 suggests that both Greece and Italy are potential outliers, with the former having the lowest and the latter the strongest correlation with core countries. As pointed out by Campos and Macchiarelli (2016), the periphery pattern that emerged after the introduction of the Euro included Spain, Portugal, Ireland and Greece, but excluded Italy. Other studies, as Lehwald (2013), do not include Italy in their definition of peripheral countries either. Greece, on the other hand, seemed to have rather different output co-movements compared with the rest of the euro area (Gayer, 2007).

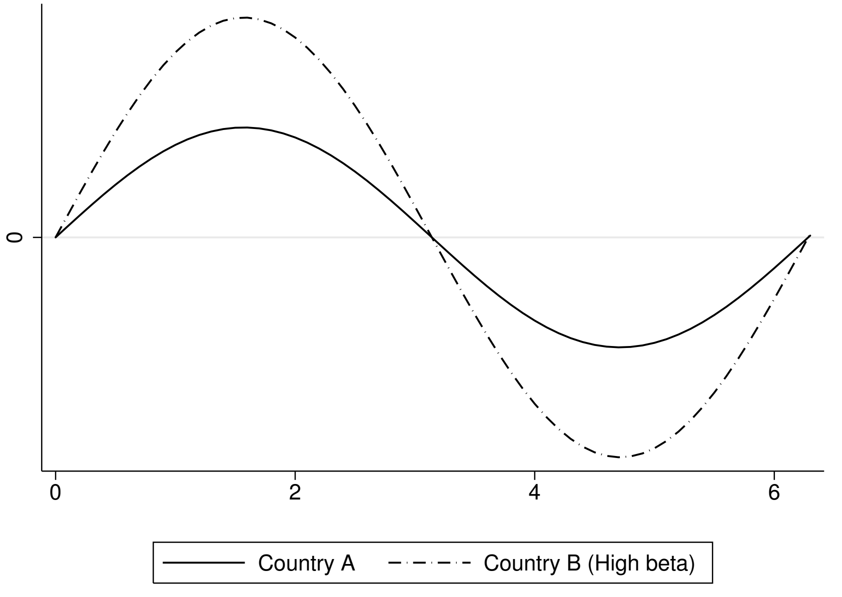
Thus, we repeat our local polynomial regressions with the same set of core countries, but exclude consecutively either Italy or Greece in the group of peripheral countries. Results from this exercise are depicted in Figure 4. Compared to the solid line, which represents our initial core-periphery country grouping, the group without Greece is actually more synchronized with the core, pointing to the particular decoupling of the Greek economy with the core countries, which was already taking place shortly after the introduction of the Euro. Our estimations support the findings of Gouveia and Correia (2008) who point out that the output co-movements of Greece were becoming weaker after 1997. If we exclude Italy from the periphery cluster, the desynchronization of the periphery with regards to the core is even more pronounced, suggesting that Italy enjoys on average a higher synchronization with the core than other peripheral countries. Our findings thus support the analysis of Campos and Macchiarelli (2016) who find that Italy may not be directly regarded as peripheral country from a business cycle synchronization point of view.

4.4. Amplitude vs Co-Movement

Most of the literature has focused on co-movements in the cycle as a measure of synchronization. But this can be misleading if the amplitudes of the cycle are very different. Figure 5 illustrates this with an example: there are two countries, which share the same (highly stylized) business cycle, but the amplitudes are very different. This has two implications: the correlation coefficient between the two series is 1, but at the peak and through of the cycle large differences appear. These differences can lead to similar problems of common policy making as if the two cycles were uncorrelated. But the problems posed by different amplitudes appear mostly around the extremes of the cycle. The widespread feeling during the peak of the crisis that the ECB's policy did not fit the needs of any country[18] could thus have two origins: either the correlation pattern changed since the financial crisis or the amplitudes of the cycles were different across countries so that one would expect at any peak and bottom of the cycle similar problems in business cycle positions. Moreover, differences in the amplitude could magnify the impact of any desynchronization.

[18] For a theoretical analysis, see Gros and Hefeker (2002).

Figure 5: Perfect co-movement but different amplitude

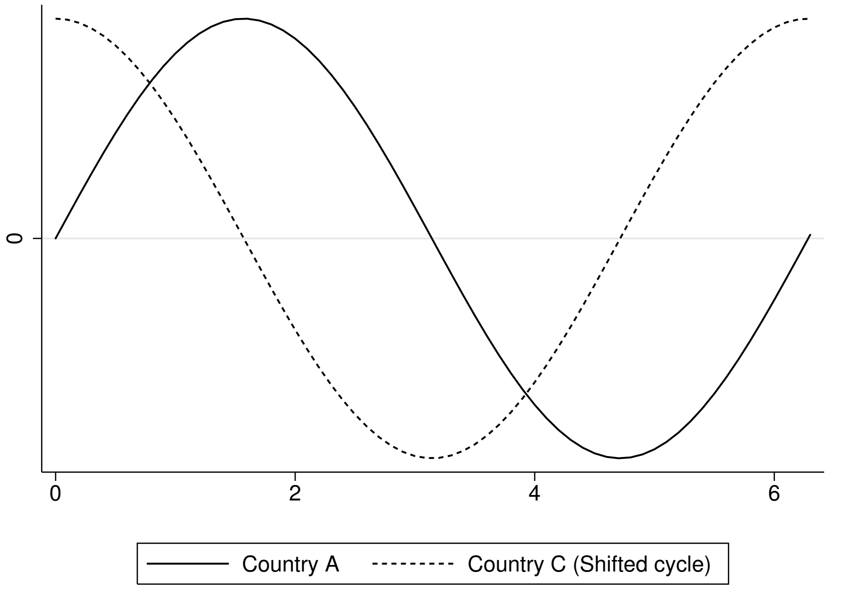


Notes: This figure shows stylized business cycles for country A and B. The business cycles are synchronous, with country B having an amplitude which is twice as large as country A's.

These considerations suggest that the emphasis on correlations makes sense only if countries have cycles which might be shifted, but have a similar amplitude (and length). Figure 6 depicts the case of two countries whose cycles are shifted over time in such a way that the correlation is equal to zero. In this case the differences in the cyclical positions are minimal at half cycle and remain constant between the peak and trough.

Different amplitudes exacerbate any lack of correlation as shown in Figure 7 which shows three lines: the common euro area cycle, the cycle of a country which is delayed by half a cycle, but has the same amplitude as the common cycle, and a country with an amplitude twice as large as the common cycle. It is apparent that the difference between the national and the euro area cycle is not the same when the amplitude changes although the correlation coefficient

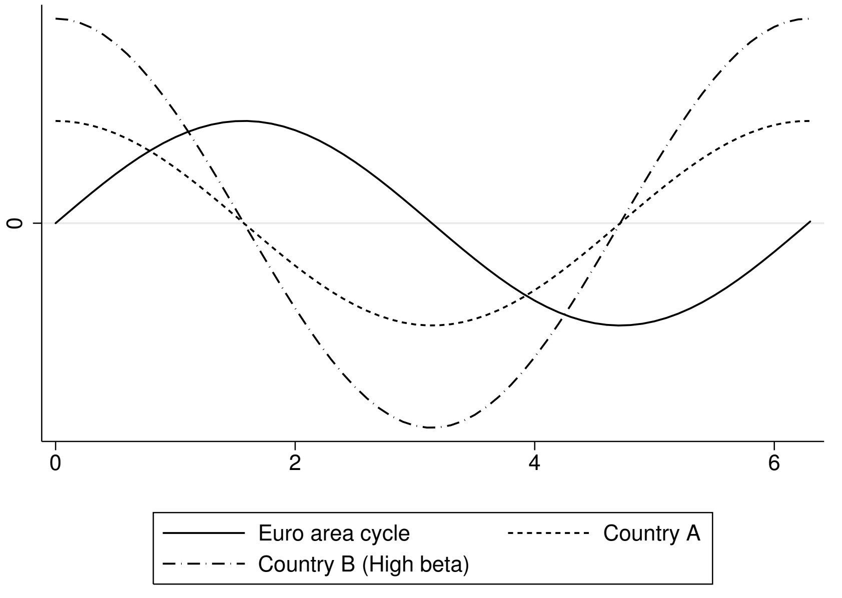
Figure 6: Zero correlation because of phase shift



Notes: This figure shows stylized business cycles for country A and C with the same amplitude but that are uncorrelated.

between the national and the euro area cycle is equal (to zero) in both cases. At the bottom of the last crisis it had been observed that the ECB policy was "one-size-fits-none" as the ECB's policy appeared too loose for the core and too tight for the periphery. A comparison between these figures suggests one way one could discriminate between the two hypotheses: if differences in amplitudes are the problem one would expect large divergences to appear mainly at the peak and trough of the cycle. By contrast, if business cycles are shifted, the divergences in cyclical positions should persist most of the time. The way the policy discussion has evolved suggests that different amplitudes might have been a key factor since differences in cyclical positions play much less of a role today than at the peak of the crisis.

Figure 7: Correlation and phase shift



Notes: This figure shows the business cycle of the euro area, country A which is shifted and country B which is shifted and has an amplitude twice as large as country A's.

A first measure of different amplitudes is the volatility of business cycles, at the national level, proxied by the standard deviation of the cyclical component of national real GDP series. A first question is thus whether there has been convergence in the amplitude of business cycles measured by their overall volatility (Gayer, 2007). As before, we rely on the HP filter for the trend-cycle decomposition.

As in previous sections, we are interested in the effects of the potential changes since the start of the financial crisis. Thus, we split the sample between the early phase of the Euro (1999Q1-2007Q4) and the crisis period (2008Q1-2015Q4), but also provide the standard deviation for the whole period from 1999Q1 to 2015Q4. The results are depicted in Table 5.

Table 5: Amplitude of business cycles

	1999Q1-2015Q4	1999Q1-2007Q4	2008Q1-2015Q4
Aggregate			
Periphery	1.32	1.12	1.52
Core	1.39	1.24	1.53
EA-12	1.29	1.18	1.40
Periphery			
Greece	2.47	1.47	3.27
Italy	1.39	1.17	1.60
Spain	1.40	1.07	1.70
Ireland	2.56	2.49	2.50
Portugal	1.43	1.24	1.63
Core			
Finland	2.11	1.76	2.43
France	1.03	0.95	1.07
Germany	1.70	1.48	1.92
Austria	1.34	1.20	1.47
Netherlands	1.46	1.52	1.40
Outside EMU			
Norway	1.12	1.19	1.04
Sweden	1.83	1.50	2.09
Denmark	1.52	1.50	1.50
Switzerland	1.27	1.42	1.10

Notes: Standard deviations of output gap in %.

Focusing on the development of volatility in the periods after the introduction of the Euro and before the crisis (column 2), Ireland and Greece exhibit the highest business cycle volatility in the periphery, which is also above the average of the (aggregate) EA-12. Among the core countries, Finland, the Netherlands and surprisingly Germany stand out, whereas France shows the lowest variation. In the period after 2007Q4, the volatility of national business cycles was generally on the rise for all peripheral and core countries, except for the Netherlands. Yet, Greece and Ireland had the highest volatility, closely followed by Finland. While the variation across countries is rather pronounced, it does not run along the core-periphery dimension.

For the functioning of the euro area, the more relevant question is whether national cycles of individual countries had a different reactivity to the aggregate EA-12 cycle, i.e whether different countries had different "betas". To measure these "betas", we run the following simple regression with heteroskedasticity- and autocorrelation-consistent (HAC) standard errors in the spirit of Gogas (2013) and De Grauwe and Ji (2016):

$$ln(c_t^i) = \beta_0 + \beta_1 \times ln(c_t^{EA-12}) + e_t \tag{5}$$

This is done for our core and peripheral countries individually with a sample running from 1999Q1-2015Q4, with c_t^i being the cyclical component of GDP for each country i and c_t^{EA-12} for the EA-12, respectively. Results for the core and the periphery are shown in Table 6 and 7.[19]

Table 6: Contemporaneous effect of EA-12 cycle on national cycle: periphery

	Greece	Italy	Spain	Ireland	Portugal
EA-12	0.477	1.031***	0.873***	1.627***	0.758***
	(0.477)	(0.0528)	(0.150)	(0.192)	(0.141)
R^2	0.062	0.912	0.650	0.670	0.472

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each peripheral country. Sample from 1999Q1 - 2015Q4. HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table 7: Contemporaneous effect of EA-12 cycle on national cycle: core

	Finland	France	Germany	Austria	Netherlands
EA-12	1.499***	0.741***	1.254***	0.949***	1.038***
	(0.127)	(0.0556)	(0.0879)	(0.0547)	(0.0969)
R^2	0.843	0.868	0.904	0.840	0.841

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each core country. Sample from 1999Q1 - 2015Q4. HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

[19] As a robustness check, we exclude for all regressions the reference country i from the EA-12 aggregate to minimize simultaneity issues. This bias should be negligible for smaller economies, but more relevant for bigger countries like France or Germany. The results do not vary significantly, and are reported in the Appendix.

The results suggest that all national cycles are tightly linked to the euro area one (with one exception, Greece). There is no distinct core-periphery pattern, except for the special case of Greece. Compared to the other nine countries that react positively to a reaction of the aggregate cycle, the coefficient for Greece is not only lower in absolute magnitude, but also statistically not significant.

Within the core there is a large, statistically significant difference between Germany and France: Germany's beta is at 1.25 almost twice as large as that of France (0.74). This means that if the common cycle shows an output gap of 2 %, that of France (compared to its own cycle) would be 1.48 %, whereas that of Germany would be 2.5 %. Any large common up- or downswing could thus lead to very large cyclical positions. Within the periphery one finds similar pronounced differences, with Ireland having a beta of 1.63, compared to 0.87 for Spain. Italy is the only large country with a beta almost exactly equal to one. From the non-EMU countries, Norway seems to react the least to the aggregate EA-12 cycle, having both the lowest coefficient and R^2, as depicted in Table 8.

Table 8: Contemporaneous effect of EA-12 cycle on national cycle: outside EMU

	Sweden	Denmark	Norway	Switzerland
EA-12	1.276***	1.023***	0.454***	0.877***
	(0.133)	(0.0786)	(0.114)	(0.0869)
R^2	0.807	0.757	0.274	0.789

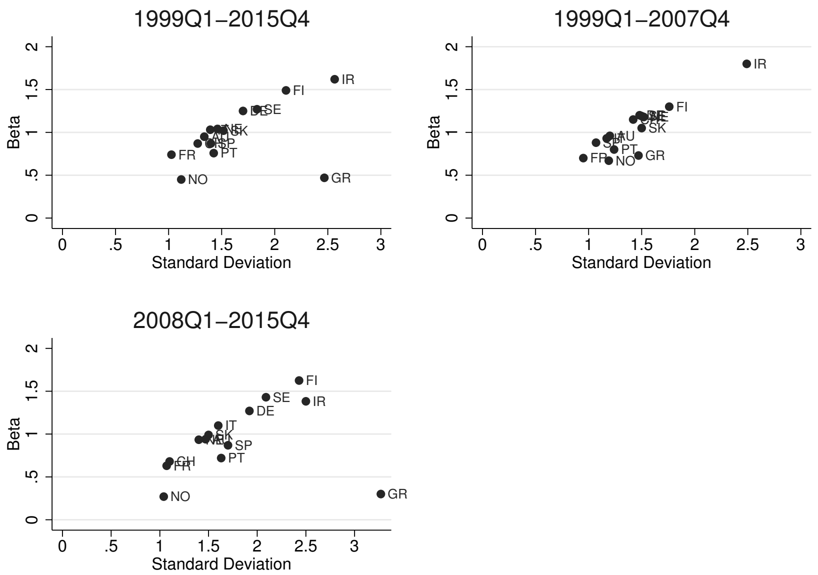
Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each core country. Sample from 1999Q1 - 2015Q4. HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

To investigate whether our relationship between the national and the aggregate cycle changed after the eruption of the financial crisis, we include a dummy variable into our empirical setting which takes the value one for the period after 2007Q4 and zero otherwise. The interaction term between this crisis dummy and the EA-12 cyclical component indicates whether there was a trend shift, as shown in equation 6:

$$ln(c_t^i) = \beta_0 + \beta_1 ln(c_t^{EA-12}) + \beta_2 D_{crisis} + \beta_3 ln(c_t^{EA-12}) \times D_{crisis} + e_t \quad (6)$$

The results are depicted in Table A.3, A.4, A.5 in the Appendix. Greece is again different, with much of the idiosyncratic movement compared to the EA-12 cycle taking place after 2007Q4. Yet the coefficient remains the lowest of all the peripheral countries. In general, our results support the notion that there is not a striking difference between core and peripheral countries in their reaction to the common EA-12 cycle.[20] However, the goodness of fit for the core regressions as shown by the R^2 is, with the exception of Italy, always lower for the periphery than for the core countries. These findings are broadly in line with Gogas (2013), but at odds with De Grauwe and Ji (2016).

Figure 8: Beta vs. standard deviation



Notes: The scatter plots show the standard deviation of the output gap from Table 5 against the "beta" from regressions in Table 6, 7, 8 (period 1999Q1 - 2015Q4) and Table A.3, A.4, A.5 in the Appendix for the period from 1999Q1-2007Q4 and from 2008Q1-2015Q4.

[20] As before, we provide a benchmark analysis that excludes the reference country in the EA-12 series. The results do not vary significantly, see Table A.6 and A.7 in the Appendix.

The large differences in the elasticity with which different countries react to the common euro area cycle begs the question whether these differences can also explain the large differences in the amplitude of national cycles discussed earlier. Figure 8 therefore shows a scatter diagram of the standard deviations in Table 5 against the beta coefficients reported in Tables 7, 6, 8 for the period from 1999Q1-2015Q1 and Tables A.3, A.4, A.5 in the Appendix for the period from 1999Q1-2007Q4 and from 2008Q1-2015Q4.

There is a rather close correlation between the standard deviation of the national business cycles and the degree to which the national cycle reacts to the common one. The exception is, again, Greece, whose economy seems to have followed a completely different pattern since the outbreak of the crisis. The close correlation between the estimated beta coefficients and the standard deviation of national cycles suggests that the much higher variability observed in some countries was not due to specific policy errors, but to the structure of the economies and their financial sectors.

5. Conclusion

Business cycle (de)synchronization plays a pivotal role for monetary policy in a currency union. When business cycle conditions diverge strongly, the stance of the ECB, which has to look only at the average, might not fit any country.

We provide evidence for the (de)synchronization of two distinct clusters within the EMU: the core and the periphery. Correlation coefficients indicate that the synchronization of economic activity between these country clusters fell markedly in the period after the start of the financial crisis (2008Q1-2015Q4) compared to the pre-crisis period (1999Q1-2007Q4). Panel and local polynomial regressions based on a quarterly correlation index by Cerqueira (2013) confirm that peripheral countries became less aligned relative to both the core countries and other economies outside of the EMU in the crisis period. Furthermore, the peripheral countries became also less aligned among themselves, in contrast to the cluster of core countries that did not show any change synchronization between the pre- and the crisis period.

We also find that it is not sufficient to look at correlation patterns if one looks for a potential for desynchronization of business cycles. Countries which share the same business cycle might nevertheless experience quite different cyclical positions, and thus require a different monetary policy stance if the amplitude of the cycle is very different. We find indeed large differences in the amplitude of national cycles and the degree to which the national cycle reacts to the common one. A first conclusion is thus that monetary policy making in the euro area faces two problems: the financial crisis led to a desynchronization of the cycle as only the periphery was affected by high risk premia for its sovereign and the private sector. Moreover, individual countries have cycles of different amplitudes, which implies that even countries which share a common cycle might require a different monetary policy stance.

A high degree of correlation is thus not the only condition to ensure "one-size-fits-all". Similarity in the amplitudes of national cycles constitutes another. Cycles have diverged between the core and the periphery (and within the periphery) since the financial crisis. It remains to be seen to what extent this represents a temporary phenomenon. If it was due to the high risk premia during the peak of the crisis, this desynchronization might have been only temporary. It seems that at any rate, the large changes in correlations after the crisis have caused most research to focus on this phenomenon, neglecting the second issue, namely different amplitudes, which can also lead to problems for the common monetary policy.

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A. Appendix

Table A.1: Contemporaneous effect of EA-11 cycle on national cycle: periphery

	gre	ita	spa	ire	por
EA-11	0.377	1.009***	0.794***	1.621***	0.738***
	(0.481)	(0.0626)	(0.156)	(0.197)	(0.139)
R^2	0.040	0.868	0.561	0.651	0.452

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each peripheral country against the EA-12 cycle excluding the reference country. Sample from 1999Q1 - 2015Q4. HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.2: Contemporaneous effect of EA-11 cycle on national cycle: core

	Finland	France	Germany	Austria	Netherlands
EA-11	1.505***	0.675***	1.270***	0.942***	1.026***
	(0.133)	(0.0632)	(0.158)	(0.0574)	(0.102)
R^2	0.835	0.818	0.782	0.831	0.819

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each core country, independent variable is the EA-12 cycle excluding the reference country. Sample from 1999Q1 - 2015Q4. HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.3: Contemporaneous effect of EA-12 cycle on national cycle: periphery

	Greece	Italy	Spain	Ireland	Portugal
EA-12	0.734**	0.936***	0.883***	1.819***	0.812***
	(0.342)	(0.0625)	(0.0627)	(0.165)	(0.134)
Crisis	0.00341	-0.000244	0.000687	-0.00699	0.00139
	(0.0120)	(0.00181)	(0.00407)	(0.00505)	(0.00490)
Crisis × EA-12	-0.429	0.169**	-0.0113	-0.418	-0.0827
	(0.725)	(0.0847)	(0.239)	(0.299)	(0.228)
R^2	0.078	0.918	0.651	0.701	0.475

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each peripheral country against the EA-12 with a sample from in 1990Q1 and ends in 2015Q4. The crisis dummy covers the period from "2008Q1 - 2015Q4". HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.4: Contemporaneous effect of EA-12 cycle on national cycle: core

	Finland	France	Germany	Austria	Netherlands
EA-12	1.317***	0.773***	1.215***	0.964***	1.183***
	(0.169)	(0.0736)	(0.0764)	(0.0504)	(0.142)
Crisis	-0.000346	-0.00190	0.000859	0.000244	0.00163
	(0.00302)	(0.00171)	(0.00249)	(0.00214)	(0.00238)
Crisis × EA-12	0.325	-0.0765	0.0787	-0.0242	-0.246
	(0.223)	(0.102)	(0.152)	(0.113)	(0.164)
R^2	0.853	0.879	0.906	0.840	0.855

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each core country against the EA-12 cycle with a sample from 1999Q1 to 2015Q4. The crisis dummy covers the period from "2008Q1 - 2015Q4". HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.5: Contemporaneous effect of EA-12 cycle on national cycle: outside EMU

	Sweden	Denmark	Norway	Switzerland
EA-12	1.119***	1.046***	0.674***	1.151***
	(0.137)	(0.144)	(0.190)	(0.119)
Crisis	-0.00393	-0.00186	-0.000271	0.00212
	(0.00325)	(0.00303)	(0.00329)	(0.00213)
Crisis × EA-12	0.244	-0.0598	-0.400**	-0.474**
	(0.263)	(0.171)	(0.190)	(0.192)
R^2	0.825	0.762	0.326	0.849

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each non-EMU country against the EA-12 cycle with a sample from 1999Q1 to 2015Q4. The crisis dummy covers the period from "2008Q1 - 2015Q4". HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.6: Contemporaneous effect of EA-11 cycle on national cycle: periphery

	Greece	Italy	Spain	Ireland	Portugal
EA-11	0.698*	0.891***	0.863***	1.824***	0.797***
	(0.350)	(0.0690)	(0.0700)	(0.174)	(0.135)
Crisis	0.00320	-0.000408	0.000630	-0.00725	0.00136
	(0.0121)	(0.00219)	(0.00460)	(0.00519)	(0.00499)
Crisis × EA-11	-0.541	0.216**	-0.117	-0.436	-0.0923
	(0.713)	(0.100)	(0.223)	(0.303)	(0.225)
R^2	0.063	0.877	0.565	0.684	0.456

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each peripheral country against the EA-12 cycle excluding the respective country. The crisis dummy covers the period from "2008Q1 - 2015Q4". HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.

Table A.7: Contemporaneous effect of EA-11 cycle on national cycle: core

	Finland	France	Germany	Austria	Netherlands
EA-11	1.315***	0.716***	1.245***	0.959***	1.177***
	(0.175)	(0.0778)	(0.124)	(0.0520)	(0.156)
Crisis	-0.000382	-0.00229	0.000918	0.000233	0.00167
	(0.00309)	(0.00199)	(0.00374)	(0.00221)	(0.00258)
Crisis × EA-11	0.340	-0.0918	0.0562	-0.0284	-0.253
	(0.231)	(0.117)	(0.287)	(0.118)	(0.178)
R^2	0.845	0.835	0.783	0.831	0.833

Notes: Dependent variable is the quarterly (HP filtered) cyclical component of each core country against the EA-11 cycle excluding the respective country. The crisis dummy covers the period from "2008Q1 - 2015Q4". HAC standard errors in parenthesis. ***/**/* indicate significance at the 1%/5%/10% level.