

What has Changed After the Great Recession on the European Cyclical Patterns?

Ana Rodriguez-Santiago

Abstract

This article analyses the business cycle dynamics in the European Union (EU28) during recent decades. Following Camacho et al. (J Econ Dyn Control 30:1687–1706, 2006), we extend the analysis of European cycles to a broader range of countries, including new entrants. In addition, we update their sample by including the Great Recession data with the aim of exploring whether the financial crisis led to changes in cyclical features across these countries. Our results indicate that the Great Recession has undermined European cyclical linkages. Notably, we succeeded in detecting that the European economies do not follow more closed dynamics, despite the fact that the countries are showing more similar cyclical characteristics.

Keywords: Business cycle characteristics · Cyclical synchronization · European Union enlargement

JEL classification: C5 · E32 · F02 · C22

1. Introduction

The study of economic cycles is currently a hot policy issue in Europe, as some countries are rethinking the new role played in the European Union (EU), and new member states are reconsidering the effects of economic integration. In some sense, one could expect that economic integration should lead to similar patterns in macroeconomic dynamics. The inexistence of a common cycle should imply the adoption of different treatments for member countries of the European Union. It is important to know whether every country follows the same cyclical pattern to adapt the economic policies that are developed by the European Union Commission for the purpose of common welfare and, especially, the European Central Bank, responsible for monetary policy and financial supervision of the economic and monetary union (EMU).

The analysis of heterogeneity between member countries is especially relevant for the application of monetary policy, since the application of a “one-size-fits-all” policy by the EMU or European Commission could not have the expected effect if the countries are showing diverging economic dynamics, in words of Feldstein (1997): “Uniform monetary policy and inflexible exchange rates will create conflicts whenever cyclical conditions differ among the member countries”. In this context, this piece of research attempts to provide empirical evidence on the existence, or not, of a business cycle pattern among member countries and on the potential effect of the 2008-financial crisis on such a pattern.

The finding of patterns in business cycles, the study of linkages among different formations of countries and the provision of explanations for these stylized facts have been the core of a body of theoretical and empirical literature devoted to the study of the business cycle (see the survey conducted by De Haan, Inklaar and Jong-A-Pin, 2008). Most authors studying European economic cycles have focused on synchronization, rather than on any other characteristic of the cycle, with few exceptions, such as Krolzig and Toro (2005) or Camacho et al. (2008). After the enlargement of the European Union, the focus was placed on the search for a core-periphery pattern in the group but taking into account only the synchronization between countries or some presupposed central core (Camacho et al., 2006, Darvas and Szapáry, 2008, Gomez et al., 2011, König and Ohr, 2013, and Wortmann and Stahl, 2016). There is still a gap in the literature about the effects of the Great Recession on the cycles of European Union countries, with some exceptions, such as Antonakakis et al. (2016), who explained the debt crisis by the shocks on the periphery countries, Grigoraş and Stanciu (2016), who stated that European economies are less synchronized after the crisis, or Ahlborn and Wortmann (2018), who applied fuzzy clustering to explain changes in European clusters after the crisis.

The issues we address in this paper are how to provide evidence on the business cycle similarities and dynamics before and after the beginning of the Great Recession. To this end, first, we check if the length, depth, shape and synchronization of business cycles across European Union countries are now following more similar dynamics than before; second, and after more than a decade, we can extend the analysis to the new entrants and provide a comprehensive analysis once the lately adhered economies to the European Union have been established; and last, we explore if the 2008-financial crisis has introduced some changes in the cyclical linkages across this set of European countries and whether the crisis has changed the way in which relationships between countries were established before the crisis.

Our results point to the reconsideration of linkages across economic cycles of member countries of the European Union. The Great Recession seems to have changed patterns in cyclical linkages since the results obtained show a desynchronization between European economies, despite the fact that the countries are now showing more similar

business cycle characteristics, as a consequence of the severity of the crisis experienced during the late 2000s.

The rest of this paper is structured as follows: Section 2 describes the methodology and data for analysing business cycle characteristics and synchronization. Section 3 develops and applies the methodologies for identifying groups of countries with similar patterns in cycles. Finally, section 4 presents some general conclusions about the research and the study.

2. Business cycle analysis

2.1. Data

Our study is focused on the cycles of the 28 member countries of the European Union group because of the recent interest in the linkages between countries forming the group after the accessions in recent decades. The EU foundation occurred in 1957 with six member countries as founders, and from there, successive incorporations have been taking place until the last and current composition of the EU28 group (the date of accession can be consulted in Table A).

For the analysis of the business cycle of the member countries of the European Union, we use the quarterly growth rate of GDP at market prices, seasonally and working day adjusted. Although most of the time series were obtained from the Organization for Economic Co-operation and Development database (OECD), some of them were obtained from national statistics institutes or central banks of the countries. We used the available data for each country. Table 1 shows the periods of each sample, the source of the data, the assigned country code for identification and the year of accession of each country to the European Union.

The aim of our work is to analyse the existence of cyclical patterns between members of the European Union. In particular, we focus on the differences in patterns for the entire period of data available, the period until the crisis started and the cycles from the beginning of the 2008-financial crisis. Furthermore, we pay special attention to different cyclical linkages among new members of the European Union.

2.2. Methodologies for dating turning points

A recession is the period between a peak and a trough, while expansion is the period between a trough and a peak. In this context, a peak is identified as the last moment of an expansion, and the trough is therefore the last moment of a recession. To establish the cycles, it seems necessary to detect the turning points, which are the moments when the cycle passes from an expansion to a recession (peak) and from a recession to an expansion (trough).

Turning points identification is made by the Economic Cycle Research Institute (ECRI) for seven countries forming the European Union group (AT, FR, DE, IT, ES, SE and UK). This institute dates peaks and troughs from the behaviour of certain economic variables. For detecting business cycles, the ECRI uses variables such as GDP, IPI, labour market, rent and sales. However, this organisation does not elaborate on the identification of turning points for the rest of the countries forming the group.

For the rest of countries, we have applied the methodology of Harding and Pagan (2002) to find maxima and minima from the series of rebuilt GDP. Harding and Pagan provided an algorithm to locate turning points and a measure of pro-cyclicality on

quarterly data¹. Their approach allows us to dissect cycles in terms of the contributions made by their different components, i.e., trend, volatility, serial correlation and non-linear effects.

The algorithm provides us a binary variable that takes the value of one on the date when a recession takes place. This variable is used to establish the peaks and troughs that a time series experienced and then analyse the cycle characteristics, distinguishing between expansions and recessions.

2.3. Business cycle characteristics and synchronization

Although there are a wide range of features identified across the empirical literature about business cycles, we have selected a set of necessary characteristics to describe the cycle from the GDP time series, apart from the business cycle synchronization between countries. The analysed features of the business cycle refer to the length, depth and shape of the cycles, which can be measured by the duration, amplitude and both excess and cumulative movement of the cycles, respectively, as Harding and Pagan (2002) considered.

Concerning the length of the cycles, duration is the time spent between peak and trough in the case of a recession or between trough and peak when an expansion takes place. In our case, duration is represented as the number of quarters for each phase for each one of the countries, and the average refers to the mean duration that cycles last in the entire group of the European Union.

Regarding the depth of the cycle, we measure the amplitude, which is referred as the total gain or loss between peak and trough, and vice versa, experienced in a phase. To measure the amplitude, the GDP of every phase is rebuilt to compare the last trough/peak of the phase and the initial value. Amplitude is represented by the rate of loss or gain, which is the mean percentage that the GDP has increased during expansions or decreased during recessions.

Finally, the last characteristic is the deepness, which is associated with the shape of the cycle. It can be measured by the so-called excess, which measures how the actual time series behaves against a hypothetical linear path between two consecutive turning points. In terms of Harding and Pagan (2002), once we have the duration and amplitude of a phase, we obtain the excess cumulated movements by the triangle approximation to the cumulative movements ($C_{Ti} = 0.5 D_i A_i$, where D is the duration and A is the amplitude) and the actual cumulative movements or *cumulation*, calculated as the sum of every period's amplitude in a phase. The calculation of the excess in every phase (E_i) may be approximated by

$$E_i = (C_{Ti} - C_i + 0.5 A_i)/D_i,$$

where the term $0.5 A_i$ removes the bias that arises in using a sum of rectangles (cumulation C_i) to approximate a triangle.

Considering the way that the excess is calculated, a negative value refers to a concave evolution against the linear path, and a positive sign would indicate a convex evolution with respect to a linear growth/decrease. In this way, a concave expansion and a convex recession evolve more sharply at the beginning of a phase and in a smooth

¹ This methodology is a refinement of the dating algorithm for monthly data suggested by Bry and Boschan (1971). Although it is possible to employ a different algorithm, such as the Markov Switching model proposed by Hamilton (1989), the literature has successfully proved the preference of BBQ over other methods due to being the most effective, easy and having the fewest restriction requirements (see Ahking (2015) on this issue).

manner at the end of a phase. In contrast, convex expansions and concave recessions present a moderate evolution at the start of the phase and become more abrupt at the end. To illustrate these concepts, check Figure A1, where a representation of different types of expansions and recessions, depending on the sign of the excess, and the concepts of amplitude and duration are represented.

Furthermore, to study the synchronization between different business cycles, the concordance index between cycles of countries i and j (IC_{ij}) has been calculated as Harding and Pagan (2006) proposed², with R_{it} being the binary variable that takes a value of 1 when country i is in recession.

$$IC_{ij} = \frac{1}{T} \sum_{t=1}^T \{R_{it} R_{jt} + (1 - R_{it})(1 - R_{jt})\}.$$

The index represents the proportion of time in which two nations experience the same state of the economy. In this way, the difference between 1 and the concordance would represent the pairwise distances in business cycle synchronization.

2.4. Results

For a better understanding of the results, Table 1 indicates the effective sample period per country as well as when the crisis started for each of the countries. It is worth mentioning that for some of the countries that accessed the EU long ago, the OECD has data since 1960 for most of the countries (1949 for France and 1955 for United Kingdom), and for the last entries, the sample of GDP starts between 1994 and 2000.³

Table 2 presents the average and standard deviation of the business cycle features for the entire sample of data, the period before the Great Recession started in 2008 and the period since it started until the last data point that we have at our disposition (refer to tables A2 to A4 to see the individual characteristics of the countries).

Starting with the length of the cycles, as we expected, expansions last much longer than recessions. The average duration for the EU28 group takes a value of 22.8 quarters, while recessions have a mean duration of 5.5 quarters. The cases of the United Kingdom and Spain, whose expansions last on average 44.6 and 36.8 quarters, much longer than the mean on EU28, are remarkable. There are also countries whose expansions are much shorter than the average of the group, such as Croatia, Greece, Malta and Poland, with expansions of 14.3, 12.3, 10.2 and 14 quarters, respectively. Concerning the recessions, the case of Spain, where recessions last a mean of 15.7 quarters, is striking.

The amplitude analysis shows an average depth of 29.2% of the GDP during expansions and -4.1% during recessions. Although most of the countries present similar results, some countries have a much higher increase in GDP during expansions, such as Slovakia, Estonia and Lithuania, whose gains rise between 46% and 48%, and Ireland, presenting an average amplitude of 65% during expansions. On the other hand, there are countries such as Croatia, Denmark, Hungary, and Poland that present more modest growth (below 18%). With regard to recessions, some special cases are Estonia and Lithuania, whose loss in recessions is between 9% and 12%.

² McDermott and Scott (2000), Harding and Pagan (2002), Krolzig and Toro (2005) and Harding and Pagan (2006) regard the use of the concordance index as being a better tool in measuring business cycle synchronization. As advocated by Harding and Pagan (2002) and McDermott and Scott (2000) the concordance indicator is a better metric, focusing on the fraction of time when the reference cycle and the specific cycle are in the same state.

³ This is except for France, Sweden, Austria and Spain, whose samples have had to be shortened, since the dating of the cycles is made by the ECRI, which only provides data from 1953 for France and 1969 for the other 3 countries.

Respecting the shape of the cycles, the mean of excess takes a positive value for both expansions and recessions (1.24 and 0.12, respectively), which means that expansions tend to be smoother at the beginning and more abrupt at the end of the phase. Conversely, during recessions, the drop is more noticeable at the beginning, and it evolves in a smoother way to the end of the recession. This reflects the presence of convex expansions and recessions on average across the EU28.

The main point in our analysis of cyclical characteristics is the one referring to the situation since the late 2000s crisis started. We analyse the characteristics of the cycles for each of the countries for the period before and after the Great Recession started. This financial crisis had effects worldwide, with more or less repercussion depending on the country, but a generalized fact is that it started between the end of 2007 and the beginning of 2008. With regard to dating for business cycles, a date for the start of the crisis period has been established for every country⁴.

The characteristics of the business cycles before the crisis started⁵ and the results for the period after the crisis (that can be consulted in individual detail in tables A3 and A5) show that the average duration before the crisis was 25.4 quarters during expansions and 4.8 in recessions, while the average duration after the crisis was 16.8 quarters and 6.1. Expansions have become shorter, while recessions have become longer. The characteristics of the depth show relevant information since expansions before the crisis presented an amplitude of 37.1% during expansions and -2.2% during recessions, changing to a growth of 13% in expansions and a loss of 6.5% in recessions during the period since the crisis started. Finally, the measure of excess seems to be similar during recession between the period before and after the crisis (from excess of 0.05 to 0.08), but the excess on expansions has been shortened (from 1.79 to 0.07), meaning that expansions are less convex now.

Regarding the synchronization between countries (whose individual results can be consulted in tables A5 to A7), we can see that, considering the entire sample of data, the smallest concordance indexes are approximately 0.51-0.59, and the average shows a value of 0.81, with Croatia and Greece being the countries with the smallest concordance indexes. For the period before the crisis, which has been considered to end in 2007 for every country, the average concordance index between the entire set of countries is situated in 0.87 and 0.74 during the period since the crisis started, which would demonstrate a decrease in synchronization between the European Union, in line with the study of Bierbaumer-Polly, Huber and Rozmahel (2016). We can check this by analysing the minima concordance index that takes a value of 0.53 before and 0.29 after the crisis, being before the less synchronized countries of the group Croatia, Cyprus, Greece, Italy and Spain, and after Romania and Germany⁶.

Although the comment on the economic reasons behind the heterogeneity found on cyclical characteristics could be discussed longer, it is kept out of the paper's scope, since it basically is to comment the evolution of dynamics between the countries of the European Union after the Great Recession. Section 3 presents the methodology and results to complete the analysis of cycle dynamics.

⁴ The moment that we consider the crisis started for each of the countries is clarified in Table 1. It has been determined based on the peak that the countries showed during the years 2007-2008.

⁵ Bulgaria, Croatia, Cyprus and Slovenia have been excluded from the sample due to lack of a complete business cycle during the period before the crisis.

⁶ Bulgaria, Croatia, Cyprus and Slovenia have also been deleted from the sample of synchronization due to the interference that they provide as consequence of little data.

3. Cycle dynamics

3.1. Data and methodology

Once we have obtained the cycle characteristics and the concordance index for the member countries of the European Union, the next step in our analysis is to determine whether business cycles are similar between these countries and/or are now following more closed dynamics, in addition to analysing this relationship, in other words, if there are one or more groups of countries presenting similar cycles. Furthermore, we try to see whether there are some differences between relationships between the subsample pre-crisis and the period since the crisis started. Unlike Grigoraş and Stanciu (2016), we are not limited to analysing only the cycle features or the synchronization with a presupposed core central country. We let the data speak by itself, by not assuming any central core of the EU aggregation, and analysing the concordance of the cycle phases between every country with each other; in order to analyse the distribution of dissimilarities for both characteristics and concordance between countries, and study the changes that may have occurred after the Great Recession.

To study the existence of patterns between the countries, we use a clustering method that finds similar behaviours on cycles' characteristics. We apply the method of multidimensional scaling (MDS), a type of multivariate data analysis. Noted by Cox and Cox (2000), supposing a set of n objects, where between each pair of objects, there is a measurement of the dissimilarity, MDS application searches for a low-dimensional space, usually Euclidean, in which points in the space represent the objects and such that the distances between the points in the space match, as well as possible, the original dissimilarities. This analysis projects the pairwise cycle distances in a map such that the distances among the countries plotted in the layout approximate the economic cycle dissimilarities. In the resulting map, countries that present high economic cycle dissimilarities have representations in the layout that are not close to one another.

The MDS that we apply is the classical one, whose aim is to find a configuration in a low number of dimensions that, in our case, is two. This method treats the distances as Euclidean distances by going from a data matrix to a Euclidean distance matrix⁷. The Euclidean distance between two points is the length of the line segment connecting them.

First, and having access to the average features that we have obtained from business cycles, we apply MDS to the results from the entire sample of data, the period before the crisis and the period since it started to build the MDS maps. Then, we perform the same process directly using the pairwise distances of business cycle synchronization, obtained as 1 minus the concordance index.

The aim is to represent in a map the different countries of the EU28 to find relationships among groups of them. The maps allow us to visually understand which countries show similar patterns about business cycle features and synchronization⁸.

After that, to prove the veracity of the results, we apply a non-parametric density estimation approach to examine the distribution of the pairwise distances that we have previously calculated. Once we have obtained the distances between each pair of countries for the characteristics and using the pairwise distances of synchronization, we represent a kernel density distribution. The Gaussian kernel density estimator smooths out the contribution of each observed pairwise distance using an optimal bandwidth h ,

⁷ We are aware of the sensitivity of Euclidean distances to outliers and composition of the sample itself.

⁸ Note that in these maps, axes are meaningless; thus, they have been deleted. Every MDS map plots the country code, whose meanings are collected in Table 2 - Data description.

which is the optimal width of the density window around each point that would minimize the mean integrated squared error. Representing the distribution of the entire sample and both pre- and post-crisis subsamples, we can check if there are any changes between the cyclical patterns of characteristics and synchronization before and after the crisis started.

Furthermore, to provide robustness, we also present a summary of the descriptive statistics including skewness and kurtosis of the different pairwise distances calculated and apply the Kolmogorov-Smirnov test of equality on the distributions of two different samples, which not only evaluates the difference in central tendency but also evaluates the shape and skewness on the distributions.

Finally, to test for the number of modes of the distributions with the purpose of checking the existence of a core-periphery structure, we use the test suggested by Silverman (1981). The null hypothesis states that a density function has at most k modes, against the alternative hypothesis that it has more than k modes. Establishing a critical bandwidth h_k^* of the kernel density estimate for which it has k modes as maximum, it is possible to resample the pairwise distances by bootstrapping techniques and repeat this process many times to test the probability of having more than the number of modes k given h_k^* . The probability that the resulting critical bandwidths given k are larger than the critical bandwidth established can be used as the *p-value* of the test.

3.2 Results

The maps of dissimilarities in average business cycle features using multidimensional scaling are represented in Figures 1 to 3. Regarding the maps, it is possible to check how there is not an approximation among countries based on the date of accession to the European Union⁹, similar to the result that Gomez, Ortega and Torgler (2012) and Wortmann and Stahl (2016) stated. Regarding the complete sample, we can identify two separated central cores that gather most of the countries. The right periphery of the main core gathers countries such as Croatia, Poland and Malta, which present shorter expansions, or Finland, Hungary and Denmark, which have shown the smallest gain during expansion. On the left side of the map, at the periphery of the core, Slovakia, Lithuania and Estonia, with larger amplitudes during expansions, are together. The UK and Spain, which had longer expansions, are represented farther away from the core, as well as Ireland, which shows a much longer average gain during expansions. Although there appears to be no relation between the date of accession to the EU and the approximation among countries, with the exception of the UK and Spain, the oldest members of the group are closer among themselves.

The MDS analysis of the distances in business cycle features before the beginning of the Great Recession, represented in Figure 2, shows a similar pattern: there is a core with the smallest distances between the countries, and the countries on the periphery are the same as those on the complete sample analysis. The MDS map for the period since the crisis started (Figure 3) seems to show that countries are now represented with a greater distance between them.

However, analysing the different kernel density functions of distances on business cycle features, represented in Figure 4, it is possible to check that there were more dissimilarities and larger distances during the period before 2008. The distribution of distances on business cycle features during the period since the crisis started shows the reduction of dissimilarities and distances between countries.

⁹ In every MDS map, the founders and oldest members of the European Union are represented in red, the members who acceded between 1973-1995 are plotted in blue, and the new members, since 2004, are represented in black.

We can confirm that since the beginning of the Great Recession, the characteristics of the business cycles of countries belonging to the European Union group have become more similar. It is also possible to see that there is not a symptom that makes us think in a pattern across new or old members of the European Union, relationships based on date of accession to the group do not seem to be defined by a pattern, and countries are showing more similar behaviours than previous decades, due to the experienced crisis.

To support this statement, summary statistics including skewness and kurtosis, multimodality and equality of distributions are also presented. If we observe the skewness and kurtosis presented in Table 3, the values corresponding to the distances on features for the period before the crisis ($S=0.76$, $K=3.23$) are higher than the values obtained considering the period since the crisis started ($S=0.57$, $K=2.31$), which shows the reduction in dissimilarities. The results from the Silverman test of multimodality, presented in Table 4, show that we cannot reject the hypothesis of unimodality for the three samples considered. Furthermore, to confirm the changes in business cycle characteristics after 2008, the results from the Kolmogorov-Smirnov test, presented in Table 5, show that it is possible to reject the null hypothesis comparing the equality between the samples before and after the crisis started.

These results point towards the reconsideration of the analysis about business cycle features made by Camacho, Perez-Quiros and Saiz (2008). They refused the existence of an attractor in cycles of member countries of the European Union; thus, it is reasonable to think that the Great Recession has introduced considerable changes in cyclical patterns. Their study only covered the sample until the last accessions in 2004; consequently, if our analysis shows the existence of that European common cycle, it is acceptable to think that studying the update sample has led to the discovery of the change in cyclical characteristics after the experienced financial crisis.

Considering the analysis of synchronization, Figures 5 to 7 show the MDS maps of dissimilarities between business cycle synchronization for the entire sample, before the crisis started and since 2008. It is possible to identify a central core that gathers most of the countries; Germany, Portugal, Italy, Spain and Cyprus are located on the periphery, but there is still a great distance between them, and much farther away, we can find Malta, Romania, Croatia and Greece. As was the case with dissimilarities between business cycle characteristics, there appears to be no relation between date of accession to the EU and distance with other countries in terms of business cycle synchronization. The map for the period until the crisis started, presented in Figure 6, shows that countries are gathered in the centre, with the exception of Germany, Sweden, Romania, Malta and Latvia. The MDS map for the period since the crisis started, plotted in Figure 7, shows the same situation. The change we can appreciate is that the main core gathers more countries now, with the exception of Latvia, situated below the core, and Italy, Cyprus, Croatia, Spain and Greece, represented at the left-hand side of this centre, due to the similarities of the Great Recession between these countries, which was considerably longer and stronger. As before, we find no differences for the last added countries to the group in terms of synchronization with the rest of EU members.

For a more visual proof, Figure 8 shows the three Kernel density distributions of distances in business cycle synchronization. While the distribution for the period before the crisis presents a smaller right-hand tail what means homogeneous synchronization, since the crisis started, we can see that the dissimilarities between countries have increased, which means that the countries are not currently following closer dynamics.

Observing the skewness and kurtosis values (Table 3), it seems that these values have been reduced during the period since the Great Recession began (kurtosis passing

from 3.92 to 2.73, and skewness from 0.75 to 0.59). The results of the Silverman test analysis (Table 4) show that we cannot reject the null hypothesis of unimodality for any of the three samples. The Kolmogorov-Smirnov test of equality of pairwise distances on synchronization (Table 5) shows that the distribution before the crisis and the one since it began are not similar.

In line with Camacho, Caro and Lopez-Buenache (2018), we can prove that differences in behaviours during the crisis and the speed of overcoming it between the countries have provoked an increase in synchronization dissimilarities. This is due to the fact that the countries have suffered different levels of impact of the recession and the idiosyncratic characteristics of the countries make the recovery phase differ in terms of duration and amplitude. Our results differ from those by Degiannakis et al. (2014), who stated the emergence of two groups of countries, and only demonstrated a decrease in synchronization of the countries out of the EMU group, while we showed that there is not proof of the existence of two cores, as well as from the conclusion achieved by Ahlborn and Wortmann (2018), which stated that the southern periphery is showing a diverging pattern while the Eastern periphery is showing convergence.

Since the sample for the period before the crisis started needed to be shortened due to a lack of complete cycles, the exercise was carried out for the three different samples excluding the same four countries (Bulgaria, Croatia, Cyprus and Slovenia) to compare pre- and post-crisis samples that actually include the same countries, obtaining the same general results¹⁰. We have obtained the pairwise distances between business cycle synchronization and other features, represented by the kernel density distribution and a summary of statistics. Figures 9 and 10 plot the kernel density distributions of both business cycle characteristics and synchronization, respectively. They show the same general shape as the ones that were previously calculated.

Regarding the summary statistics in Table 6, although we can check how the entire sample shows smaller skewness and kurtosis values, the sample before crisis still presents a higher variance value, that confirms the reduction of dissimilarities of business cycle characteristics from the period before the crisis to the period post-crisis, which means that countries are now showing more similar cyclical characteristics. On the other hand, analysing synchronization between countries, we can check that the skewness value is also higher for the sample since the crisis started. Furthermore, the increase in the variance indicates that there are more dissimilarities between the countries' synchronization, which we can visually check regarding the long right tail and the shift to the right side that the density function has experienced

4. Conclusions

In this paper, we study and analyse possible changes in cyclical linkages among countries of the European Union introduced after the Great Recession based on the similarities in their cyclical features and synchronization. To some extent, this paper is an update and an extended version of previous works performed within the European Union. In particular, the consideration of a wide set of countries during an additional decade and the severity of the Great Recession seem to be behind these new empirical findings and the change in the relationship.

To summarize, we report the results obtained by applying a methodology for detecting turning points in GDP time series for each country. These turning points help

¹⁰ The completed results of the exercise with the reduced samples are available upon request.

to date expansions and recessions of every country, which allows us to analyse the length, depth and shape for different cycles, in addition to the synchronization.

Perhaps the most important contribution of our analysis emerges from the cyclical pattern observed after the 2008-financial crisis. In particular, cyclical characteristics after the crisis compared with the results obtained from the period before. Basically, recessions become longer and deeper during the Great recession.

On the other hand, focusing on the linkages between countries, and to check potential changes in the relationship after the crisis, we carried out an exhaustive analysis of distances on business cycle features and synchronization, for the entire sample, the period before 2008 and the period since the Great Recession started. In doing so, we apply a multidimensional scaling methodology to represent, in a map, every country by using their distances on features and synchronization of the business cycle. No evidence of a definite linkage among countries is found. In other words, it is not possible to establish definite relationships depending on the date of the entry to the group. To check the robustness of these findings, we represent the density distribution by kernel estimator on each of the distances for the characteristics and synchronization in business cycles.

Finally, we check the existence of an attractor in these distributions and verify the hypotheses that the 2008-crisis has probably powered linkages among countries, making their cyclical characteristics more similar, given that the Great Recession has had similar effects across the European Union, besides the fact that the countries are now more desynchronized due to the different evolutions of the cycles since the Great Recession started.

All in all, these results are important to distinguish different groups of economies in terms of heterogeneous dynamics and groups with close linkages. Identifying these groups is a key element for improving the effectiveness of European policies and especially the monetary policies developed by the European Central Bank in order to promote economic stabilization.

5. References

Ahking, F.W. (2015). Measuring U.S. business cycles: A comparison of two methods and two indicators of economic activities. *Journal of Economic and Social Measurement*, 39: 199-216.

Ahlborn, M., and Wortmann, M. (2018). The core-periphery pattern of European business cycles: A fuzzy clustering approach. *Journal of Macroeconomics*, 55: 12-27.

Antonakakis, N., Chatziantoniou, I., and Filis, G. (2016). Business Cycle Spillovers in the European Union: What is the Message Transmitted to the Core? *The Manchester School*, 84(4): 437-481.

Bierbaumer-Polly, J., Huber, P., and Rozmahel, P. (2016). Regional Business-Cycle Synchronization, Sector Specialization and EU Accession. *Journal of Common Market Studies*, 54(3): 544-568.

Bry, G., and Boschan, C. (1971). Cyclical analysis of time series: Selected procedures and computer programs. *National Bureau of Economic Research*.

Camacho, M., Caro, A., and Lopez-Buenache, G. (2018). The two-speed Europe in business cycle synchronization. *Working paper*.

- Camacho, M., Perez-Quiros, G., and Saiz, L. (2006). Are European business cycles close enough to be just like one? *Journal of Economic Dynamics & Control*, 30: 1687-1706.
- Camacho, M., Perez-Quiros, G., and Saiz, L. (2008). Do European business cycles look like one? *Journal of Economic Dynamics & Control*, 32: 2165-2190.
- Cox, T. F., and Cox, M. A. (2000). *Multidimensional Scaling*. Chapman and Hall.
- Darvas, Z., and Szapáry, G. (2008). Business cycle synchronization in the enlarged EU. *Open Economies Review*, 19(1): 1-19.
- De Haan, J., Inklaar, R., and Jong-A-Pin, R. (2008). Will business cycles in the euro area converge? A critical survey of empirical research. *Journal of economic surveys*, 22(2): 234-273.
- Degiannakis, S., Duffy, D., and Filis, G. (2014). Business Cycle Synchronization in EU: A Time-Varying Approach. *Scottish Journal of Political Economy*, 61(4): 348-370.
- Feldstein, M. (1997). The political economy of the European Economic and Monetary Union: Political sources of an economic liability. *Journal of Economic Perspectives*, 11(4): 23-42.
- Gomez, D. M., Ortega, J., G. and Torgler, B. (2012). Synchronization and diversity in business cycles: A network approach applied to the European Union. *CREMA Working Paper*.
- Grigoraş, V., and Stanciu, I. E. (2016). New evidence on the (de)synchronisation of business cycles: Reshaping the European business cycle. *International Economics*, 147: 27-52.
- Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica*, 57(2): 357-384.
- Harding, D., and Pagan, A. (2002). Dissecting the cycle: a methodological investigation. *Journal of Monetary Economics*, 49: 365-381.
- Harding, D., and Pagan, A. (2006). Synchronization of cycles. *Journal of Econometrics*, 132(1): 59-79.
- König, J., and Ohr, R. (2013). Different Efforts in European Economic Integration: Implications of the EU Index. *JCMS: Journal of Common Market Studies*, 51(6): 1074-1090.
- Krolzig, H., and Toro, J. (2005). Classical and modern business cycle measurement: the European case. *Spanish Economic Review*, 7: 1-22.
- McDermott, C. J. and Scott, A. (2000). Concordance in business cycles. *Technical report, IMF*.
- Silverman, B. W. (1981). Using kernel density estimates to investigate multimodality. *Journal of the Royal Statistical Society. Series B (Methodological)*, 97-99.

Wortmann, M., and Stahl, M. (2016). One Size Fits Some: A Reassessment of EMU's Core-periphery Framework. *Journal of Economic Integration*, 31(2): 377-413.

Table 1. Data description.

Country	Code	Period	Source	Date of accession	Beginning of the crisis
AUSTRIA	AT	1969/Q1 – 2017/Q2	OECD	01/01/1995	2008Q2
BELGIUM	BE	1960/Q2 – 2017/Q2	OECD	25/03/1957	2008Q3
BULGARIA	BG	2000/Q2 – 2017/Q2	Statistical Institute	01/01/2007	2009Q1
CROATIA	HR	2001/Q1 – 2017/Q2	Statistical Institute	01/07/2013	2008Q3
CYPRUS	CY	1995/Q2 – 2017/Q2	Statistical Institute	01/05/2004	2008Q4
CZECH REPUBLIC	CZ	1994/Q2 – 2017/Q2	OECD	01/05/2004	2008Q4
DENMARK	DK	1960/Q2 – 2017/Q2	OECD	01/01/1973	2008Q1
ESTONIA	EE	1995/Q2 – 2017/Q2	Statistical Institute	01/05/2004	2008Q1
FINLAND	FI	1960/Q2 – 2017/Q2	OECD	01/01/1995	2008Q1
FRANCE	FR	1953/Q1 – 2017/Q2	Statistical Institute	25/03/1957	2008Q2
GERMANY	DE	1960/Q2 – 2017/Q2	OECD	25/03/1957	2008Q3
GREECE	EL	1960/Q2 – 2017/Q2	OECD	01/01/1981	2007Q3
HUNGARY	HU	1995/Q2 – 2017/Q2	OECD	01/05/2004	2008Q3
IRELAND	IE	1960/Q2 – 2017/Q2	OECD	01/01/1973	2008Q1
ITALY	IT	1960/Q2 – 2017/Q2	OECD	25/03/1957	2007Q4
LATVIA	LV	1995/Q2 – 2017/Q2	OECD	01/05/2004	2007Q4
LITHUANIA	LT	1995/Q2 – 2017/Q2	Statistical Institute	01/05/2004	2008Q3
LUXEMBOURG	LU	1960/Q2 – 2017/Q2	OECD	25/03/1957	2008Q2
MALTA	MT	2000/Q2 – 2017/Q2	Central Bank	01/05/2004	2008Q4
NETHERLANDS	NL	1960/Q2 – 2017/Q2	OECD	25/03/1957	2008Q3
POLAND	PL	1995/Q2 – 2017/Q2	OECD	01/05/2004	2008Q4
PORTUGAL	PT	1960/Q2 – 2017/Q2	OECD	01/01/1986	2008Q2
ROMANIA	RO	1995/Q2 – 2017/Q2	Statistical Institute	01/01/2007	2008Q4
SLOVAKIA	SK	1993/Q2 – 2017/Q2	OECD	01/05/2004	2009Q1
SLOVENIA	SI	1995/Q2 – 2017/Q2	Statistical Institute	01/05/2004	2008Q3
SPAIN	ES	1969/Q1 – 2017/Q2	OECD	01/01/1986	2008Q2
SWEDEN	SE	1969/Q1 – 2017/Q2	OECD	01/01/1995	2008Q3
UNITED KINGDOM	UK	1955/Q2 – 2017/Q2	OECD	01/01/1973	2008Q3

Table 2. Summary of BC features for the entire sample, before and since the crisis started.

	Business Cycle							
	Duration		Amplitude		Excess		Cumulation	
	E	R	E	R	E	R	E	R
Entire sample (28)	22.79 (7.47)	5.45 (3.00)	29.24 (11.96)	-4.10 (2.88)	1.24 (1.06)	0.12 (0.34)	5.03 (3.45)	-0.17 (0.15)
Before crisis (24)	25.44 (8.81)	4.79 (2.64)	37.08 (16.17)	-2.20 (1.81)	1.79 (2.05)	0.05 (0.36)	6.60 (4.82)	-0.07 (0.09)
Since crisis (28)	16.80 (9.21)	6.06 (4.35)	12.98 (9.18)	-6.51 (4.70)	0.07 (0.78)	0.08 (0.67)	1.53 (1.63)	-0.32 (0.41)

Note: Standard error in parentheses

Table 3. Summary statistics of distances in BC features and synchronization.

BC characteristics					
	Mean	Std. Dev.	Variance	Skewness	Kurtosis
Entire sample	17.1351	11.5603	133.6394	0.9075	3.2526
Before crisis	22.7648	14.5324	211.1893	0.7603	3.2369
Since 2008	15.9950	10.3724	107.5868	0.5714	2.3175
BC synchronization					
	Mean	Std. Dev.	Variance	Skewness	Kurtosis
Entire sample	0.2016	0.0736	0.0054	0.6038	3.5031
Before crisis	0.1728	0.0709	0.0050	0.7486	3.9210
Since 2008	0.2792	0.1429	0.0204	0.5935	2.7322

Table 4. Silverman test of multimodality. P-values.

BC characteristics						
	Entire sample		Before crisis		Since 2008	
	Critical bw	p-value	Critical bw	p-value	Critical bw	p-value
1 mode	3.101	0.42	4.563	0.46	2.819	0.44
2 mode	1.998	0.92	3.248	0.62	2.509	0.02
BC synchronization						
	Entire sample		Before crisis		Since 2008	
	Critical bw	p-value	Critical bw	p-value	Critical bw	p-value
1 mode	0.0196	0.56	0.0247	0.38	0.0334	0.66
2 mode	0.0141	0.58	0.0202	0.10	0.0280	0.44

Table 5. Kolmogorov-Smirnov test of the equality of pairwise distances distributions. P-values.

	Before vs Since 2008	All vs Before crisis	All vs Since 2008
BC characteristics	0.000	0.000	0.785
BC synchronization	0.000	0.000	0.000

Table 6. Summary statistics of distances in BC characteristics and synchronization. Reduced samples.

BC characteristics					
	Mean	Std. Dev.	Variance	Skewness	Kurtosis
Entire sample	18.3141	11.8798	141.1303	0.7477	2.8939
Before crisis	22.7648	14.5324	211.1893	0.7603	3.2369
Since 2008	16.7593	10.2237	104.5241	0.4817	2.2930
BC synchronization					
	Mean	Std. Dev.	Variance	Skewness	Kurtosis
Entire sample	0.2040	0.0690	0.0048	0.6870	3.8119
Before crisis	0.1728	0.0709	0.0050	0.7482	3.9211
Since 2008	0.2645	0.1460	0.0213	0.7750	3.0092

Figure 1. MDS map of Business Cycle features. Entire sample.

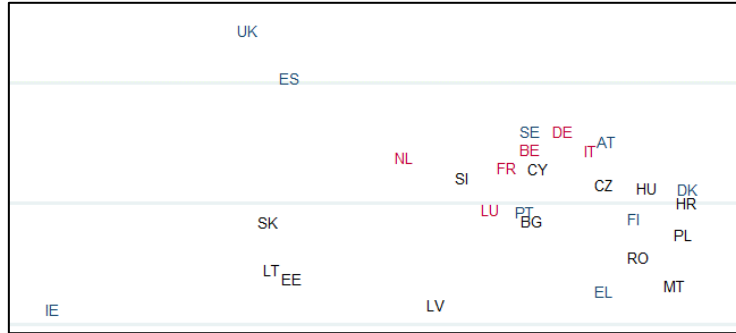


Figure 2. MDS map of Business Cycle features. Period before the crisis.

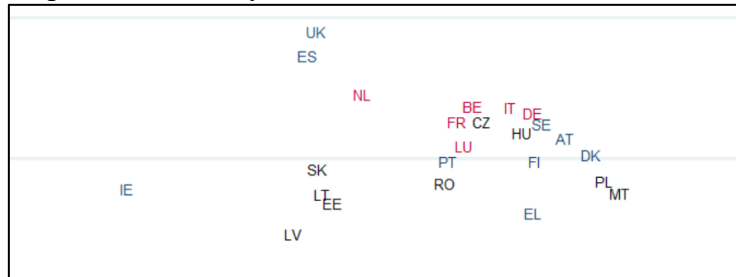


Figure 3. MDS map of Business Cycle features. Period since the crisis started.

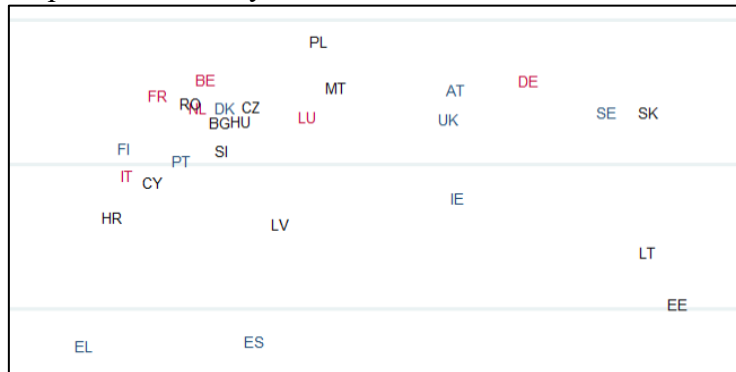


Figure 4. Kernel density function of distances on BC features. Original samples.

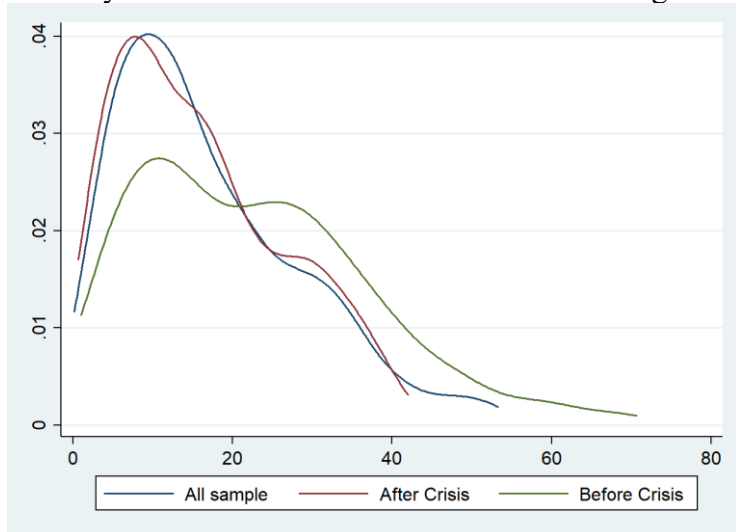


Figure 5. MDS map of Business Cycle synchronization. Entire sample.

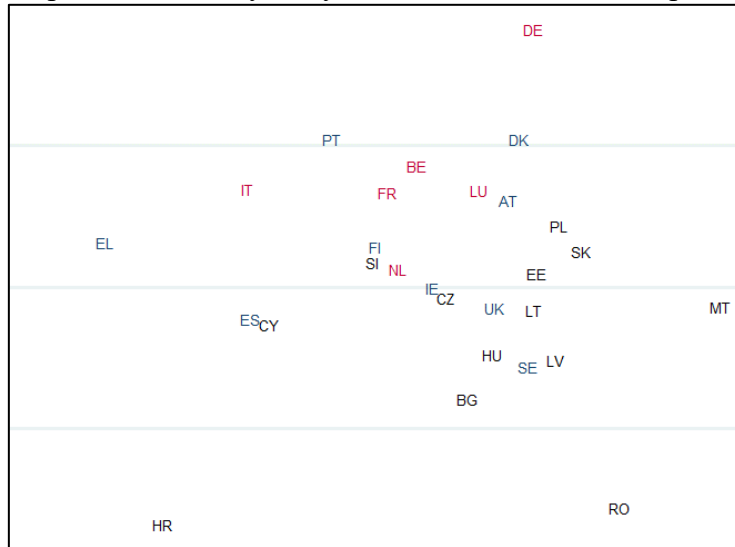


Figure 6. MDS map of Business Cycle synchronization. Period before the crisis.

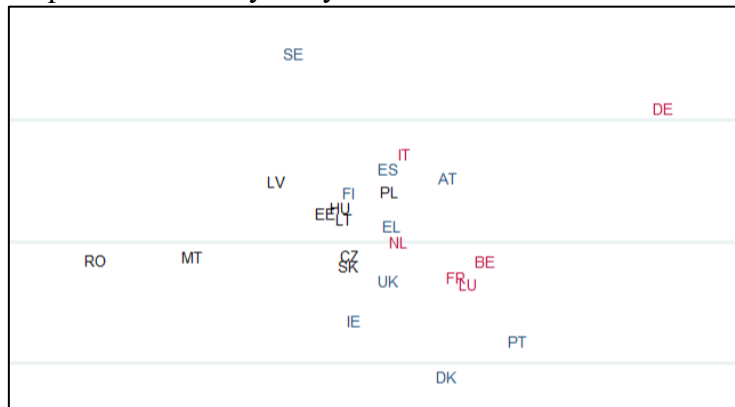


Figure 7. MDS map of Business Cycle synchronization. Period since the crisis started.

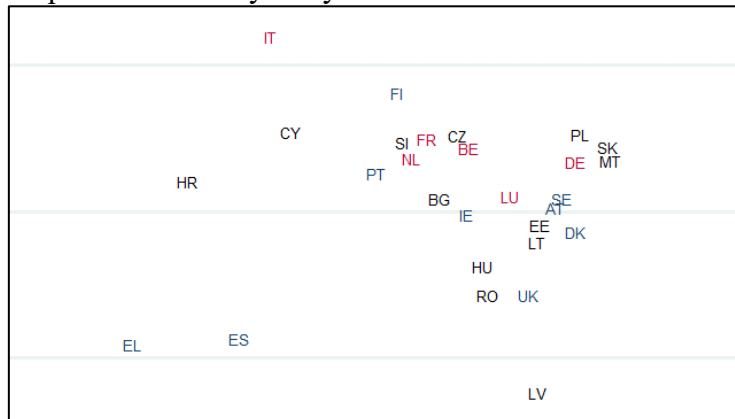


Figure 8. Kernel density function of distances on BC synchronization. Original samples.

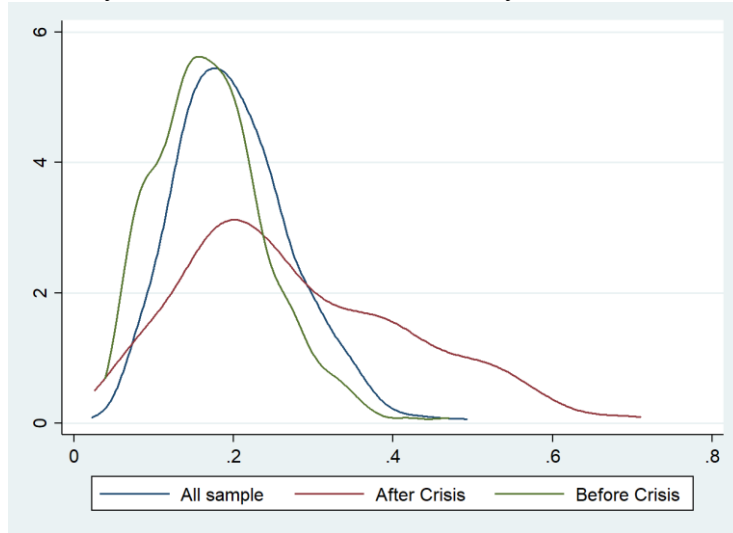


Figure 9. Kernel density function of distances on BC features. Reduced samples.

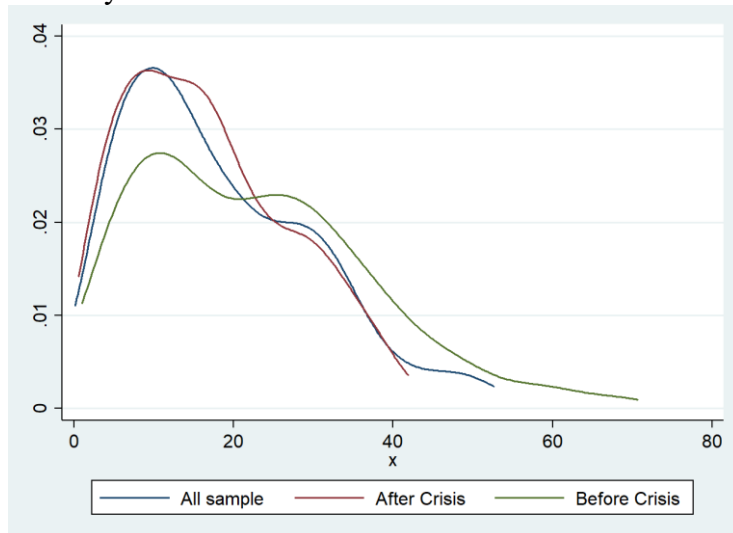
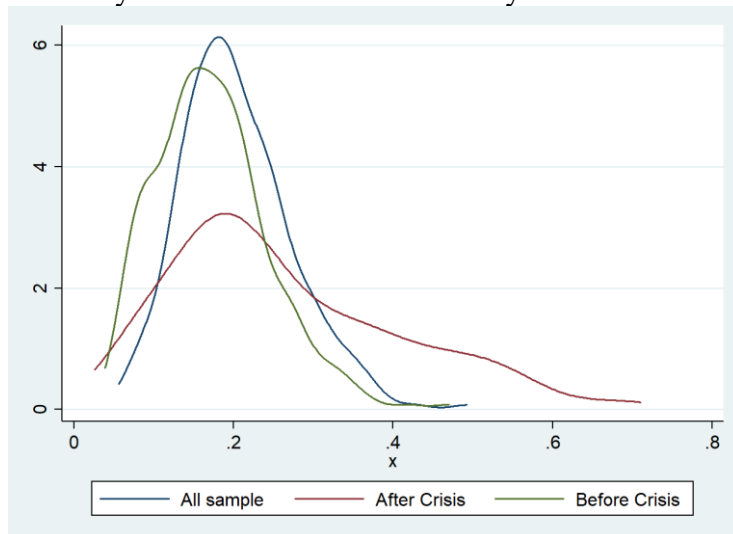


Figure 10. Kernel density function of distances on BC synchronization. Reduced samples.



Appendix

Table A1. Chronological enlargement of the European Union.

Date	Countries	Date	Countries
1957 Founders	Belgium France Germany Italy Luxembourg Netherlands	2004	Cyprus Czech Republic Estonia Hungary Latvia Lithuania Malta
1973	Denmark Ireland United Kingdom		Poland Slovakia Slovenia
1981	Greece	2007	Bulgaria Romania
1986	Portugal Spain	2013	Croatia
1995	Austria Finland Sweden		

Table A2. Business cycle features for the entire sample. Average for EU28.

	Duration (Q)		Amplitude (%)		Excess (%)		Cumulation	
	E	R	E	R	E	R	E	R
AUSTRIA	23.4	5	19.66	-0.58	0.44	0.22	2.44	-0.02
BELGIUM	25.5	3.6	25.21	-1.93	1.53	0.05	4.80	-0.05
BULGARIA	20	4.5	27.81	-3.57	1.65	0.40	3.79	-0.11
CROATIA	14.3	11.5	15.71	-7.11	0.39	0.68	2.06	-0.44
CYPRUS	24	8.5	25.82	-6.88	1.72	0.43	5.46	-0.44
CZECH REPUBLIC	20.3	4	21.07	-3.11	1.40	0.06	2.74	-0.07
DENMARK	18	3.1	15.98	-2.52	0.04	-0.10	2.27	-0.05
ESTONIA	26	5.5	47.60	-11.70	1.90	-0.51	6.99	-0.42
FINLAND	16.8	4.4	19.89	-3.66	0.38	0.10	3.26	-0.16
FRANCE	24.1	5.1	28.06	0.08	0.96	-0.03	5.77	0.02
GERMANY	25.6	8.3	23.84	-1.39	0.67	-0.26	3.05	-0.02
GREECE	12.3	5.8	24.50	-7.22	0.74	-0.35	3.33	-0.42
HUNGARY	18.3	4	18.01	-2.98	0.78	0.54	2.90	-0.12
IRELAND	29.6	3.7	65.34	-2.46	3.66	0.20	16.83	-0.10
ITALY	22.4	7.1	21.34	-1.95	-0.04	0.13	3.06	-0.11
LATVIA	17.3	5	37.65	-6.83	3.43	0.22	4.38	-0.43
LITHUANIA	26.3	5	48.04	-9.84	1.89	0.49	6.89	-0.36
LUXEMBOURG	22.6	3.3	30.49	-2.81	1.70	0.00	4.00	-0.08
MALTA	10.2	1.6	20.08	-1.00	0.55	-0.12	1.31	-0.01
NETHERLANDS	28.6	4.8	34.04	-3.68	0.74	-0.46	10.35	-0.09
POLAND	14	1	17.28	-1.13	0.14	0.00	1.45	-0.01
PORTUGAL	21.4	4.5	27.81	-3.82	0.95	-0.16	3.68	-0.12
ROMANIA	13.4	4.4	21.14	-4.42	1.79	-0.02	2.57	-0.18
SLOVAKIA	30.7	2.5	46.59	-7.63	3.12	0.59	6.55	-0.15
SLOVENIA	26	5.5	30.48	-7.08	2.75	-0.19	5.92	-0.20
SPAIN	36.8	15.7	40.82	-3.38	-0.41	0.11	9.50	-0.39
SWEDEN	25.5	8.6	23.60	-2.52	0.28	0.43	4.40	-0.15
UK	44.6	6.5	40.79	-3.77	1.52	0.88	11.18	-0.21
Average EU28	22.79	5.45	29.24	-4.10	1.24	0.12	5.03	-0.17

Table A3. Business cycle features before the crisis started. Average for EU28

	Duration (Q)		Amplitude (%)		Excess (%)		Cumulation	
	E	R	E	R	E	R	E	R
AUSTRIA	22.00	5.00	20.85	0.34	0.54	0.36	2.50	0.00
BELGIUM	29.30	3.40	31.58	-1.78	2.18	0.03	6.23	0.03
BULGARIA	35.00	-	64.63	-	4.41	-	10.09	-
CROATIA	30.00	-	38.70	-	0.89	-	5.73	-
CYPRUS	54.00	-	66.75	-	4.66	-	15.84	-
CZECH REPUBLIC	27.00	4.00	31.45	-1.60	2.33	-0.02	4.70	-0.04
DENMARK	18.70	2.90	18.06	-2.19	0.04	-0.01	2.63	-0.04
ESTONIA	23.50	4.00	55.46	-2.50	3.74	-0.29	7.66	-0.05
FINLAND	20.40	4.00	25.83	-3.18	0.60	0.30	4.39	-0.17
FRANCE	27.10	5.20	34.76	0.68	1.13	0.08	7.33	0.04
GERMANY	24.30	9.40	24.82	-0.33	0.91	-0.05	3.00	-0.01
GREECE	13.60	3.90	28.64	-5.68	0.89	-0.33	3.93	-0.14
HUNGARY	23.00	3.50	26.56	-0.90	1.30	0.09	4.97	-0.02
IRELAND	35.80	3.00	79.37	-0.61	5.46	-0.02	22.46	-0.01
ITALY	26.70	6.00	27.49	-0.49	-0.13	0.31	4.03	-0.02
LATVIA	22.00	3.00	62.03	-2.14	7.53	-0.28	7.40	-0.03
LITHUANIA	24.50	4.00	56.73	-2.89	3.49	-0.34	7.77	-0.06
LUXEMBOURG	24.70	3.20	35.08	-2.12	2.46	0.02	4.73	-0.06
MALTA	10.30	1.50	17.15	-1.94	-0.24	-0.08	1.05	-0.02
NETHERLANDS	35.00	4.50	44.92	-3.89	0.70	-0.56	14.32	-0.09
POLAND	12.80	1.00	18.48	-1.68	-0.17	0.00	1.59	-0.02
PORTUGAL	24.10	3.80	34.29	-3.02	1.14	0.06	4.63	-0.09
ROMANIA	20.00	7.00	39.59	-5.50	3.31	-0.36	5.36	-0.33
SLOVAKIA	29.50	4.00	55.46	-6.15	4.79	1.19	7.33	-0.20
SLOVENIA	53.00	-	74.84	-	6.70	-	16.66	-
SPAIN	44.00	12.50	50.72	-0.29	-0.77	0.03	12.40	0.00
SWEDEN	23.80	9.80	23.31	-1.57	-0.02	0.47	4.53	-0.15
UK	48.50	6.30	47.19	-3.46	1.84	0.53	13.42	-0.17
Average EU28	25.44	4.79	37.08	-2.20	1.79	0.05	6.60	-0.07

Table A4. Business cycle features since the crisis started. Average for EU28.

	Duration (Q)		Amplitude (%)		Excess (%)		Cumulation	
	E	R	E	R	E	R	E	R
AUSTRIA	32	5	12.53	-5.17	-0.16	-0.51	2.12	-0.13
BELGIUM	14	4	6.10	-2.32	-0.41	0.12	0.51	-0.06
BULGARIA	12.5	4.5	9.40	-3.57	0.27	0.40	0.64	-0.11
CROATIA	6.5	11.5	4.22	-7.11	0.14	0.68	0.23	-0.44
CYPRUS	9	8.5	5.36	-6.88	0.25	0.43	0.27	-0.44
CZECH REPUBLIC	13.5	4	10.70	-3.86	0.47	0.11	0.79	-0.09
DENMARK	15	4	6.61	-3.81	0.04	-0.49	0.62	-0.10
ESTONIA	31	7	31.87	-20.89	-1.80	-0.72	5.66	-0.79
FINLAND	7.3	5.3	4.06	-4.76	-0.18	-0.37	0.24	-0.13
FRANCE	13.5	5	4.63	-1.74	0.34	-0.36	0.31	-0.03
GERMANY	33	3	17.99	-6.67	-0.77	-1.34	3.31	-0.09
GREECE	5	15	1.72	-14.91	-0.13	-0.40	0.07	-1.81
HUNGARY	13.5	4.5	9.45	-5.05	0.26	1.00	0.83	-0.23
IRELAND	14	5	30.26	-6.17	-0.81	0.62	2.75	-0.27
ITALY	9.5	10	2.88	-5.61	0.24	-0.32	0.13	-0.33
LATVIA	12.5	7	13.26	-11.52	-0.67	0.72	1.36	-0.82
LITHUANIA	30	6	30.65	-16.78	-1.31	1.32	5.14	-0.67
LUXEMBOURG	15	3.5	14.40	-4.88	-0.96	-0.05	1.43	-0.13
MALTA	10	1.7	23.01	-0.37	1.34	-0.14	1.58	-0.00
NETHERLANDS	12.5	5.5	6.84	-3.28	0.85	-0.26	0.42	-0.08
POLAND	16.5	1	14.88	-0.29	0.76	0.00	1.17	-0.00
PORTUGAL	12	6.5	5.11	-6.20	0.29	-0.80	0.35	-0.20
ROMANIA	9	2.7	8.84	-3.71	0.77	0.20	0.72	-0.08
SLOVAKIA	33	1	28.85	-9.12	-0.20	0.00	4.97	-0.09
SLOVENIA	12.5	5.5	8.31	-7.08	0.78	-0.19	0.56	-0.20
SPAIN	15	22	11.12	-9.55	0.65	0.26	0.79	-1.16
SWEDEN	34	4	25.05	-6.34	1.82	0.27	3.77	-0.17
UK	29	7	15.20	-4.72	0.22	1.92	2.22	-0.32
Average EU28	16.80	6.06	12.98	-6.51	0.07	0.08	1.53	-0.32

Table A5. Business Cycle Synchronization, concordance index. EU28, 1953-2017.

	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE
AT	1.00													
BE	0.88	1.00												
BG	0.81	0.84	1.00											
HR	0.65	0.71	0.79	1.00										
CY	0.75	0.83	0.88	0.91	1.00									
CZ	0.82	0.89	0.93	0.77	0.85	1.00								
DK	0.82	0.84	0.75	0.59	0.72	0.83	1.00							
EE	0.87	0.83	0.86	0.70	0.78	0.81	0.85	1.00						
FI	0.77	0.84	0.78	0.77	0.85	0.85	0.75	0.83	1.00					
FR	0.82	0.86	0.86	0.73	0.84	0.86	0.80	0.82	0.77	1.00				
DE	0.86	0.81	0.71	0.55	0.71	0.76	0.77	0.80	0.75	0.79	1.00			
EL	0.69	0.74	0.67	0.77	0.79	0.68	0.70	0.67	0.71	0.71	0.65	1.00		
HU	0.85	0.80	0.88	0.76	0.79	0.80	0.80	0.81	0.75	0.79	0.74	0.66	1.00	
IE	0.82	0.86	0.87	0.74	0.85	0.89	0.82	0.92	0.82	0.83	0.73	0.73	0.82	1.00
IT	0.84	0.81	0.75	0.83	0.90	0.81	0.75	0.76	0.79	0.83	0.77	0.76	0.71	0.78
LV	0.81	0.73	0.78	0.65	0.70	0.71	0.78	0.88	0.73	0.72	0.70	0.69	0.82	0.82
LT	0.85	0.84	0.90	0.74	0.81	0.82	0.82	0.92	0.80	0.81	0.81	0.66	0.84	0.89
LU	0.85	0.86	0.84	0.68	0.81	0.85	0.83	0.88	0.81	0.84	0.84	0.70	0.82	0.83
MT	0.83	0.77	0.78	0.62	0.70	0.83	0.77	0.84	0.71	0.75	0.75	0.51	0.78	0.80
NL	0.88	0.87	0.91	0.82	0.89	0.90	0.83	0.84	0.76	0.85	0.79	0.75	0.83	0.84
PL	0.87	0.88	0.86	0.67	0.80	0.85	0.81	0.87	0.81	0.84	0.84	0.63	0.81	0.85
PT	0.78	0.86	0.78	0.74	0.79	0.81	0.81	0.76	0.76	0.92	0.79	0.73	0.73	0.81
RO	0.74	0.69	0.87	0.71	0.67	0.80	0.71	0.79	0.64	0.70	0.65	0.57	0.75	0.71
SK	0.85	0.85	0.88	0.67	0.78	0.84	0.81	0.87	0.79	0.81	0.78	0.62	0.79	0.87
SI	0.84	0.92	0.91	0.82	0.91	0.92	0.81	0.84	0.88	0.93	0.80	0.76	0.83	0.92
ES	0.82	0.78	0.81	0.89	0.88	0.81	0.71	0.76	0.74	0.84	0.75	0.80	0.78	0.78
SE	0.83	0.79	0.87	0.71	0.83	0.89	0.73	0.92	0.82	0.74	0.79	0.66	0.87	0.77
UK	0.84	0.86	0.88	0.76	0.84	0.86	0.82	0.91	0.83	0.80	0.81	0.70	0.90	0.83

Table A5. *Continued.*

	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
IT	1.00													
LV	0.69	1.00												
LT	0.73	0.82	1.00											
LU	0.80	0.78	0.87	1.00										
MT	0.65	0.74	0.86	0.80	1.00									
NL	0.84	0.74	0.85	0.86	0.81	1.00								
PL	0.76	0.76	0.88	0.85	0.87	0.87	1.00							
PT	0.80	0.66	0.75	0.86	0.71	0.84	0.79	1.00						
RO	0.62	0.80	0.78	0.75	0.83	0.74	0.76	0.64	1.00					
SK	0.73	0.74	0.92	0.87	0.90	0.86	0.89	0.78	0.76	1.00				
SI	0.88	0.74	0.85	0.90	0.78	0.98	0.87	0.88	0.74	0.84	1.00			
ES	0.85	0.75	0.78	0.77	0.65	0.85	0.74	0.82	0.69	0.71	0.88	1.00		
SE	0.79	0.82	0.93	0.76	0.88	0.79	0.92	0.70	0.78	0.91	0.92	0.78	1.00	
UK	0.76	0.85	0.94	0.89	0.84	0.86	0.89	0.80	0.76	0.90	0.89	0.76	0.81	1.00

Table A6. Business Cycle Synchronization before the crisis, concordance index. EU28, 1953-2007.

	AT	BE	CZ	DK	EE	FI	FR	DE	EL	HU	IE	
AT	1.00											
BE	0.88	1.00										
CZ	0.82	0.85	1.00									
DK	0.79	0.85	0.89	1.00								
EE	0.80	0.84	0.84	0.80	1.00							
FI	0.79	0.85	0.93	0.76	0.92	1.00						
FR	0.82	0.86	0.87	0.81	0.86	0.79	1.00					
DE	0.84	0.80	0.73	0.75	0.73	0.76	0.78	1.00				
EL	0.76	0.79	0.82	0.76	0.84	0.74	0.75	0.71	1.00			
HU	0.86	0.78	0.78	0.82	0.78	0.86	0.80	0.67	0.78	1.00		
IE	0.81	0.85	0.93	0.82	0.92	0.82	0.84	0.71	0.77	0.86	1.00	
IT	0.90	0.84	0.91	0.79	0.90	0.79	0.84	0.81	0.79	0.84	0.81	1.00
LV	0.82	0.78	0.78	0.75	0.90	0.86	0.80	0.67	0.82	0.84	0.86	0.88
LT	0.80	0.84	0.84	0.80	0.92	0.92	0.86	0.73	0.84	0.78	0.92	0.90
LU	0.83	0.87	0.87	0.82	0.86	0.84	0.83	0.83	0.75	0.80	0.84	0.83
MT	0.81	0.77	0.90	0.77	0.90	0.90	0.81	0.58	0.77	0.84	0.90	0.87
NL	0.90	0.87	0.93	0.85	0.92	0.78	0.84	0.80	0.79	0.86	0.85	0.87
PL	0.86	0.90	0.86	0.82	0.90	0.94	0.88	0.78	0.86	0.80	0.94	0.92
PT	0.79	0.88	0.84	0.84	0.82	0.79	0.92	0.80	0.76	0.76	0.83	0.82
RO	0.69	0.65	0.80	0.69	0.80	0.73	0.67	0.53	0.65	0.71	0.73	0.71
SK	0.81	0.86	0.85	0.81	0.88	0.92	0.85	0.68	0.83	0.78	0.93	0.86
ES	0.88	0.82	0.93	0.77	0.92	0.80	0.87	0.81	0.79	0.86	0.82	0.91
SE	0.79	0.77	0.93	0.69	0.92	0.85	0.73	0.75	0.74	0.86	0.76	0.85
UK	0.82	0.87	0.93	0.82	0.92	0.87	0.82	0.79	0.75	0.86	0.84	0.81

Table A6. *Continued.*

	LV	LT	LU	MT	NL	PL	PT	RO	SK	ES	SE	UK
LV	1.00											
LT	0.82	1.00										
LU	0.80	0.86	1.00									
MT	0.87	0.90	0.81	1.00								
NL	0.86	0.92	0.87	0.90	1.00							
PL	0.84	0.90	0.88	0.87	0.94	1.00						
PT	0.76	0.82	0.87	0.74	0.83	0.84	1.00					
RO	0.82	0.76	0.67	0.90	0.73	0.75	0.63	1.00				
SK	0.78	0.96	0.88	0.90	0.93	0.86	0.85	0.73	1.00			
ES	0.86	0.92	0.81	0.90	0.88	0.94	0.83	0.73	0.88	1.00		
SE	0.86	0.92	0.72	0.90	0.79	0.94	0.69	0.73	0.90	0.85	1.00	
UK	0.86	0.92	0.90	0.90	0.89	0.94	0.83	0.73	0.93	0.79	0.78	1.00

Table A7. Business Cycle Synchronization after the crisis, concordance index. EU28, 2008-2017.

	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE
AT	1.00													
BE	0.87	1.00												
BG	0.74	0.82	1.00											
HR	0.47	0.61	0.63	1.00										
CY	0.58	0.71	0.79	0.84	1.00									
CZ	0.82	0.95	0.87	0.61	0.76	1.00								
DK	0.92	0.79	0.66	0.39	0.50	0.74	1.00							
EE	0.95	0.82	0.74	0.47	0.58	0.76	0.92	1.00						
FI	0.71	0.79	0.61	0.61	0.66	0.74	0.68	0.71	1.00					
FR	0.82	0.84	0.82	0.61	0.71	0.84	0.74	0.76	0.68	1.00				
DE	0.95	0.87	0.74	0.47	0.58	0.82	0.87	0.89	0.66	0.82	1.00			
EL	0.39	0.47	0.50	0.71	0.61	0.47	0.42	0.45	0.53	0.53	0.34	1.00		
HU	0.84	0.82	0.84	0.63	0.68	0.82	0.76	0.84	0.61	0.76	0.84	0.50	1.00	
IE	0.87	0.89	0.76	0.55	0.66	0.84	0.84	0.92	0.79	0.79	0.82	0.53	0.76	1.00
IT	0.58	0.66	0.58	0.74	0.79	0.66	0.55	0.58	0.82	0.76	0.58	0.61	0.53	0.66
LV	0.79	0.66	0.63	0.42	0.47	0.61	0.82	0.84	0.55	0.61	0.74	0.50	0.79	0.76
LT	0.92	0.84	0.82	0.55	0.66	0.79	0.84	0.92	0.63	0.74	0.92	0.42	0.92	0.84
LU	0.95	0.82	0.79	0.53	0.63	0.82	0.87	0.89	0.66	0.87	0.89	0.45	0.84	0.82
MT	0.84	0.76	0.68	0.42	0.53	0.76	0.76	0.79	0.55	0.71	0.89	0.29	0.74	0.71
NL	0.79	0.87	0.84	0.68	0.74	0.87	0.71	0.74	0.66	0.92	0.79	0.55	0.79	0.76
PL	0.87	0.84	0.76	0.45	0.61	0.84	0.79	0.82	0.63	0.79	0.92	0.32	0.82	0.74
PT	0.74	0.76	0.74	0.68	0.63	0.76	0.66	0.68	0.61	0.92	0.74	0.61	0.68	0.71
RO	0.82	0.74	0.76	0.50	0.61	0.79	0.74	0.76	0.53	0.74	0.82	0.47	0.82	0.68
SK	0.89	0.82	0.79	0.42	0.58	0.82	0.82	0.84	0.61	0.76	0.95	0.29	0.79	0.76
SI	0.79	0.92	0.84	0.68	0.79	0.92	0.71	0.74	0.71	0.92	0.79	0.55	0.79	0.82
ES	0.55	0.63	0.66	0.82	0.71	0.63	0.47	0.55	0.47	0.68	0.50	0.84	0.66	0.63
SE	0.97	0.89	0.76	0.50	0.61	0.84	0.89	0.92	0.68	0.79	0.97	0.37	0.87	0.84
UK	0.89	0.82	0.79	0.58	0.63	0.76	0.82	0.89	0.61	0.71	0.89	0.45	0.95	0.82

Table A7. *Continued.*

	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
IT	1.00													
LV	0.42	1.00												
LT	0.50	0.82	1.00											
LU	0.63	0.74	0.87	1.00										
MT	0.47	0.63	0.82	0.79	1.00									
NL	0.68	0.58	0.76	0.84	0.74	1.00								
PL	0.55	0.66	0.84	0.82	0.87	0.76	1.00							
PT	0.68	0.53	0.66	0.79	0.68	0.89	0.71	1.00						
RO	0.50	0.76	0.79	0.87	0.76	0.76	0.79	0.66	1.00					
SK	0.53	0.68	0.87	0.84	0.89	0.74	0.92	0.68	0.82	1.00				
SI	0.74	0.58	0.76	0.84	0.68	0.95	0.76	0.84	0.76	0.74	1.00			
ES	0.61	0.61	0.58	0.61	0.45	0.71	0.47	0.76	0.63	0.45	0.71	1.00		
SE	0.55	0.76	0.95	0.92	0.87	0.82	0.89	0.71	0.84	0.92	0.82	0.53	1.00	
UK	0.47	0.84	0.97	0.84	0.79	0.74	0.82	0.63	0.82	0.84	0.74	0.61	0.92	1.00

Figure A1. Duration, amplitude and excess. Stylized pictures of expansions and recessions depending on the excess.

