Business Cycles Synchronization: Literature Review

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Abstract

A wealth of literature exists on the business cycles synchronisation and its main determinants, since the seminal paper on Optimum Currency Areas (OCA) by Mundell (1961). This work provides a systematic review of this research field both at country-level synchronization, as well as, at regional level. In this review paper, we evaluate papers on their contribute to methodological aspects regarding the measurement of the business cycle and the estimation of the level of synchronization. The collection of those articles is essential for the researchers who would like to start exploring the various econometric techniques that have been proposed in this line of research.

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1. Introduction

The seminal work by Mundell (1961) on Optimum Currency Areas (OCA) opened up a new line of research related to the estimation of the business cycles synchronization among countries that would like to join a currency union. The OCA informs us that high level of synchronization is required should a common currency union provide greater gains for its members, compared to the loss that is incurred due to the abandonment of the independent monetary policy.

This survey provides a detailed account of the current literature that has focused on both the country-level, as well as, the regional-level synchronization. We aim to draw insights in relation to the methodologies that have been employed in this line of research, either for the measurement of the business cycles or the estimation of the synchronization level. We also hope to open new avenues in this interesting line of research.

Before we proceed, we should first outline the process that it was used to reach to our final sample of published work. First, we searched in Google Scholar using terms, such as "Business cycle synchronization", "Business cycles in EU" and "Regional business cycle synchronization".

A vast number of papers were returned from our Google Scholar search, so in our next step we developed a process to identify the papers that would be included in this review. To do so, we decided to include only papers that are published in international academic journals. Hence, working papers are excluded from our review. The only exception is when the working papers are published in the depository of central banks or other institutions. Finally, we decided to confine our research in the period 2001-2021, which coincides with the creation of the Euro currency, however seminal papers that were published before 2001 are also included. The number of papers that have been published each year and are included in this review is presented in Figure 1.

[FIGURE 1 HERE]

Figure 1 shows that there was a cluster of high activity in this line of research in the years following the Global Financial Crisis of 2007-2009. Furthermore, we observe that there is potentially a revival of this interest in the last 2-3 years of our sample period.

A study that is close to our work is the meta-analysis study by Jarko *et al*. (2018) that considers about 3,000 business cycles synchronization coefficients and their design and estimation characteristics. They find that: (1) synchronization increased from about 0.4 before the introduction of the euro in 1999 to 0.6 afterwards; (2) this increase occurred in both euro and non-euro countries (larger in former); (3) there is evidence of country-specific publication

bias; (4) their differences-in-differences estimates suggest the euro accounted for approximately half of the observed increase in synchronization.

The review begins in Section 2 by reviewing the studies that concentrate on the country-level business cycles synchronization. Section 3 focuses on the regional business cycles synchronization. Finally, Section 4 concludes the review and provides a summary of the key points. A summary of the studies that are analysed in this paper can be found in Table 1 in the Appendix.

2. Business cycles synchronization at country level

We start our review of the related literature focusing on the studies that assess the level of business cycles synchronization at country level.

De Haan et al. (2002), attempt to answer the question 'Will further integration make business cycles in EMU countries more similar?', by analyzing to what extent business cycles in US and German states have become more synchronized and by examining whether synchronization in OECD countries is affected by trade intensity and exchange rate stability. Using long-run data for the US they find only mixed evidence for synchronization. However, post-war data for Germany suggest that business cycles behave more similarly over time. The evidence for OECD countries is mixed: trade intensity has led to more, and exchange rate stability to less, synchronization.

Kose et al (2003) examine the impact of rising trade and financial integration on international business cycle co-movement among a large group of industrial and developing countries. The results provide at best limited support for the conventional wisdom that globalization has increased the degree of synchronization of business cycles. The evidence that trade and financial integration enhance global spillovers of macroeconomic fluctuations is stronger for industrial countries. An important result is that, on average, cross-country consumption correlations have not increased in the 1990s, precisely when financial integration would have been expected to result in better risk-sharing opportunities, especially for developing countries.

Kose et al. (2003), investigate the common dynamic properties of business-cycle fluctuations across countries, regions, and the world. They employ a Bayesian dynamic latent factor model to estimate common components in macroeconomic aggregates (output, consumption, and investment) in a 60-country sample covering seven regions of the world. The results indicate that a common world factor is an important source of volatility for aggregates

in most countries, providing evidence for a world business cycle. They find that region-specific factors play only a minor role in explaining fluctuations in economic activity.

Bergman (2004) studied how similar the European business cycles are. The data set of this study consists of quarterly observations on industrial production for the EU14 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom) and five non–EU countries (Canada, Japan, Norway, Switzerland and the US) for the sample 1961q1 to 2001q4. Regarding the methodology used in this study, Baxter and King (1999) have developed a bandpass filter that isolates cyclical components of economic time series. This filter can be designed to isolate cyclical components of economic time series conforming to a certain definition of business cycles. Bergman isolates cyclical components of the data with durations conforming to the Burns–Mitchell definition of the business cycle. He used a 12–order two–sided filter following Baxter and King (1999) to extract all fluctuations at frequencies between 6 and 32 quarters (1.5 year and 8– eight years) from the logarithm of industrial production in each country. The main finding of this study is that European business cycles are highly synchronized, although synchronization was higher during periods with highly flexible exchange rates. In addition, a positive tradeoff was found between timing and magnitude such that more synchronization coincides with larger relative magnitude. These results raise a concern about the consequences of a common monetary policy within EMU.

Altavilla (2004) examines whether the EMU members share the same business cycle and uses quarterly GDP data for 6 EU countries and the US for the period 1980 to 2002. The study uses the phase, steepness of phase, cumulative movements between phases, amplitude and concordance of the countries' cycles. Also, in their research they aim to extract the cyclical component and they used HP and Band-pass filters. They also use Markov switching models and they also compute the mean corrected index of concordance. The results suggest that, although during the main recessionary periods the euro area economies shared a similar output dynamic, some differences still remain in the size and timing of the business cycle features. The results also suggest that adhesion to the new currency area is likely to lead to stronger synchronization of EMU members' business cycles.

Kose *et al.* (2008) examined the changes in world business cycles during the period 1960-2003 for the G7 countries. They employ a Bayesian dynamic latent factor model to estimate common and country-specific components in the main macroeconomic aggregates (output, consumption and investment). Then, they quantify the relative importance of the common and country components in explaining co-movement in each observable aggregate

over three distinct time periods: the Bretton Woods (BW) period (1960:1-1972:2), the period of common shocks (1972:3-1986:2) and the globalization period (1986:3-2003:4). The results of their study indicate that the common (G-7) factor explains, on average, a larger fraction of output, consumption and investment volatility in the globalization period than it does in the BW period.

Furceri and Karras (2008) use quarterly GDP data for 12 EMU countries for the period 1993 to 2004. The cyclical component of economic activity is extracted using: simple differencing, the HP filter and the Band–Pass filter. They find the correlation between the cyclical output of each individual country with the EMU-wide cyclical output. They also apply a Panel IV regression to examine the effect of trade and fiscal policy on synchronization. The findings of the study show that all countries in the sample were better synchronized with the EMU-wide economy in the period 1999 to 2004 than during 199. They also find that the increase in overall synchronization is more due to trade factors and less (if at all) to fiscal policy coordination.

Darvas and Szapáry (2008) use quarterly GDP data for 10 EMU countries and 8 CEEC countries for the period 1983 to 2002. According to their study, the determinants of synchronization are trade, industrial production, gdp components. Furthermore, they employed a dynamic factor model using various measures of synchronization (correlations, leads and lags in the cycles, volatility of business cycles and persistence of the business cycle). The results of the study reveal that countries have become more synchronized over time and trade is a major driver of synchronization.

Camacho et al. (2008), analyze if each European country presents business cycles that are similar enough to validate what some authors call the European cycle. Contrary to most papers on business cycles, they concentrate on the appearance of the cycle, not on the synchronization. They provide a robust methodology for dating and characterizing business cycles and their phases and adopt the model-based cluster analysis to test the existence of a unique cluster (a common cycle) against more than one. They find evidence against a common cycle. Finally, they find no clear relation between similarities in business cycle appearance and synchronization across countries.

Koopman & Azevedo (2008), investigate business cycle relations among different economies in the Euro area. Cyclical dynamics are explicitly modelled as part of a time series model. They introduce mechanisms that allow for increasing or diminishing phase shifts and for time-varying association patterns in different cycles. Standard Kalman filter techniques are used to estimate the parameters simultaneously by maximum likelihood. The empirical

illustrations are based on gross domestic product (GDP) series of seven European countries that are compared with the GDP series of the Euro area and that of the US. The original integrated time series are band-pass filtered. They find that there is an increasing resemblance between the business cycle fluctuations of the European countries analyzed and those of the Euro area, although with varying patterns.

Dimitru and Dimitru (2010) examine the business cycle correlation of the new member states of Eurozone, and they focus on the case of Romania. They use quarterly GDP data from 1997Q1 until 2009Q2 for their study and the countries that are included in their study are EA and 11 countries that joined the EU in 2004 and 2007 and for Eurozone. They use Quadratic trend, HP, Band-Pass filter, Beveridge-Nelson decomposition and Wavelet transformation in order to find the appropriate results for their study. The results of their study indicate cross-correlations in different sub-periods and concordance index. Also, the correlation of Romania with Eurozone was the lowest, after Hungary. According to the results of this study, the correlation increased in time, the most in the case of Slovakia and Romania and Slovenia was the most synchronized country.

Filis *et al*. (2010) examine whether EU and Bulgarian business cycles are synchronized. They use GDP data from 1997q1 until 2007q2 for their study and the countries that are included in their study are EA15 and Bulgaria. They use HP filter and spectral analysis and squared coherency and they find that cycles are correlated at 17 and 34 quarters. But a negative phase shift implies that their phases are not coordinated.

Papageorgiou *et al.* (2010) use major annual macroeconomics series data from 1960 until 2009 and their study is about business cycles synchronization and clustering in Europe. The countries that are included in their study are major European countries, US and Japan. They use HP filter and correlations in different sub-periods and mean rolling correlations to find important results for their study that was about Business cycles synchronization and clustering in Europe. The results of their study indicate that there is a different degree of synchronization between core and peripheral European countries. Also, the results of their study show that European countries increased their synchronization in 1992–1999, but decreased in 2000–2009.

Savva *et al*. (2010) use monthly seasonally adjusted industrial production index for existing EMU, 9 enlargement countries and 3 candidate countries for the period Jan-1980 to Jun-2006. They use Bivariate VAR-GARCH and double smooth transition conditional correlation GARCH model. They also use HP filter for the cyclical component. They find that all new EU members and negotiating countries have at least doubled their business cycle

synchronization with the euro area or changed from negative to positive correlations, since the early 1990s.

Aguiar-Conraria and Soares (2011) use industrial production data from 1975M7 to 2010M5 for EU15 and EA12 countries and their study is about business cycles synchronization and the Euro with an application of wavelet analysis. The methodology that they employ in their study is the Wavelet power spectra between 1.5- and 8-years frequencies and a metric based on wavelet spectra. They find that France and Germany are most synchronized countries with the rest of Europe and Portugal, Greece, Ireland, and Finland do not show statistically relevant degrees of synchronization.

Artis *et al.* (2011) focus on business cycles synchronization since 1880. They use annual GDP data for their study for 25 advanced and emerging economies. The data cover the period 1880-2006. They use HP filter and correlation in different sub-periods and they find that synchronization increased during 1950–1973 and accelerated since 1973 within a group of European countries. Moreover, in other regions, country specific shocks were the dominant forces of business cycle dynamics.

The study of Benčík (2011) is about business cycle synchronization between the Visegrád Group countries and the euro area. He uses GDP data from 1995Q1 until 2010Q3. The countries that are included in the study are Czech Republic, Hungary, Poland and Slovakia. He uses the HP filter and correlation as a synchronization measure in different sub-periods. The findings of his study indicate that before 2000, at least one significant negative correlation for each country, between 2001 and 2007 for the Czech Republic and Hungary, the contemporaneous correlations are significant, for Poland, there are no significant correlations and for Slovakia, the first and third lag and third lead are significant.

Bergman and Jonung (2011) use annual GDP data from Sweden, Norway, Denmark and selected OECD countries from 1834 to 2008. They focus on evidence from the Scandinavian currency union. The econometric methods that they employ in their study were Christiano-Fitzgerald filter and Rolling average cross correlations. The results of their study show that business cycles in the three Scandinavian countries are more synchronized during the SCU compared to the post-World War II period, but not more than during the period prior to the establishment of the union. For the European countries, an increase in average cross-correlations is recorded.

Mink *et al*. (2011) use GDP data from 11 European countries from 1970Q1 to 2006Q4. They use Christiano-Fitzgerald, HP and Baxter-King filters and synchronicity and similarity as synchronization measure. The results of their study show that the EA output gaps are not more

synchronous or similar at the end of our sample period than in the 1970s. They also find that synchronicity and similarity between output gaps of individual countries and the EA fluctuate over time and often are not higher than would be expected under output gap independence.

Allegret, J. P., & Essaadi, E. (2011), analyze the feasibility of a monetary union in East Asia focusing on business cycles synchronization. They suggest a different empirical approach allowing, contrary to the previous studies, to detect endogenously structural changes in the co-movement process between outputs. They apply a new measure based on the time-varying coherence function. They also compute cohesion statistics to test if countries tend to be more synchronized or not. Their main finding is that the increase in bilateral trade inside the East Asian region significantly improves long-run business cycle synchronization. The short-run influence of bilateral trade shows mixed results. Indeed, short-run cycles remain significantly influenced both by shocks hitting each country and by economic policy responses. Therefore, more bilateral trade and convergence in economic policy constitute two complementary processes to promote business cycle synchronization.

Lee (2012) re-examines the effect of the European Economic and Monetary Union (EMU) on the extent of business cycle synchronization across its member states. A dynamic latent factor model is used to identify the 'regional' effect of the euro area on output growth and inflation dynamics across European countries. The results of variance decomposition analysis confirm that both output growth and inflation tended to be more synchronized among European countries during the run-up to the EMU, but there is no strong evidence to support the argument that the 'regional' effects prevailed after 1999.

Dufrenot and Keddad (2013), attempt to analyze the relationships between the ASEAN-5 countries' business cycles. They examine the nature of business cycles correlation trying to disentangle between regional spillover effects (expansion and recession phases among the ASEAN-5 are correlated) and global spillovers where the business cycles of other countries (China, Japan, and the US) play an important role in synchronizing the activity within the ASEAN-5. They employ a time-varying transition probability Markov switching framework to allow the degree of synchronization to fluctuate over time and across the phases of the business cycles. They provide evidence that the signals contained in some leading business cycles can impact the ASEAN-5 countries' individual business cycles.

Kolasa (2013) uses data for major economic series from 1996Q1 until 2011Q4 and investigates how and why the business cycles are different. The countries that are involved in the study are Czech Republic, Hungary, Poland, Slovenia, Slovakia. HP filter and correlations

in different sub-periods are used in the empirical part of the study. The findings of the study indicate that the degree of synchronization increased for all countries after joining EU.

Obradović and Mihajlović (2013) use GDP data for Bulgaria, Croatia, Hungary, Romania, Serbia and Slovenia from 2001Q1 until 2009Q4 and their study focus on the synchronization of business cycles in these countries. They use econometric methods in their study, such as HP and Baxter-King filters, correlations in different sub-periods and rolling cross-correlations. They find that Serbian cycle is not synchronized with cycles in other countries with Hungary as the only exception. They also find that there is a tendency of increasing a degree of synchronization.

Stanisic (2013) focus on the synchronization of business cycles among Central and Eastern European countries (CEECs) and the EA and quarterly, seasonally adjusted real GDP data series for the period 1995–2012, obtained from the Eurostat National Accounts database. Moreover, the HP filter method used to extract the business cycles from GDP data series and the degree of co-movement of cycles is evaluated on the basis of various methods of rolling correlation. The results of the study show that there is no common CEE business cycle, although a synchronization trend is evident. Similarly, there is a strong trend of convergence of CEEC national business cycles toward that of the EA.

Crespo-Cuaresma and Fernández-Amador (2013) use quarterly real GDP data for all EU countries and 11 OECD countries for the period 1960-2008. They use business cycle convergence/divergence test and business cycle dispersion measure for the proxy of synchronization. Furthermore, they identify significant business cycle divergence taking place in the mid-eighties, followed by a persistent convergence period spanning most of the nineties. This convergent episode finishes roughly with the birth of the European Monetary Union.

Jiménez-Rodríguez *et al*. (2013) use quarterly data on real output growth, real consumption growth and real investment growth of selected euro area and CEE countries for the period 1995 –2011. They also use Markov switching models and concordance indices for the empirical part of the study. The results show that an increase in business cycle synchronization, with the degree of concordance between country-specific and European business cycles being high.

The study of Degiannakis *et al*. (2014) is about business cycle synchronization in EU12 countries for the period 1980-2010 using scalar-BEKK and multivariate Riskmetrics model frameworks. The results of the study provide evidence that changes in the business cycle synchronization correspond to major economic events that have taken place at a European level. In addition, they find that business cycle synchronization until 2007 had moved in a

direction positive for the operation of a single currency, suggesting that the common monetary policy was less costly in terms of lost flexibility at the national level. However, as a result of the Great Recession of 2007 and the subsequent Eurozone Crisis, a number of periphery countries, most notably Greece, have experienced desynchronization of their business cycles with the EU12-wide cycle. Nevertheless, for most countries, any questions regarding the optimality and sustainability of the common currency area in Europe should not be attributed to a lack of cyclical synchronization.

Gouveia (2014) examines the business cycle correlation between the Euro area and the Balkan countries. She uses GDP data for these countries that cover the period from 2001Q1 to 2011Q4. The econometric methods that used in this study are HP and Baxter-King filters and Concordance index, rolling concordance index, Spearman's rank-order correlation coefficients, rolling correlation coefficients were used to measure synchronization. The findings of the study provide evidence that the degree of synchronization of Balkan countries (except Greece) tends to increase with slight degrease at the end of the period.

Konstantakopoulou and Tsionas (2014) concentrate on GDP data for main OECD countries for the period 1960Q1-2010Q4. They use HP, Christiano-Fitzgerald and Baxter-King filters and cross-correlations to measure synchronization. The results indicate that synchronization is stronger between the Euro-area's countries and cycles of Germany, France, Italy, Netherlands, Austria and Belgium are highly synchronized.

Bekiros *et al*. (2015) employ cross-wavelet coherence measure to detect and identify the scale-dependent time-varying (de)synchronization effects amongst Eurozone and the broad Euro area business cycles before and after the financial crisis. The results suggest that the enforcement of an active monetary policy by the ECB during crisis periods could provide an effective stabilization instrument for the entire Euro area. However, as dynamic patterns in the lead-lag relationships of the European economies are revealed, (de)synchronization varies across different frequency bands and time horizons.

Degiannakis *et al*. (2016) uses annual GDP and cyclically adjusted net lending (NLB) data from 10 EMU member-countries and the aggregate EMU12 from 1980 to 2012. Their study is about business cycle synchronization in EMU and they examine whether fiscal policy can bring member-countries closer. In this study, a time-varying framework is used in order to obtain the results. The findings suggest that fiscal policy has important effects on business cycle synchronization for all 10 EMU countries. Hence, fiscal policy is shown to have the potential to be supportive of macroeconomic stabilization in the Eurozone. However, the

evidence reveals that none of the countries under examination consistently uses fiscal policy to promote business cycle synchronization.

Di Giorgio (2016) use quarterly seasonally adjusted real GDP growth rates for the period 1993-2014 for CEEC and EA countries. They apply MSI(H)-AR (Markov switching intercept heteroscedastic) and MSI(H)-VAR models in this study. The results indicate that CEEC countries share the same business cycle features with EA cycles when they are in a recession regime; however, this is less evident when they are in an economic expansion phase. They also reject the hypothesis of the independence of CEEC cycles from the EA cycle.

Grigoraș and Stanciu (2016) use GDP data for 30 European countries and for the United States for their study that is about new evidence on the (de)synchronization of business cycle. The data cover the period 1960/95q1-2014q3. They also use classical definition of business cycles and concordance index and correlations. They find that a high level of concordance with both US and Germany characterizes old EU members, while the most recent countries to join the EU demonstrate the lowest level of concordance.

The study of Monnet and Puy (2016) assesses the strength of business cycle synchronization between 1950 and 2014 in a sample of 21 countries using a new quarterly dataset (industrial production) based on IMF archival data. To enhance the comparability of the results with the previous literature, in particular Kose *et al.* (2008), they rely on the same econometric methodology to assess the importance of a world business cycle. The world business cycle was as strong during Bretton Woods (1950-1971) than during the Globalization period (1984-2006). Although globalization did not affect the average level of co-movement, trade and financial integration strongly affect the way countries co-move with the rest of the world. They find that financial integration de-synchronizes national outputs from the world cycle, although the magnitude of this effect depends crucially on the type of shocks hitting the world economy. This de-synchronizing effect has offset the synchronizing impact of other forces, such as increased trade integration.

Belke *et al*. (2017) use seasonally adjusted real gross domestic product (GDP) on a quarterly basis from the OECD. The data cover the period from 1970Q1 to 2015Q4. They use in their study quarterly index for business cycle synchronization by Cerqueira (2013) and also correlation coefficients and nonparametric local polynomial regressions. The findings of their study about business cycle synchronization in the EMU show that the usual focus on co-movements and correlations might be misleading, however, since they 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.

Duran and Ferreira-Lopez (2017) for their study in a Eurozone context use GDP and employment as the business cycle measures and the determinants of business cycle synchronization identified in the literature were namely bilateral trade intensity, dissimilarity of labor market rigidity, dissimilarity in industrial structures, financial openness and foreign direct investment relations. In order to investigate empirically the determinants of business cycle correlation, they employ simultaneous four-equations model by OLS and three-stage least squares. They find that bilateral trade relations present a positive influence on business cycle correlations, while the dissimilarity of labor market rigidity presents a negative influence. They also find that rest of the variables are non-significant. They also find that these results are robust to the use of the HP filter and first differences as the de-trending methods, as well as the use of GDP as the business cycle measure, excluding the financial crisis years (2008 and 2009). They also find that results for employment as the business cycle measure are in contrast with the previous ones and find industrial dissimilarity to be the relevant variable to determine business cycles synchronization. In what concerns the determinants of the lead and lag behavior, results show that the member states of the Eurozone that usually lead the cycle are the ones that are wealthier, with strict employment legislation, more specialized in construction and finance sectors and more prone to international capital movements. Differences in the determinants between contemporaneous business cycles and lead and lag behavior of business cycles are especially important for policy-makers in the Eurozone to know about, in particular if asymmetric shocks between countries are set in place.

The study of Karadimitropoulou (2018) is about on 5 developed economies (G5) and 19 emerging economies for the 1972-2009 period value-added growth in a multi-sector dynamic factor model. The empirical part of this study includes methods such as multi-factor dynamic model to a multi-sector setting. It is augmented with a region-specific factor to capture sectoral synchronization at a regional level. Also, in the empirical part of the study, correlations and variance decomposition are included. The results suggest that, while there exists a common 'regional business cycle' in the G5, fluctuations in sectoral value-added growth are dominated by country specific factors in the emerging markets. Despite that, the international factor (the sum of world and sector factors) is more important than the region factor, suggesting that the emerging markets are more synchronized with the G5. A simple regression shows that (i) the world factor would be more important the larger the share of agriculture in output; (ii) in more open economies the sector factor is more important in explaining sectoral value-added growth fluctuations; (iii) the region factors is more important the richer and the less volatile the economy. Finally, a comparison of the variance of sectoral value-added growth accounted

for by each factor from the pre- to the post-globalization period shows convergence of the business cycles within the G5 and EM, respectively. The changes in the contribution of the world, sector and region factor are due to changes in the importance of those factors within sectors. However, for the emerging markets, the fall in the importance of the country factors is dominated by changes in the structural composition of the economies. Therefore, the evolution of the structural composition in the emerging markets could be an important driver for more synchronised business cycles at the regional and international level.

The study of Camacho *et al*. (2019) is about all the members of the EA using a large panel of cross-country data. They use macroeconomic series of production, consumption and investment for each country. In particular, they use the demeaned growth rates of GDP, Household and NPISH Final Consumption Expenditure and Gross Fixed Capital Formation. The seasonally adjusted series were downloaded from the Eurostat database at a quarterly frequency. Effective sample spans the period between the first quarter of 2000 to the last quarter of 2015 for all the nineteen countries of the EA but Cyprus. They take advantage of the dimension reduction properties of dynamic factor models to summarize a large dataset of macroeconomic indicators for the Euro Area countries. Then, they estimate latent state variables based on Markov-switching methodologies to obtain a time-varying measure of business cycle synchronization. The combination of the techniques allows them to describe the evolution in the degree of coincidence of the business cycle phases along time for this set of countries. Their results suggest that there was a general decline in the degree of business cycle synchronization across the Euro Area countries following the financial and the sovereign debt crises. Although they have recovered the levels of business cycle synchronization exhibited before these events, there are significant differences across countries in the required time to recover those levels.

Nkwatoh (2019) analyses the degree of business cycles' synchronization of ECOWAS economies and uses annual GDP growth rate data that cover the period from 1975 to 2015. Nkwatoh (2019) uses HP filter and country correlations in order to find the results of the study. The result from the transitory component shows that the business cycles of WAEMU sub-economies are similar. But on a general note, the correlation coefficients of both components show that the business cycles of ECOWAS economies differ significantly, suggesting that, a broader monetary union involving both WAEMU and WAMZ economies will not be beneficial to the entire ECOWAS region. However, ECOWAS governments can take the risk of forming a monetary union in 2020 since a high probability of addressing a wide range of macroeconomic differentials across the region is incumbent on ex-post conditions, rather than

on ex-ante prerequisite conditions that only focuses on the cost of relinquishing monetary autonomy.

Abdallah (2020) uses trade intensity data for Tunisia. The data cover the period 1980-2018. Regarding the empirical part of the study and the methodology used, the synchronization of economic cycles is measured by calculating the correlations between the cyclical components of certain macroeconomic variables. In their work, they use GDP in real terms to calculate the cyclical correlations between Tunisia and each partner country of the European Union (France, Italy, Germany, Spain and Belgium). The cyclical components are extracted by the HP filter. Following the crisis of 2008, Tunisia experienced an economic recession characterized by a high unemployment rate consequence by the decline in these exports after the decline in demand of the European Union, which is the main trading partner for the Tunisian economy. France, Italy, Spain, Germany and Belgium absorb more than 67.89% of Tunisian exports. To absorb the negative effects of this economic dependence in the existence of a crisis, other new markets must be explored. The most important market in the last decade is the African market, which is distinguished by an average real gross domestic product growth, approximately 5%. In this sense, we will study, in this research, the correlation of the Tunisian economic cycle as well as the degree of commercial intensity with that of the main European partner countries.

Bunyan *et al*. (2020) examine the pairwise synchronization for 14 EU countries. They use annual GDP data for the period 1981-2014. The determinants of synchronization are the countries' pairwise differentials of cyclically adjusted net lending, government expenditure, gross exports, total factor productivity, labour productivity, capital productivity, inflation, industrial structure, private and national savings rates. They use in their study Diag-BEKK time-varying pairwise correlation of the GDP cyclical component, which have been extracted using HP filter as a measure of synchronization and they applied a dynamic panel model with GMM. They find that countries with similarly sized public sectors and fiscal divergence, have more synchronized business cycles. They also find that trade intensity, inflation differentials and differences in capital productivity growth rates matter for synchronization. They also find that country-pairs that trade more intensely and have similar productivity growth rates have more synchronized business cycles, while differences in inflation rates (i.e. higher inflation differentials) across country-pairs lead to increased business cycle synchronization.

Beck (2021), quantified the different channels through which capital mobility affects business cycle synchronization (BCS), considering dynamic panel framework accounting for model uncertainty, reverse causality, and contagion. Four different channels are examined:

exuberance of business cycles through short run flows, risk-sharing-induced specialization, international value chain integration resulting from foreign direct investment, and contagion. The results show that the overall impact of capital mobility on BCS is positive in the EU.

Next, we proceed with the studies that directed their attention towards the regional business cycles synchronization.

3. Business cycles synchronization at regional level

The paper of Bandrés *et al*. (2017) is a review about regional-level approach. They mention in their paper that most of these studies focus on examining synchronization among short-term fluctuations in regional real economic activity. They also mention that there are four types of methodologies that are considered and are pairwise correlations, dynamic factor models, regime switching approaches and clustering techniques. Most of the regional literature focuses on simple pairwise correlations. Specifically, in most papers, the series are transformed by using, mainly, the Hodrick-Prescott (HP) filter[1] and then pairwise correlations are computed based on the filtered data. Different measures of economic activity are used; for example, Fatas (1997), Barrios and De Lucio (2003) and Belke and Heine (2006) use employment data while Acedo-Montoya and de Haan (2008) use gross value added (GVA) and Barrios *et al*. (2003) work with GDP series. Finally, Clark and van Wincoop (2001) work with GVA and employment measures of real activity to compare synchronization patterns among European countries and US Census regions. With respect to the regime-switching approach, in a recent paper, Gadea *et al*. (2017) combine regime-switching models and dynamic model averaging to measure time-varying synchronization for GDP. They also refer that many papers deal with a short number of European regions, which are quite aggregated. The nomenclature of territorial units for statistics (NUTS) 2013 classification lists 98 regions at NUTS1 level, 276 regions at NUTS2 level and 1,342 regions at NUTS 3 level in the European Union. They also mention that some of the papers identify a border effect, regions belonging to the same country are more synchronized than regions belonging to different countries. Some papers also identify a role of the productive structure in accounting for synchronization, although results differ across papers, which could be due to differences in the definition of sectors, in the specialization measures, in the database and/or in the techniques.

[1] There are other filtering methods that have been considered by the literature. Canova (1998) is the first to provide a thorough evaluation of the different filtering methods for extracting the cyclical components of different macroeconomic series.

Despite the important review conducted by Bandrés *et al*. (2017), it is important to review some of the individual papers, starting from the seminal paper on regional business cycles by Sala-i-Martin (1996). This study is one of the first studies regarding regional business cycle synchronization. In this study, 73 NUTS2 (DE, UK, FR, IT, NE, BE and SP), 47 US regions, 10 Canadian provinces, 47 Japanese prefectures were used and data for personal income (some years depending on the sample) were collected (the period covered: for Europe 1950-1990, for United States 1880-1990, for Canada 1961-1991 and for Japan 1955-1990). In the empirical part of the study, β convergence and σ convergence were used. The results show that there are both types of convergence across regions of the US, Japan, Europe, Spain and Canada, at about the same rate.

In 2003, Barrios *et al*. (2003) examined the patterns and determinants of business cycle correlations among 11 UK regions and six Eurozone countries. They used data for GDP that covered the period from 1966 to 1997. They introduced the HP filter and correlation in the empirical part of their study and they found that UK regions are less correlated with the EA than other EU countries and divergence has increased 6 EA countries GMM correlations. Moreover, they found that sectoral similarity promotes cyclical symmetry OLS Regression (explanatory variables) and high correlations among UK regions.

Barrios and De Lucio (2003) use quarterly employment data from 1988-1998 for Spanish and Portuguese regions and they also use data for direct investment flows, exports, bilateral trade and distance between regions' capital. The econometric methods that they apply in their study are cross-correlation coefficient between HP filtered series and fourth difference and dissimilarity index for sectoral employment. They show that the so-called border effect (i.e. the difference of between- and within-country business cycles correlations) has notably decreased in Iberian regions in the aftermath of the accession of Spain and Portugal to the European Community. In testing the determinant of economic co-fluctuations, they show that the relative size and industrial structures of regions were the most significant variables.

Belke and Heine (2006) examined the degree of correlation in their study among EU regional employment cycles and tried to connect it to the changing patterns of specialization. They used data for employment for 1989-2006 for 30 NUTS1 (BE, FR, DE, IE, NET, SP) countries. They employed HP filter and correlation in the empirical part of their study and they found that the decline in regional synchronization is due to differences in regional industry structure pairwise correlation (Bravais-Pearson coefficient).

Rodríguez-Pose and Fratesi (2007) use NUTS II data for GDP, employment (overall, in services and non-services industries), industrial structure covering the period 1980-2000 for

5 EU countries. They test the pro-cyclicality of regional growth vis-à-vis national growth (sheltered economy hypothesis). Also, the regional growth differentials are with respect to the national growth rate. They apply an OLS regression to test the effects of macro-variables on changes in sheltered economies. The results of the analysis support the hypothesis of a change towards a pro-cyclical evolution of regional disparities in the cases of Italy, Portugal and Spain, but not in those of Greece and France. A relationship between these pro-cyclical patterns and the emergence of less dynamic sheltered economies is also detected in peripheral regions. This lack of dynamism is related to the fact that numerous peripheral areas in southern Europe have become increasingly dependent on factors such as transfers or public investment and employment and therefore are less exposed to changes in market conditions.

Acedo-Montoya and de Haan (2008) analyzed regional business cycle synchronization in the Eurozone and they focused on 53 NUTS1 (12 EMU countries). They used data for Gross Value Added for the period 1978-2005. They employed HP and Cristiano-Fitzgerald filters and correlation as synchronization measure. They found that correlation has increased during the period considered, except in the 80s and the beginning of the 90s. According to the findings of their study, they also show the existence of a national border effect.

Montoya and De Haan (2008) use GVA per capita data for each of the 53 EU Nuts 1 regions. The data cover the period from 1975 to 2005. They find the regional business cycle synchronization using rolling-window correlation coefficient. Furthermore, the cyclical components are extracted using HP and CF band-pass filter. They also employ multidimensional scaling techniques to the cyclical component of GVA of the 53 NUTS 1 regions. They find that synchronization has increased for the period considered, with exceptions during the eighties and the beginning of the nineties. Still, the correlation of the business cycle in some regions with the benchmark remained low or even decreased. Their findings also support the hypothesis of the existence of a 'national border' effect.

Regarding the study of Artis *et al.* (2010), data for 41 EU regions and 48 US states are exploited and annual data on regional real GDP are available for the 1982-2007 period. They examine what drives the business cycles and also the role of common and spatial components. They use in the empirical part of their study panel models with spatial dependencies and spatial correlation and the results obtained by a panel model with spatial effects indicate that the impact of national business cycles for the regional development has been rather stable over the past two decades, in particular across US states. A tendency for convergence in business cycles often detected in country data is not confirmed at the regional level. The pattern of synchronization across the euro area is similar to that across US states. Although cyclical

heterogeneity is detected, it does not indicate a serious impediment to a common monetary policy of the European Central Bank.

Panteladis and Tsiapa (2011), examine the degree of synchronicity in business cycles in Greek regions associated with specific spatial and economic characteristics that explain, to a large extent, synchronization dynamics. They conducted an analysis of almost 30 years' (1980-2008) worth of data at the NUTSIII level (prefectures). They conclude that prefectures are more synchronized with the NUTSII regions than the national level, accentuating a regional (NUTSII) border effect. Moreover, the intensification of the integration process and the free operation of markets seem to diachronically affect the structural characteristics of the Greek regions and the geography of cyclical synchronization. Their study revealed a two-stage integration in which in the first stage they are detected urbanization economies, while in the second one localization economies. The metropolitan region, apart from its prominent position in economic growth, shows a confined level of business synchronization with the other regions, stressing Greece's pattern of economic and structural dualism.

The study of Park (2013) is about regional business synchronization in East Asian countries. He uses data for real GDP, real private consumption expenditure and real investment that cover the period from 2000Q1 to 2011Q4. He uses the dynamic factor model to extract the regional common factor. The degree of business cycle synchronization is measured by time-varying dynamic conditional correlation for each country. Finally, the determinants of business cycle synchronization are examined by differentiating the monetary and fiscal policy variables as well as the non-policy variables. The estimation of a dynamic two-factor model extracts the common factor and the nation-specific factor from both the macroeconomic aggregates and plausible driving forces of regional business cycles. According to the findings of the study, the evidence for regional business cycle synchronization is particularly strong for Korea, Malaysia and the Philippines, while Japan shows weak evidence of regional synchronization. On the other hand, Indonesia, Thailand, Singapore and China are decoupling from regional business cycles. The driver of monetary aggregate is the most significant determinant of regional fluctuations of macroeconomic aggregates, whereas oil price and productivity are on average important driving forces of nation-specific fluctuations of real economic activities.

The study by Panteladis and Tsiapa (2014) focuses on the Greek regional business cycle synchronization. They use data from 1980 to 2008 at the NUTSII and NUTSIII level. The study uses the HP filter to extract the cyclical components of the regional GDP per capita series. Subsequently, the employ the Pearson correlation with 8-years rolling window, to approximate a time-varying correlation measure. Their findings show that the business cycles of the

NUTSIII regions are more synchronized with the NUTSII level rather than the national business cycle. In terms of the drivers of synchronization or de-synchronization, these seem to be the industrial dissimilarity, similarity in manufacturing specialization, similarity in input-output linkages and agglomeration economies.

Ozyurt and Dees (2015) examine the regional dynamics of economic performance in the EU and to what extent spatial spillovers matter. They use data for real GDP for 253 NUTS2 EU for 2001-2008. They use moral index and Spatial Durbin random-effect panel model. According to the findings of the study, social-economic environment and traditional determinants of economic performance are relevant and also there are high-income clusters (in Western Europe) with positive effects on development of neighboring regions.

Beck (2016) analyzes time series of real GDP for 24 EU countries, 82 NUTS 1, 242 NUTS 2 and 1264 NUTS 3 regions over the period between 1998 and 2010. The methods that used in the study about business cycle synchronization in European Union are HP, as well as Christiano and Fitzgerald filters. The results of the analysis support the European Commission's view and show a very high degree of BSC within EU countries. The country level analysis also reveals that within the EU there is a group of countries that could form an effectively working monetary union based on the BCS criterion.

Gadea *et al*. (2017) assessed the regional economic interlinkages within the European countries. They use GDP data for 213 NUTS2 (18 EU countries). The data cover the period from 1980-2011. They apply regime switching and dynamic model averaging in their study and also correlation in order to measure synchronization. They find that the Great Recession synchronized Europe twice as much as the EU process in decades, Ile de France acts is the main channel of transmission of business cycle shocks and increases in regional sectoral composition similarity have a positive effect on business cycle synchronization, only for regions that already experience high levels of similarity in their productive structure.

Bandrés *et al*. (2017) use European and regional level data for NUTS 2013 classification which lists 98 regions at NUTS1 level, 276 regions at NUTS2 level and 1,342 regions at NUTS 3 level. The data cover a period of 32 years, from 1980 to 2011. They use Finite Mixture Markov Models Clustering based on finite mixtures of dynamic regression models. The idea is to pool time series to obtain posterior inferences but without being necessary an overall pooling within clusters. The main findings of their study that is about regional business cycles across Europe are the following: (i) evidence of just one cluster amongst the European countries while, at the regional level, there is more heterogeneity and we identify five different groups of European regions; (ii) the groups are characterized as

follows: the first contains most of the Greek regions; groups two and three include, in most cases, regions from Germany (plus a couple of regions from southern European countries in group two and some regions of the core countries in group three); group four is populated mainly by regions belonging to northern European countries; and group five is the largest and is composed of the rest of European regions; (iii) we notice that the degree of homogeneity of regional business cycles within countries is quite different; (iv) we also observe that spatial correlation increased during the convergence process towards the introduction of the euro and has taken a big leap with the Great Recession, both at country and regional level. In fact, co-movements among regions have mainly increased during the last decade. These results have important implications for policymakers in the design of convergence policies at the European level and also in the design of fiscal policies to reduce regional disparities at the country level.

Camacho *et al*. (2017) focus on 17 Spanish regions using total security system affiliation as the measure of economic activity and the data cover the period 1983.01-2017.05. Their study is about business cycles phases in Spain. They use Single-equation Markov-switching model and concordance index. Based on a set of Markov-switching models, they find substantial synchronization of regional business cycles, which has increased since the Great Recession. They do however evidence a regional leading and lagging performance that repeats itself across the different recessions. Typically, earlier signals of national recessions appear in the Islands and Valencia and are propagated from the periphery to the center. Moreover, north-western regions tend to start the regional recoveries with a significant lag.

Lange (2017) uses data for total employment for both sexes, 15 years and over. The estimation period is from 1976:5 to 2010:6. He uses Markov switching methodology to capture the asymmetric nature of provincial business cycles in Canada and also used Concordance indices and cross-correlations. The results of the study show that the estimations identify two- and three-regime provincial business cycles, as well as some provincial economies that do not experience explicit cycle phases. Despite the asychronicity of provincial business cycles, concordance indices identify a very close cyclical pattern between most provinces and Canada as the reference economy and maximum correlation coefficients indicate that recessions in Ontario, which has a relatively large concentration of manufacturing, lead overall recessions in Canada and in some of the other provinces.

Leiva-Leon (2017) uses data on U.S. states coincident indexes were provided by the Federal Reserve Bank of Philadelphia. The sample spans from August 1979 until February 2016. The Chicago Fed National Activity Index (CFNAI) is used as a monthly measure of the U.S. national business cycle. All these indexes of real economic activity, for each state and for

the entire United States, have been constructed based on the principle of co-movement among industrial production, employment, sales and income measures. Leiva-Leon (2017) based the methodology they will apply in their research on Markov-switching framework to endogenously identify periods where economies are more likely to (i) synchronously enter recessionary and expansionary phases and (ii) follow independent business cycles. The reliability of the framework is validated with simulated data in Monte Carlo experiments. The main results report substantial changes over time in the cyclical affiliation patterns of US states and show that the more similar the economic structures of states, the higher the correlation between their business cycles. A synchronization-based network analysis discloses a change in the propagation pattern of aggregate contractionary shocks across states, suggesting that the US has become more internally synchronized since the early 1990s.

Gomez-Losko *et al*. (2019) use annual real GDP data for NUTS2 regions corresponding to 16 European countries. The series are available from 1980 to 2011. They also apply econometric methods in their research, such as Finite Mixture Markov models that allow to deal with technical difficulties that arise in capturing business cycles with short samples and heterogeneous data. The aim of this paper was threefold. First, they analyze the co-movements of the business cycles of European regions. Second, they date these business cycles, for the first time in the literature and identify clusters of regions with similar business cycle behavior, using Finite Mixture Markov models. Third, they develop a new index to measure within-country homogeneity. They find that co-movement among regions is, on average, quite low, although it increased during the convergence process prior to the euro cash changeover and after the onset of the Great Recession. They identify five different groups of European regions. They also find heterogeneity in the size of border effects.

Gießler *et al*. (2020) use real GDP, unemployment rates and survey data as business cycle indicators. They distinguish between two regions-East Germany and West Germany. They use quarterly, seasonally adjusted GDP growth for the period 1991-2017. In order to extract results for their study, they construct a coincident index determined by an inverse standard deviation weighting for all indicators. Furthermore, they estimate a factor model of the indicators where the indicators are represented by two unobservable components: the common component (factor) F and the idiosyncratic component. They also use correlations of quarterly GDP growth, output gap, first differences of unemployment rates, the cyclical component of unemployment rates and first differences of survey data for the time period between 1991 and 2017. They employ a cycle synchronization index (CSI) to assess the degree of business cycle synchronization. The CSI counts the sum of sign concordances of two

indicators and relates this sum to the number of observations of the time series. Overall, according to the application of the econometric methods, they find that the regional business cycles have synchronized over time. GDP-based indicators and survey data show a higher degree of synchronization than the indicators based on unemployment rates. However, synchronization among East and West German business cycles seems to have become weaker again recently.

4. Conclusion

The aim of this work is to provide a detailed review of the literature on business cycles synchronization. Our review started with those studies that focus at the country-level and subsequently we review the studies at regional level.

The main conclusions that can be drawn are as follows: Most of the studies use the HP filter for the extraction of the cyclical component of the GDP or GVA, depending on whether studies assess the country-level or the regional-level synchronization, respectively. There are studies that use additional filtering methods for robustness purposes. Such filtering methods include the Baxter-King and the Christiano-Fitzgerald. In terms of the estimation methods for the level of synchronization we observe that the majority of the studies use the simple correlation coefficient. To observe how this correlation evolves over time, the studies typically use rolling-window correlations. However, there is a trend observed recently to employ multivariate GARCH models, as a more robust approach for the estimation of the time-varying synchronization. Another standard approach that is used for the level of business cycles synchronization at different time periods is the use of Markov-Switching models.

In terms of the main drivers of synchronization, these are mainly the bilateral trade intensity, dis(similarity) of industrial structure, financial integration, fiscal stance, political ideologies, globalization and distance between countries being among the most identified factors.

Future research should examine further the regional business cycles synchronization in EU, given that the bulk studies concentrate their attention at country-level. In addition, this area of research should employ more sophisticated time-varying synchronization measures, such as multivariate GARCH models. Finally, modelling approaches that identify the time-varying effects of the synchronization's determinants should be employed, given that the determinants could be different at different time periods.

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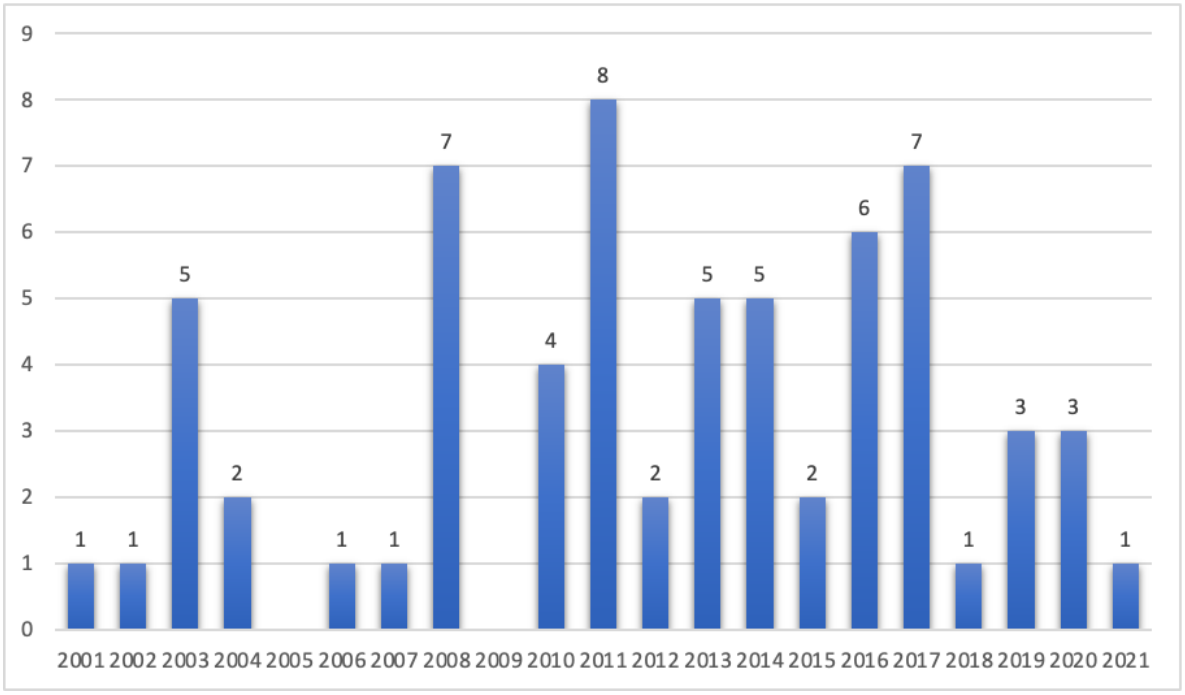
FIGURES

Figure 1: Number of papers published in academic journals and central banks' repositories per year



Appendix

Table 1. Summary of Literature

Authors	Geography, Period, Data	Methodology, Synchronization Measure
Sala-i-Martin (1996)	Period: EU: 1950-1990, US: 1880-1990, CA: 1961-1991, JA: 1955-1990 Countries: 73 NUTS2 (DE, UK, FR, IT, NE, BE and SP), 47 US regions, 10 Canadian provinces, 47 Japanese prefectures Series: personal income	β convergence and σ convergence
Clark, T. E., & Van Wincoop, E. (2001)	Countries: European countries and US Census regions Series: GVA and employment measures of real activity	Hodrick-Prescott filter & Baxter and King filter
De Haan, J. et al. (2002)	Period: 1929-1996 Countries: OECD Countries, USA & Germany	They focus on the correlation coefficient of the cyclical parts of income.
Barrios *et al*. (2003)	Period: 1966-1997 Countries: 11 UK regions Series: GDP	Hodrick-Prescott filter
Barrios and De Lucio (2003)	Period: 1988-1998 Country: Spanish and Portuguese regions. Series: Quarterly employment data, Direct investment flows, exports, bilateral trade and distance between regions' capital	Cross-correlation coefficient, dissimilarity index for sectoral employment.
Kose, M. A.et al. (2003)	Macroeconomic aggregates (output, consumption, and investment) in a 60-country sample covering seven regions of the world.	Bayesian dynamic latent factor model

Kose, M. A. et al. (2003)	Period: Annual data over the period 1960–99. Country: A sample of 76 countries—21 industrial and 55 developing. Series: Per capita real GDP and real private consumption constitute the measures of national output and consumption	Regression analysis of the factors that influence correlations of individual country macroeconomic aggregates with the corresponding world aggregates. They use nonoverlapping ten-year correlations as the dependent variable.
Bergman (2004)	Period: January 1961 – April 2001 Countries: EU– 14 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom) and five non–EU countries (Canada, Japan, Norway, Switzerland and the US) Series: quarterly observations on industrial production	Baxter and King bandpass filter, Burns–Mitchell definition of the business cycle.
Altavilla (2004)	Period: 1980 - 2002 Countries: 6 EU countries and the US Series: quarterly GDP	Hodrick-Prescott filter, Band-pass filters, Markov-Switching models, Mean corrected index of concordance.
Belke and Heine (2006)	Period: 1989-1996 Countries: 30 NUTS1 (BE, FR, DE, IE, NET, SP) Series: Employment	Hodrick-Prescott filter Bravais-Pearson correlation
Rodríguez-Pose and Fratesi (2007)	Period: 1980-2000 Countries: NUTS II, 5 EU countries Series: GDP, Employment (overall, in services and non-services industries), industrial structure	Regional growth differentials, OLS regression to test the effects of macro-variables on changes in sheltered economies
Acedo-Montoya and de Haan (2008)	Period: 1978-2005 Countries: 53 NUTS1 (12 EMU countries) Series: GVA	Hodrick-Prescott filters, Cristiano-Fitzgerald filters, correlation

Camacho, M.et al. (2008)	Period: monthly]1965:01 to 2004:03 Countries: EU Countries Series: Industrial Production (IP)	Stationary bootstrap methods. Their proposal minimizes typical problems of other studies on business cycles, such as the dependence of the results to the choice of a dating rule, and the short number of complete cycles observed in most of the countries. Finally, they adopt a model based on clustering approach.
Koopman, S. J., & Azevedo, J. V. E. (2008)	Countries: Seven European countries that are compared with the GDP series of the Euro area and that of the US Series: GDP	Standard Kalman filter techniques are used to estimate the parameters simultaneously by maximum likelihood.
Korse *et al.* (2008)	Period: 1960-2003 Countries: G-7 countries Series: world business cycles	Bayesian dynamic latent factor model
Furceri and Karras (2008)	Period: 1993 to 2004 Countries: 12 EMU countries Series: quarterly GDP data	Panel IV regression models Hodrick–Prescott filter, Band–Pass filter
Darvas and Szapáry (2008)	Period: 1983 - 2002 Countries: 10 EMU countries and 8 CEEC countries Series: quarterly GDP, trade, industrial production, GDP components	Dynamic factor model
Montoya and De Haan (2008)	Period: 1975-2005 Countries: 53 EU NUTS 1 regions Series: GVA per capita for each NUTS I region.	Hodrick-Prescott filter, Christiano and Fitzgerald filter, Multidimensional scaling techniques
Artis *et al.* (2010)	Period: 1982-2007 Countries: 41 EU regions and 48 US states Series: annual data on regional real GDP	Panel models with spatial dependencies, spatial correlation

Dimitru and Dimitru (2010)	Period: 1997q1-2009q2 Countries: EA and 11 countries joined EU in 2004 and Eurozone in 2007 Series: quarterly GDP	Quadratic trend, Hodrick-Prescott, Band-Pass filter, Beveridge-Nelson decomposition and Wavelet transformation
Filis *et al*. (2010)	Period: 1999q1-2007q2 Countries: Bulgaria and EA15 Series: GDP	Hodrick-Prescott filter, spectral analysis, squared coherency
Papageorgiou *et al.* (2010)	Period: 1960-2009 Countries: major European countries, US and Japan Series: Major annual macroeconomics series	Hodrick-Prescott filter, mean rolling correlations
Savva *et al*. (2010)	Period: January 1980 to June 2006 Countries: existing EMU, 9 enlargement countries and 3 candidate countries Series: monthly industrial production.	VAR-GARCH models, Double smooth transition conditional correlation GARCH model
Allegret, J. P. & Essaadi, E. (2011)	Period: Quarterly1975-2007 Countries: East Asian Countries	Dynamic correlations and TVCF as a measure of co-movement variability by the frequency approach.
Aguiar-Conraria and Soares (2011)	Period: July 1975 – May 2010 Countries: EU15 and EA12 Series: Industrial production.	Wavelet power spectra, Metric based on wavelet spectra
Artis *et al.* (2011)	Period: 1880-2006 Countries: 25 advanced and emerging economies Series: annual GDP.	Hodrick-Prescott filter, correlations in different sub-periods
Benčík (2011)	Period: 1995q1-2010q3 Countries: Czech Republic, Hungary, Poland, Slovakia and EA15 Series: GDP	Hodrick-Prescott filter cross-correlations in different sub-periods
Bergman and Jonung (2011)	Period: 1834-2008	Christiano-Fitzgerald filter, rolling average cross correlations

	Countries: Sweden, Norway, Denmark and selected OECD countries Series: annual GDP	
Mink *et al.* (2011)	Period: 1970q1-2006q4 Countries: 11 European countries Series: GDP	Christiano-Fitzgerald filter, Hodrick-Prescott filter, Baxter-King filter, synchronicity and similarity
Panteladis and Tsiapa (2011)	Period: 1980-2008 worth of data at the NUTSIII level (prefectures). Country: Greece Series: GDP	Hodrick-Prescott filter
Lee (2012)	Period: 1990-2009 Countries: EMU countries Series: extent of business cycle synchronization across its member states.	Dynamic latent factor model
Kolasa (2013)	Period: 1996q1- 2011q4 Countries: Czech Republic, Hungary, Poland, Slovenia, Slovakia Series: major economic series	Hodrick-Prescott filter, correlations in different sub-periods
Obradović and Mihajlović (2013)	Period: 2001q1- 2009q4 Countries: Bulgaria, Croatia, Hungary, Romania, Serbia and Slovenia Series: GDP	Hodrick-Prescott and Baxter-King filters, correlation in different sub-periods, rolling cross-correlations
Park (2013)	Period: 2000q1-2011q4 Countries: East Asian countries Series: real GDP, real private consumption expenditure and real investment	dynamic factor model, time-varying dynamic conditional correlation, differentiation of monetary and fiscal policy

Stanisic (2013)	Period: 1995–2012 Countries: Central and Eastern European countries (CEEC) Series: quarterly, seasonally adjusted real GDP, obtained from the Eurostat National Accounts database.	double Hodrick–Prescott filter, rolling correlation
Crespo-Cuaresma and Fernández-Amador (2013)	Period: 1960-2008 Countries: EU countries and 11 OECD countries Series: quarterly real GDP	Convergence/divergence test, Business cycle dispersion measure
Jiménez-Rodríguez *et al*. (2013)	Period: 1995 –2011 Countries: selected euro area and CEE countries Series: quarterly data on real output growth, real consumption growth and real investment growth	Markov switching models, concordance index
Degiannakis *et al*. (2014)	Period: 1980q1-2012q4 Countries: 14 EU countries Series: quarterly GDP	Scalar-BEKK, multivariate Risk metrics
Dufrénot, G., & Keddad, B. (2014)	Period: Quarterly data 1975-2010 Countries:ASEAN-5 countries Series: Real GDP	Business cycle correlation based on a Markov-switching forewarning model
Gouveia (2014)	Period: 2000q1- 2011q4 Countries: 8 countries in Southeastern Europe Series: GDP	Hodrick-Prescott and Baxter-King filters, rolling concordance index, Spearman's rank-order correlation
Konstantakopoulou and Tsionas (2014)	Period: 1960q1-2010q4 Countries: main OECD countries Series: GDP	Hodrick-Prescott, Christiano-Fitzgerald and Baxter-King filters, cross-correlation
Panteladis and Tsiapa (2014)	Period: 1980-2008 Countries: Greece Series: Regional GDP	The study uses the HP filter to extract the cyclical components of the regional GDP per capita series. Subsequently, the employ the Pearson correlation with 8-years rolling window, to approximate a time-varying correlation measure.

Bekiros *et al*. (2015)	Period: 1990-2010 Countries: Eurozone Countries Series: GDP	cross-wavelet coherence measure, scale-dependent time-varying (de)synchronization
Ozyurt and Dees (2015)	Period: 2001-2008 Countries: 253 NUTS2 EU Series: real GDP	Moran index Spatial Durbin random-effect panel model
Beck (2016)	Period: 1998 - 2010 Countries: 24 EU countries, 82 NUTS 1, 242 NUTS 2 and 1264 NUTS 3 regions Series: real GDP	Hodrick-Prescott filter, Christiano and Fitzgerald filter
Degiannakis *et al*. (2016)	Period: 1980 - 2012 Countries: 10 EMU member-countries and the aggregate EMU12 Series: annual GDP and cyclically adjusted net lending (NLB) data	Time-varying correlation coefficients from dynamic auto-correlated and cross-correlated models
Di Giorgio (2016)	Period: 1993-2014 Countries: CEEC and EA countries Series: quarterly seasonally adjusted real GDP	AR Markov switching intercept heteroscedastic model, Vector Autoregressive Markov switching intercept heteroscedastic model
Grigoraş and Stanciu (2016)	Period: 1960q1- 2014q3 Countries: 30 European and US Series: GDP	classical definition of business cycles, concordance index and correlation
Monnet and Puy (2016)	Period: 1950- 2014 Countries: 21 Series: quarterly industrial production based on IMF archival data	Similar to Kose *et al.* (2008) econometric methodology.
Gadea *et al*. (2017)	Period: 1980-2011 Countries: 213 NUTS2 (18 EU countries)	Regime switching, Dynamic model averaging,

	Series: GDP	correlation
Bandrés *et al.* (2017)	Period: 1980 - 2011 Countries: NUTS 2013 classification which lists 98 regions at NUTS1 level, 276 regions at NUTS2 level and 1,342 regions at NUTS 3 level Series: European and regional GDP	Finite Mixture Markov Models, Clustering based on finite mixtures of dynamic regression models.
Belke *et al.* (2017)	Period: 1970q1-2015q4 Countries: EA-12 countries, plus Norway, Switzerland, Denmark, Sweden Series: GDP on a quarterly basis from OECD.	Nonparametric local polynomial regressions
Duran and Ferreira-Lopez (2017)	Period: 2000 -2015 Countries: Eurozone Series: GDP and employment, trade intensity, dissimilarity of labor market rigidity, dissimilarity in industrial structures, financial openness and foreign direct investment relations	Four-equations model by OLS and three-stage least squares
Lange (2017)	Period: May 1976 - June 2010 Countries: Canada Series: employment	Markov-switching model, concordance index and cross-correlation
Leiva-Leon (2017)	Period: August 1979 - February 2016 Countries: US states Series: Chicago Fed National Activity Index (CFNAI) and the coincident indexes by the Federal Reserve Bank of Philadelphia	Markov-switching framework, endogenous identification
Jarko et al. (2018)	About 3,000 business cycles synchronization coefficients and their design and estimation characteristics	Meta-regression analysis

Karadimitropoulou (2018)	Period: 1972-2009 Countries: 5 developed economies (G5) and 19 emerging economies Series: GGDC 10-Sector annual macroeconomic data	Multi-factor dynamic model to a multi-sector setting. Region-specific factor that captures sectoral synchronization at a regional level
Gomez-Losko *et al.* (2019)	Period: 1980 - 2011 Countries: NUTS2 regions corresponding to 16 European countries Series: annual real GDP	Finite Mixture Markov models
Camacho *et al.* (2019)	Period: 2000q1-2015q4 Countries: EA members Series: macroeconomic series of production, consumption and investment	Dynamic factor models, large panel of cross-country model, latent state variables based on Markov-switching
Nkwatoh (2019)	Period: 1975 - 2015 Countries: ECOWAS economies Series: annual real GDP	Hodrick-Prescott filter
Abdallah (2020)	Period: 1980-2018 Countries: Tunisia Series: trade intensity	Hodrick-Prescott filter
Gießler *et al.* (2020)	Period: 1991-2017 Countries: East Germany and West Germany Series: quarterly real GDP, unemployment rate and survey data	Coincident index, factor model of unobservable components, cycle synchronisation index
Bunyan *et al.* (2020)	Period: 1981-2014 Countries: 14 EU countries Series: annual GDP, net lending, government expenditure, gross exports, total factor productivity, labour productivity, capital productivity, inflation, industrial structure, private and national savings rates	Diag-BEKK time-varying models, dynamic panel model with GMM.

Beck, K. (2021)	Period: 1996-2019 Countries: 26 European Union countries (without Croatia and Malta). To obtain the measure of business cycle synchronization, quarterly time series of the real GDP for 1996–2019 were utilized.	He quantified the different channels through which capital mobility affects BCS, considering dynamic panel framework accounting for model uncertainty, reverse causality, and contagion. Four different channels are examined: exuberance of business cycles through short run flows, risk-sharing-induced specialization, international value chain integration resulting from foreign direct investment, and contagion.