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Business Cycles Synchronization: Literature Review

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ABSTRACT

Following the seminal paper on Optimum Currency Areas (OCA) by Mundell (1961) a wealth of literature has been published on the business cycles synchronisation and its main determinants. This work provides a systematic review of this research field both at country-level synchronization and regional level. The paper aims to evaluate the contribution of the related literature's methodologies to the measurement of the business cycle and the estimation of the level of synchronization. The discussion of the collected papers is expected to substantially assist researchers, practitioners, and policy makers keen to employ themselves in the area of business cycles synchronisation.

KEYWORDS

Business Cycle; Optimum Currency Areas; Synchronization

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1. Introduction

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

This paper's survey provides detailed review of the current literature on the country and regional-level synchronization. It aims to draw insights on developed and employed methodologies to either measure of the business cycles or to estimate the synchronization level. The aim is also to open new avenues in this interesting area of research.

Before proceeding, the process that it was used to reach to the final sample of published work should be outlined. First, the Google Scholar was searched using terms, such as "Business cycle synchronization", "Business cycles in EU" and "Regional business cycle synchronization". Next, having identified a vast number of papers from the Google Scholar search, a process employed to identify the papers that would be included in this review. To do so, it was decided to be included only papers published in international academic journals. Hence, working papers were excluded, unless they were published in the depository of central banks or other institutions, from the review. Finally, it was decided to confine the research over the period 2001-2021, which coincides with the creation of the Euro currency, though seminal papers published before 2001 are also included. The number of papers been published each year and been included in this review is presented in Figure 1.

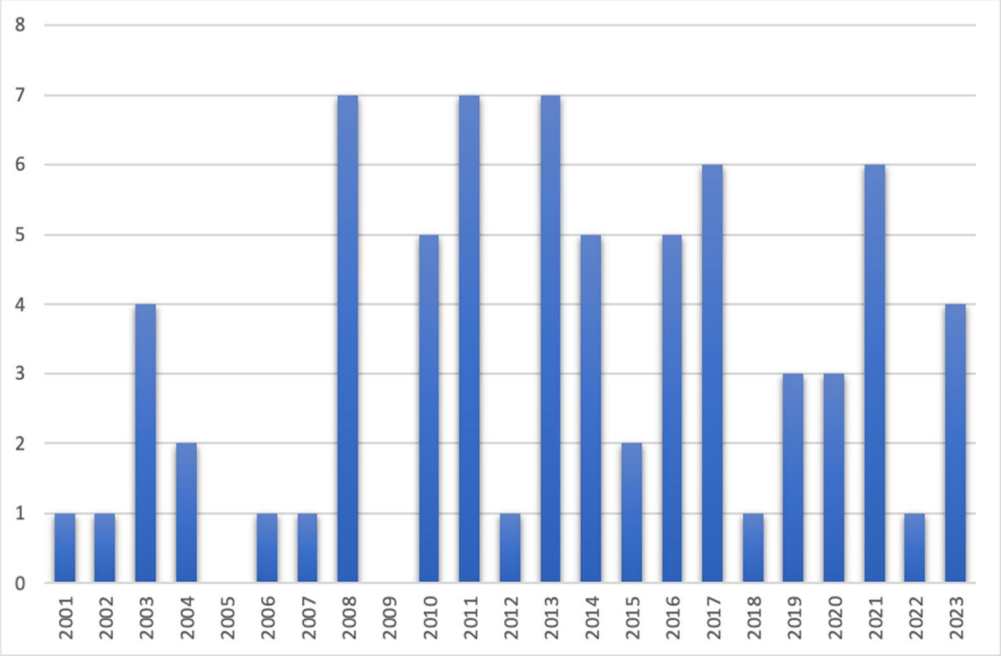

Figure 1. Number of papers published in academic journals and central banks' repositories per year

Figure 1 shows that there was a cluster of high activity on the under-review area in the years following the Global Financial Crisis of 2007-2009 with a revival of this interest in the last 2-3 years of our sample period.

It is interesting to notice, Figure 2, that most papers are focusing on country-level analysis rather than on regional business cycle synchronization. Worth mentioning that, though in 2017 most of the papers focused on regional-level analysis, that interest diminished in the following years. It could be said that the regional-level analysis might deserve more attention from future studies.

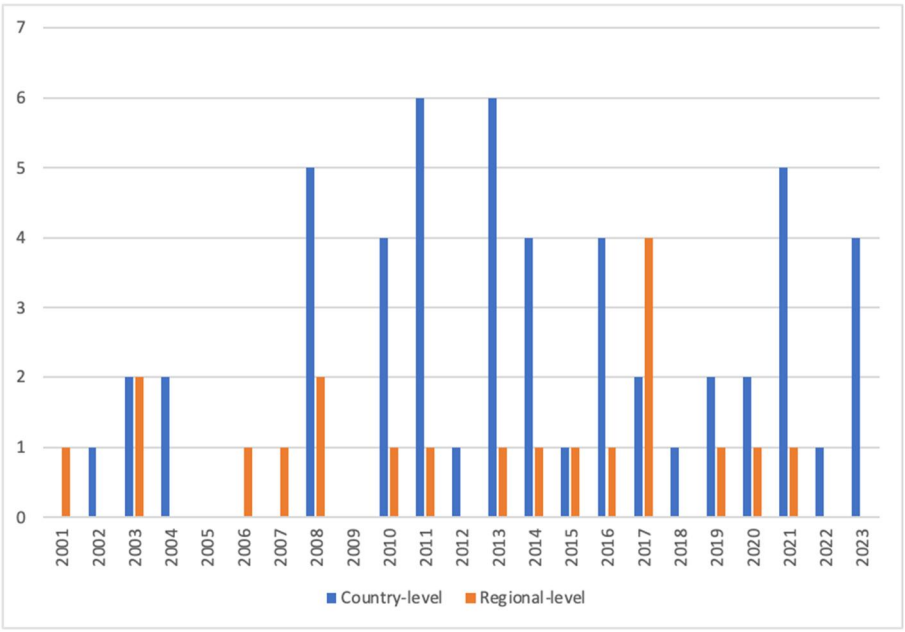

Figure 2. Number of papers focusing on country vs. regional level analysis.

Furthermore from Figure 3, where is quoted the frequency of the sample countries that appear in the reviewed papers, becomes clear that, as expected, the studies focus on the EU/EMU countries, as well as other non-EU European economies either the studies employ a country-level or regional-level analysis. The region that appears the least in the literature is Latin America, whereas there were no studies for the Australian continent. To this extend there could be an opportunity for future studies to focus on regions, beyond the European continent, given that there are areas which either have formed (formal or informal) currency unions (e.g. the Australian continent, Eastern Caribbean economies, among others) or plan to form currency unions (e.g. African Economic Community, Gulf Cooperation Council countries, Association of Southeast Asian Nations).

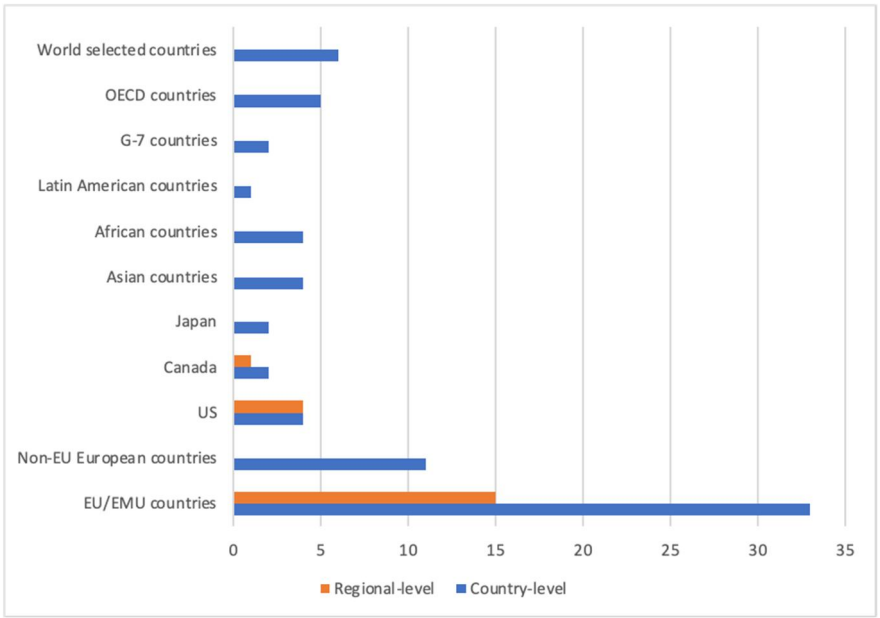

Figure 3. Countries that are included in the sample of the studies under review.

Finally, in Figures 4 and 5 the main filtering and synchronization methods are reported. It is rather clear that they most used filtering method in the Hodrick-Prescott, followed by the Baxter-King Band-Pass filter. This might be explained by the fact that the Hodrick-Prescott filter is simpler to be implemented, as it requires minimal

parameter tuning and it can easily separate the cyclical from the trend component of a time-series variable. Turning to the synchronization method a correlation-type is the most common, with the simple static cross-correlation to be the most preferred choice, followed (more recently) by the dynamic correlations so that they can capture the potential changes in the synchronization level over time. Nevertheless, dynamic factor models and Markov regime-switching models are also frequently used.

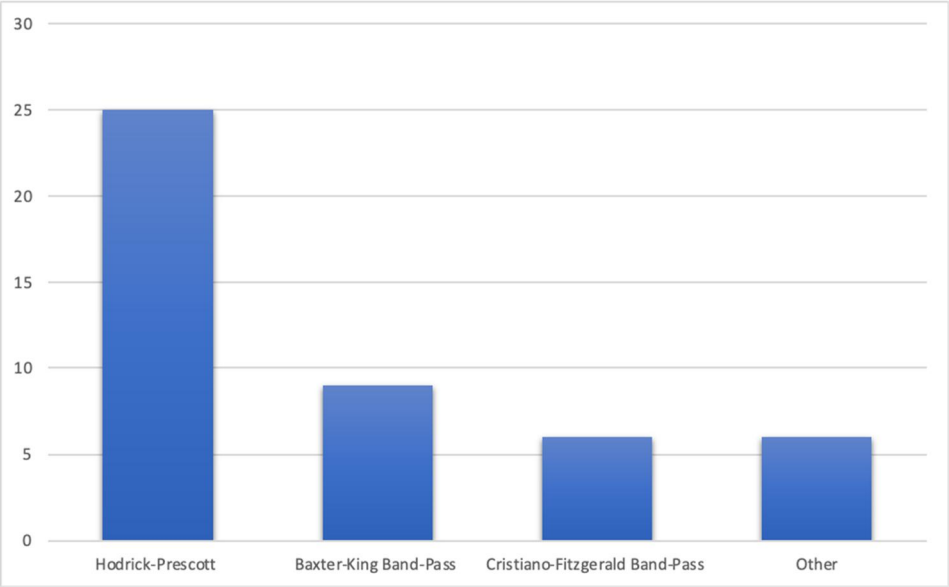

Figure 4. Filtering methods reported in the studies under review.

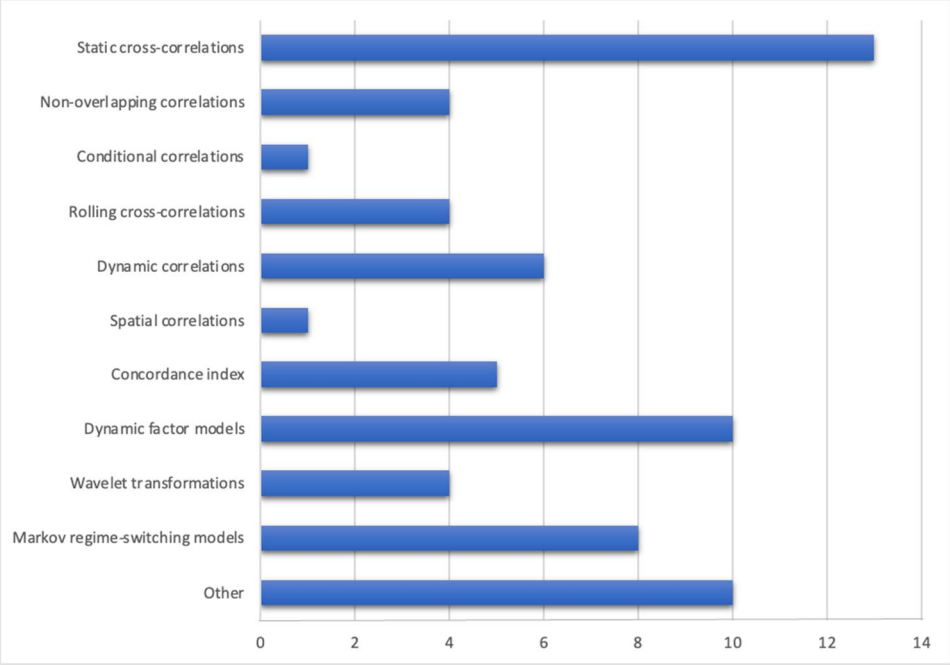

Figure 5. Business cycle synchronisation measures reported in the studies under review.

A study that is close to our work is the meta-analysis study by Fidrmuc *et al*. (2018) that considers about 3,000 business cycles synchronization coefficients and their design and estimation characteristics. The main results of their paper were: (a) synchronization increased from about 0.4, before the introduction of the euro, to 0.6 after its introduction; (b) this surge happened in both euro and non-euro countries (larger in former); (c) there is indication of country-specific publication bias; (d) the differences in the estimates imply that the euro accounted for

approximately half of the estimated increase in synchronization.

The review commences in Section 2 by examining research dedicated to the synchronization of business cycles at the country level. Section 3 delves into the synchronization of regional business cycles. In conclusion, Section 4 summarizes the review and highlights key points. A summary of the studies that are analyzed in this paper can be found in Table 1 in the Appendix.

2. Business cycles synchronization at country level

We initiate our examination of the relevant literature by concentrating on studies that evaluate the degree of synchronization in business cycles at the national level.

De Haan *et al*. (2002) aimed to address the query of whether increased integration would result in greater similarity in business cycles among EMU countries. Their analysis delves into the extent to which business cycles in US and German states have become more synchronized. Additionally, they explore whether synchronization in OECD countries is influenced by trade intensity and exchange rate stability. Findings from long-run data for the US show mixed evidence for synchronization. However, post-war data for Germany indicates that business cycles exhibit greater similarity over time. The evidence for OECD countries is varied: increased trade intensity has led to more synchronization, while exchange rate stability has resulted in less synchronization.

Kose *et al*. (2003a) investigated the impact of escalating trade and financial integration on the co-movement of international business cycles among a diverse group of industrial and developing countries. The results provide, at best, limited support for the conventional belief that globalization has heightened the degree of business cycle synchronization. Notably, the evidence suggesting that trade and financial integration amplify global spillovers of macroeconomic fluctuations is more pronounced for industrial countries. An important finding is that, on average, cross-country consumption correlations did not increase in the 1990s, a period when financial integration was anticipated to provide better risk-sharing opportunities, especially for developing countries.

In a related study, Kose *et al*. (2003b) investigated the common dynamic characteristics of business-cycle fluctuations across countries, regions, and the globe. Employing a Bayesian dynamic latent factor model, they estimated common components in macroeconomic aggregates (output, consumption, and investment) across a 60-country sample covering seven world regions. Results suggest that a common world factor significantly contributes to volatility in aggregates in most countries, supporting the existence of a world business cycle. The study reveals that region-specific factors play a minor role in explaining fluctuations in economic activity.

Bergman (2004) explored the similarity of European business cycles using a dataset comprising quarterly observations on industrial production for EU14 countries and five non-EU countries from 1961q1 to 2001q4. Employing a bandpass filter developed by Baxter and King (1999), Bergman isolated cyclical components of the data conforming to the Burns-Mitchell definition of the business cycle. The key finding indicates that European business cycles exhibit high synchronization, although synchronization was more pronounced during periods with highly flexible exchange rates. Furthermore, a positive tradeoff was observed between timing and magnitude, with greater synchronization coinciding with larger relative magnitude. These results raise concerns about the implications of a common monetary policy within the EMU.

Altavilla (2004) investigated the shared business cycle among EMU members, utilizing quarterly GDP data for six EU countries and the US spanning from 1980 to 2002. The study employed various measures such as phase, steepness, cumulative movements, amplitude, and concordance of countries' cycles. The research utilized HP and Band-pass filters, Markov switching models, and mean-corrected index of concordance to extract cyclical components. Results indicated that, while euro area economies displayed similar output dynamics during major recessionary periods, differences in the size and timing of business cycle features persisted. Moreover, adherence to the new currency area was suggested to enhance synchronization among EMU members.

Kose *et al*. (2008) examined changes in world business cycles from 1960 to 2003 for G7 countries, utilizing a Bayesian dynamic latent factor model to estimate common and country-specific components in macroeconomic aggregates. The study found that the common (G-7) factor explained a larger fraction of output, consumption, and investment volatility in the globalization period compared to the Bretton Woods period.

Furceri and Karras (2008) utilized quarterly GDP data for 12 EMU countries from 1993 to 2004, extracting cyclical components through differencing, HP filter, and Band-Pass filter. Their findings indicated increased synchronization with the EMU-wide economy during 1999-2004, primarily driven by trade factors rather than fiscal policy coordination. While Darvas and Szapáry (2008) analyzed quarterly GDP data for 10 EMU countries and 8 CEEC countries from 1983 to 2002. The study identified trade, industrial production, and GDP components as determinants of synchronization. Results indicated increasing synchronization over time, with trade being a major driver.

Camacho *et al*. (2008) focused on the appearance of business cycles in European countries, employing model-based cluster analysis. Contrary to synchronization, they found evidence against a common European cycle, with no clear relation between cycle appearance similarities and synchronization.

Koopman & Azevedo (2008) investigated business cycle relations among Euro area economies, modeling cyclical dynamics within a time series framework. Their findings suggested an increasing resemblance between business cycle fluctuations of European countries and those of the Euro area.

Dimitru and Dimitru (2010) examined business cycle correlations among new Eurozone member states, including Romania, using various filters and transformations. The study found increasing correlation over time, with Romania showing the lowest initial correlation with the Eurozone.

Filis *et al*. (2010) explored the synchronization of EU and Bulgarian business cycles using GDP data from 1997 to 2007. The study found cycles to be correlated at specific quarters but with a negative phase shift, indicating a lack of coordination in their phases.

Papageorgiou *et al*. (2010) studied business cycle synchronization and clustering in Europe from 1960 to 2009, using major macroeconomic series. Results indicated varying degrees of synchronization between core and peripheral European countries, with an increase during 1992-1999 and a decrease in 2000-2009.

Savva *et al*. (2010) used monthly industrial production data for existing EMU, enlargement countries, and candidate countries from Jan-1980 to Jun-2006. Employing Bivariate VAR-GARCH and double smooth transition conditional correlation GARCH models, the study found increased business cycle synchronization with the euro area for new EU members and negotiating countries since the early 1990s.

Aguiar-Conraria and Soares (2011) utilized industrial production data spanning from July 1975 to May 2010 for EU15 and EA12 countries. Their focus was on examining the synchronization of business cycles and the Euro, employing wavelet analysis. The methodology involved Wavelet power spectra within 1.5- and 8-year frequencies and a metric based on wavelet spectra. Their findings revealed that France and Germany demonstrated high synchronization with the rest of Europe, while Portugal, Greece, Ireland, and Finland did not exhibit statistically significant degrees of synchronization.

Artis *et al*. (2011) concentrated on business cycle synchronization dating back to 1880. They employed annual GDP data for 25 advanced and emerging economies from 1880 to 2006. Using the HP filter and correlation in different sub-periods, they observed increased synchronization from 1950–1973 and a further acceleration since 1973 among a group of European countries. In other regions, country-specific shocks played a dominant role in business cycle dynamics.

Benčík (2011) studied business cycle synchronization between the Visegrád Group countries and the euro area, using GDP data from Q1 1995 to Q3 2010. Employing the HP filter and correlation as synchronization measures in various sub-periods, the study found significant negative correlations before 2000 for each country. Between 2001

and 2007, the Czech Republic and Hungary exhibited contemporaneously significant correlations, while Poland showed no significant correlations, and Slovakia displayed significant correlations in the first and third lags and third lead.

Bergman and Jonung (2011) analyzed annual GDP data from Sweden, Norway, Denmark, and selected OECD countries spanning from 1834 to 2008, focusing on evidence from the Scandinavian currency union. They utilized the Christiano-Fitzgerald filter and rolling average cross correlations. Results indicated that business cycles in the three Scandinavian countries were more synchronized during the Scandinavian currency union compared to the post-World War II period, though not exceeding synchronization levels before the union. European countries exhibited an increase in average cross-correlations.

Mink *et al*. (2011) utilized GDP data from 11 European countries from Q1 1970 to Q4 2006. Applying Christiano-Fitzgerald, HP, and Baxter-King filters, and using synchronicity and similarity as measures, the study concluded that Euro Area output gaps did not become more synchronous or similar at the end of the sample period compared to the 1970s. Synchronicity and similarity between output gaps fluctuated over time, often not exceeding expectations under output gap independence.

Allegret and Essaadi (2011) explored the feasibility of a monetary union in East Asia, focusing on business cycle synchronization. They employed a novel empirical approach detecting endogenous structural changes in output co-movement, using a measure based on the time-varying coherence function. Cohesion statistics were computed to test synchronization tendencies, with their main finding suggesting that increased bilateral trade in East Asia significantly improved long-run business cycle synchronization, though short-run effects were mixed.

Lee (2012) re-evaluated the impact of the European Economic and Monetary Union (EMU) on business cycle synchronization among its member states. In this paper a dynamic latent factor model was used with which the regional effect of the euro area on output growth and inflation dynamics across European countries was identified. Results from variance decomposition analysis indicated increased synchronization leading up to the EMU, but no robust evidence supporting continued regional effects post-1999.

Dufrenot and Keddad (2013) aimed to analyze the relationships between ASEAN-5 countries' business cycles, distinguishing between regional and global spillover effects. They employed a time-varying transition probability Markov switching framework to capture fluctuations in synchronization over time and across business cycle phases. The study provided evidence that signals from leading business cycles impacted individual business cycles within the ASEAN-5.

Kolasa (2013) used quarterly data on major economic series from 1996 to 2011 to investigate differences in business cycles among Czech Republic, Hungary, Poland, Slovenia, and Slovakia. Employing the HP filter and correlations in different sub-periods, the study found that the degree of synchronization increased for all countries after joining the EU.

Obradović and Mihajlović (2013) focused their study on business cycle synchronization in Bulgaria, Croatia, Hungary, Romania, Serbia, and Slovenia using GDP data from Q1 2001 to Q4 2009. Employing econometric methods such as HP and Baxter-King filters, correlations in different sub-periods, and rolling cross-correlations, they discovered that the Serbian cycle was not synchronized with other countries, with Hungary being the sole exception. Their findings also suggested a tendency towards an increasing degree of synchronization.

Stanisic (2013) examined the synchronization of business cycles among Central and Eastern European countries (CEECs) and the Euro Area (EA) using quarterly, seasonally adjusted real GDP data from 1995 to 2012. The study employed the HP filter method to extract business cycles and evaluated the degree of co-movement through various methods of rolling correlation. Results indicated no common CEE business cycle, but a noticeable synchronization trend. Additionally, a strong trend of convergence of CEEC national business cycles towards that of the EA was observed.

Crespo-Cuaresma and Fernández-Amador (2013) used quarterly real GDP data for all EU countries and 11 OECD countries from 1960 to 2008. Utilizing business cycle convergence/divergence tests and a business cycle dispersion measure for synchronization proxy, they identified significant divergence in the mid-eighties, followed by a persistent convergence period throughout most of the nineties. This convergent episode coincided with the establishment of the European Monetary Union.

Jiménez-Rodríguez *et al*. (2013) focused on quarterly data on real output growth, real consumption growth, and real investment growth for selected euro area and CEE countries from 1995 to 2011. Using Markov switching models and concordance indices, the study revealed an increase in business cycle synchronization, with a high degree of concordance between country-specific and European business cycles.

Degiannakis *et al*. (2014) studied business cycle synchronization in EU12 countries from 1980 to 2010, employing scalar-BEKK and multivariate Riskmetrics model frameworks. Results suggested that changes in business cycle synchronization corresponded to major economic events in Europe. Until 2007, business cycle synchronization favored the operation of a single currency, but the recession and the subsequent Eurozone crisis led to desynchronization, particularly for periphery countries like Greece.

Gouveia (2014) examined business cycle correlation between the Euro area and Balkan countries using GDP data from Q1 2001 to Q4 2011. Econometric methods such as HP and Baxter-King filters, Concordance index, rolling concordance index, Spearman's rank-order correlation coefficients, and rolling correlation coefficients were applied. Findings indicated an increasing degree of synchronization among Balkan countries (excluding Greece) with a slight decrease towards the end of the period.

Konstantakopoulou and Tsionas (2014) concentrated on GDP data for main OECD countries from Q1 1960 to Q4 2010. Using HP, Christiano-Fitzgerald, and Baxter-King filters, along with cross-correlations, the study revealed strong synchronization between Euro-area countries, with cycles of Germany, France, Italy, Netherlands, Austria, and Belgium highly synchronized.

Bekiros *et al*. (2015) employed cross-wavelet coherence measures to detect scale-dependent time-varying (de)synchronization effects among Eurozone and the broader Euro area business cycles before and after the financial crisis. The results of the paper suggested that active monetary policy by the ECB during crisis periods could effectively stabilize the entire Euro area, although (de)synchronization varied across frequency bands and time horizons.

Degiannakis *et al*. (2016) used annual GDP and cyclically adjusted net lending (NLB) data from 10 EMU member-countries and the aggregate EMU12 from 1980 to 2012. The study focused on business cycle synchronization in EMU and examined whether fiscal policy could bring member countries closer. Results from a time-varying framework indicated that fiscal policy had significant effects on business cycle synchronization for all 10 EMU countries, supporting its potential for macroeconomic stabilization in the Eurozone.

Di Giorgio (2016) utilized quarterly seasonally adjusted real GDP growth rates from 1993 to 2014 for CEEC and EA countries. Applying MSI(H)-AR and MSI(H)-VAR models, the study found that CEEC countries shared business cycle features with EA cycles during recession regimes but less so during economic expansion phases. The hypothesis of the independence of CEEC cycles from the EA cycle was rejected.

Grigoraș and Stanciu (2016) used GDP data for 30 European countries and the United States from 1960/Q1 to 2014/Q3 to investigate new evidence on business cycle (de)synchronization. Using classical definitions of business cycles, concordance index, and correlations, they observed a high level of concordance with both the US and Germany characterizing old EU members, while the most recent EU entrants demonstrated the lowest level of concordance.

Monnet and Puy (2016) conducted a study assessing business cycle synchronization from 1950 to 2014 in a sample of 21 countries, utilizing a new quarterly dataset based on IMF archival data. They adopted the same

econometric methodology as Kose *et al*. (2008) to evaluate the significance of a world business cycle. The study found that the strength of the world business cycle was comparable during both the Bretton Woods era (1950-1971) and the Globalization period (1984-2006). While globalization did not impact the average level of co-movement, trade and financial integration significantly influenced how countries co-moved with the rest of the world. Financial integration was found to de-synchronize national outputs from the world cycle, with the magnitude depending on the type of shocks affecting the global economy.

The paper of Belke *et al*. (2017) utilized seasonally adjusted real GDP on a quarterly basis (OECD database) which covered the period 1970Q1-2015Q4. The study employed the Cerqueira (2013) quarterly index for business cycle synchronization, together with correlation coefficients and nonparametric local polynomial regressions. The main findings of the paper denoted that the focus on co-movements and correlations might be false, as there were significant differences in the scale of national cycles. A common cycle could lead to significant differences in cyclical positions, even when national cycles were clearly correlated.

The paper of Duran and Ferreira-Lopez (2017) was focused on Eurozone. The business cycle measures of the paper were GDP and employment. In this paper the determinants of business cycle synchronization, including bilateral trade intensity, labor market rigidity, dissimilarity in industrial structures, financial openness, and foreign direct investment relations were studied. In the empirical part of the paper, a simultaneous four-equation model by OLS and three-stage least squares were employed. The results showed that bilateral trade relations had a positive effect on business cycle correlations, while the dissimilarity of labor market rigidity had a negative impact. The paper's robustness was assessed using different de-trending methods and business cycle measures, producing consistent results.

The paper of Karadimitropoulou (2018) studied five developed economies (G5) and 19 emerging economies for the period 1972-2009. The paper focused on value-added growth in a multi-sector dynamic factor model. The study featured a region-specific factor to capture sectoral synchronization at a regional level. Methods included a multi-factor dynamic model in a multi-sector setting, correlations, and variance decomposition. Results suggested the existence of a common 'regional business cycle' in the G5, while fluctuations in sectoral value-added growth in emerging markets were dominated by country-specific factors. Despite this, the international factor (sum of world and sector factors) was more important than the region factor, indicating greater synchronization with the G5 in emerging markets. The study highlighted the impact of structural composition changes in emerging markets on business cycle synchronization at the regional and international levels.

Camacho *et al*. (2019) focused on all Euro Area (EA) members, using a large panel of cross-country data. They utilized macroeconomic series such as production, consumption, and investment for each country, employing demeaned growth rates of GDP, Household and NPISH Final Consumption Expenditure, and Gross Fixed Capital Formation. The effective sample covered the period from the first quarter of 2000 to the last quarter of 2015 for all nineteen EA countries except Cyprus. The study employed dynamic factor models for dimension reduction and Markov-switching methodologies to estimate latent state variables, providing a time-varying measure of business cycle synchronization. Results indicated a general decline in the degree of synchronization across EA countries following the financial and sovereign debt crises. While levels of synchronization have recovered, there are significant differences across countries in the time required to reach pre-crisis synchronization levels.

Nkwatoh (2019) analyzed the degree of business cycle synchronization among Economic Community of West African States (ECOWAS) economies, using annual GDP growth rate data from 1975 to 2015. The study applied the Hodrick-Prescott (HP) filter and country correlations. Results from the transitory component suggested similarity in business cycles among West African Economic and Monetary Union (WAEMU) sub-economies. However, overall correlation coefficients indicated significant differences in business cycles across ECOWAS economies. The study suggested that a broader monetary union involving both WAEMU and West African Monetary Zone (WAMZ)

economies might not be beneficial for the entire ECOWAS region.

Abdallah (2020) used trade intensity data for Tunisia covering the period 1980-2018. The study measured economic cycle synchronization by calculating correlations between the cyclical components of macroeconomic variables. GDP in real terms was used, and the cyclical components were extracted using the HP filter. Following the 2008 crisis, Tunisia experienced an economic recession due to a decline in exports, particularly to the European Union. The study explored the correlation of the Tunisian economic cycle and the degree of commercial intensity with major European partner countries. It emphasized the need to explore new markets, with a focus on the growing African market.

Bunyan *et al*. (2020) examined pairwise synchronization for 14 EU countries using annual GDP data from 1981 to 2014. Determinants of synchronization included pairwise differentials of various economic indicators. The study used Diag-BEKK time-varying pairwise correlation of the GDP cyclical component, extracted using the HP filter, as a measure of synchronization. A dynamic panel model with GMM was applied. Findings indicated that countries with similarly sized public sectors and fiscal divergence exhibited more synchronized business cycles. Trade intensity, inflation differentials, and differences in capital productivity growth rates were also found to impact synchronization.

Beck (2021) quantified different channels through which capital mobility affects business cycle synchronization, focusing on the European Union (EU). The study considered dynamic panel frameworks, accounting for model uncertainty, reverse causality, and contagion. Four channels were 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 overall impact of capital mobility on business cycle synchronization in the EU was found to be positive.

Lopez *et al.* (2021) studied a large dataset of 89 developed and developing countries to investigate the relationship between economic globalization and synchronization. Their study provides evidence that the non-synchronized countries can benefit more increasing their levels of economic globalization. Moreover, the synchronized countries benefit more from global expansions and, of course, these countries suffer more from the recessions.

Arčabić and Škrinjarić (2021) provided evidence that sharing is caring, as business cycle spillovers are shown to be a factor leading to more integrated and synchronized Europe. Authors analyzed the business cycle spillovers and synchronization between fifteen old EU-member states who joined the EU before 2004 and EU member states who joined the EU after 2004 (EU-13). Their study concludes that as the new member states are highly integrated, they are very sensitive to spillovers from old member states.

Berger *et al.* (2021) constructed a Bayesian three-level dynamic factor model for GDP growth of 60 countries from Europe, North America, Latin America and Asia. The contribution of this paper is that shows the importance to estimate a factor model which includes global, regional and development level factors simultaneously.

Chionis *et al.* (2021) estimated the synchronization of business cycles among EU countries for three different periods; i.e. 1990–1998 (participation in the union), 1999–2007 (participation in a common currency area before crisis), and 2008–2016 (common currency union after crisis), examining the co-movements of economic growth and foreign direct investments.

Based on a dynamic spatial model for a financial network of ten European countries, Böhm *et al.* (2022) noted that shocks are transmitted across countries via their financial linkages resulting in positive co-movements of GDP growth. The analysis was conducted for the period from 1996 up to 2017.

Fankem *et al.* (2023) used the estimated business cycle synchronization in order to investigate whether an African monetary union is feasible. As the African business cycles are not synchronized enough, they concluded that the African countries will not be benefited yet from a common monetary policy.

More recently, Guerini *et al.* (2023) studied the synchronization patterns in the European Union based on monthly industrial production from 2000 up to 2017. They concluded that i) after the introduction of the common currency and before the Great Recession, the synchronization has increased, but ii) after the Great Recession two separated clusters of countries have appeared, the northern economies against the southern ones.

Mansour-Ibrahim (2023) studied the relationship between financial and business cycles. She provided empirical evidence via the maximum overlap discrete wavelet transformation that financial and business cycles are co-moving and synchronized in boom and expansion phases.

Finally, Stiblarova (2023) examined the effect of extensive and intensive FDI margins on the synchronization of the euro area countries. This study concludes that an increase in new FDI leads to less synchronized business cycles among euro area countries, mainly because the new FDI enhances specialization.

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

3. Business cycles synchronization at regional level

Sala-i-Martin (1996) is recognized as one of the first studies on regional business cycle synchronization. It covers 73 NUTS2 regions in Europe, 47 US regions, 10 Canadian provinces, and 47 Japanese prefectures. The study uses personal income data from 1950 to 1990 for Europe, 1880 to 1990 for the United States, 1961 to 1991 for Canada, and 1955 to 1990 for Japan. The empirical part employs β convergence and σ convergence, revealing both types of convergence across regions in the US, Japan, Europe, Spain, and Canada.

The paper of Bandrés *et al*. (2017) is a review on regional-level approach. The main findings of the paper are: (1) most of the reviewed studies focus on examining synchronization among short-term variabilities in regional real economic activity; (2) there are four types of methodologies that are considered namely pairwise correlations, dynamic factor models, regime switching approaches and clustering techniques; (3) most of the regional literature cores on simple pairwise correlations; (4) in most papers, the series are transformed with the Hodrick-Prescott (HP) filter and then pairwise correlations are computed; (5) different measures of economic activity are employed namely employment data (Fatas, 1997, Barrios and De Lucio, 2003 and Belke and Heine, 2006), gross value added (Acedo-Montoya and de Haan, 2008), GDP series (Barrios *et al*., 2003) and GVA and employment measures of real activity to compare synchronization patterns among European countries and US Census regions (Clark and van Wincoop, 2001). With respect to the regime-switching approach, Gadea *et al*. (2017) combine regime-switching models and dynamic model averaging to measure time-varying synchronization for GDP. Also, a large number of papers deal with a short number of European regions, which are quite aggregated, and some of the papers recognize a border effect which means that regions belonging to the same country are more synchronized than regions belonging to different countries. Finally, a number of papers identify a role of the productive structure in accounting for synchronization which, however, might be explained for example by differences in the definition of sectors, the database, etc.

Barrios *et al*. (2003) examined business cycle correlations among 11 UK regions and six Eurozone countries using GDP data from 1966 to 1997. They employed the HP filter and correlation methods, finding that UK regions are less correlated with the Eurozone than with other EU countries. They observed an increase in divergence among Eurozone countries. The study also highlighted the promotion of cyclical symmetry through sectoral similarity.

Barrios and De Lucio (2003) focused on Spanish and Portuguese regions, using quarterly employment data from 1988 to 1998. They examined the border effect and its changes following Spain and Portugal's accession to the European Community. The study used cross-correlation coefficients between HP filtered series and dissimilarity indices for sectoral employment. Results showed a notable decrease in the border effect after accession, with the relative size and industrial structures of regions being significant determinants of economic co-fluctuations.

Belke and Heine (2006) explored the degree of correlation among EU regional employment cycles, connecting it to changing patterns of specialization. The study used employment data for 1989-2006 for 30 NUTS1 countries, employing the HP filter and correlation methods. Findings indicated that the decline in regional synchronization was attributed to differences in regional industry structures.

Rodríguez-Pose and Fratesi (2007) used NUTS II data for GDP, employment, and industrial structure from 1980 to 2000 for five EU countries. They tested the pro-cyclicality of regional growth compared to national growth, applying OLS regression to explore the effects of macro-variables on changes in sheltered economies. Results supported a shift towards pro-cyclical evolution of regional disparities in Italy, Portugal, and Spain, with implications for less dynamic sheltered economies in peripheral regions.

Acedo-Montoya and de Haan (2008) focused on analyzing regional business cycle synchronization in the Eurozone, specifically considering 53 NUTS1 regions from 12 EMU countries. They utilized Gross Value Added (GVA) data spanning from 1978 to 2005. The study employed the HP and Cristiano-Fitzgerald filters and correlation as measures of synchronization. The findings of the paper indicated an overall increase in correlation over the 1978-2005 period, with exceptions in the 80s and early 90s. The study also emphasized the existence of a national border effect.

The paper of Montoya and De Haan (2008) extended the analysis of regional business cycle synchronization using GVA per capita data for the same 53 EU NUTS1 regions, covering the 1975-2005 period. Rolling-window correlation coefficients, HP and CF band-pass filters, and multidimensional scaling techniques were employed to evaluate synchronization dynamics. The main findings of the paper were aligned with those of Acedo-Montoya and de Haan, indicating increased synchronization over the 1975-2005 period. The study also supported, as the one by Acedo-Montoya and de Haan (2008), the existence of a 'national border' effect.

The paper of Artis *et al*. (2010) investigated the determinants of business cycles across 41 EU regions and 48 US states, using annual data on regional real GDP for the 1982-2007 period. The paper used panel models with spatial dependencies and spatial correlation to examine the role of common and spatial components. The results implied a stable impact of national business cycles on regional development, with no significant tendency for convergence at the regional level. The synchronization patterns across the euro area were similar to those across US states, suggesting no serious impediment to a common monetary policy for the European Central Bank.

Panteladis and Tsiapa (2011) focused on the degree of synchronicity in business cycles in Greek regions, analyzing spatial and economic characteristics influencing synchronization dynamics. The study covered almost 30 years of data (1980-2008) at the NUTSIII level. The findings highlighted that prefectures were more synchronized with NUTSII regions than at the national level, emphasizing a regional (NUTSII) border effect. The integration process and market operation intensification were identified as key factors affecting the structural characteristics and geography of cyclical synchronization.

Park (2013) studied regional business cycle synchronization in East Asian countries, analyzing real GDP, real private consumption expenditure, and real investment data from 2000Q1 to 2011Q4. The study used a dynamic factor model to extract the regional common factor and measured synchronization with time-varying dynamic conditional correlation. The determinants of business cycle synchronization were examined, differentiating between monetary and fiscal policy variables and non-policy variables. The findings suggested strong synchronization for Korea, Malaysia, and the Philippines, weak evidence for Japan, and decoupling for Indonesia, Thailand, Singapore, and China. Monetary aggregate was identified as the most significant determinant of regional fluctuations.

Panteladis and Tsiapa (2014) revisited Greek regional business cycle synchronization using HP filter and Pearson correlation with an 8-year rolling window. The findings indicated that NUTSIII regions were more synchronized with NUTSII levels than the national business cycle. The drivers of synchronization or de-

synchronization were identified as industrial dissimilarity, similarity in manufacturing specialization, similarity in input-output linkages, and agglomeration economies.

Ozyurt and Dees (2015) investigated the regional dynamics of economic performance in the EU, examining spatial spillovers with real GDP data for 253 NUTS2 EU regions from 2001 to 2008. The study used the Moran index and Spatial Durbin random-effect panel model. The findings indicated that socio-economic environment and traditional determinants of economic performance were relevant, and high-income clusters in Western Europe positively affected the development of neighboring regions.

Beck (2016) analyzed real GDP time series for 24 EU countries, 82 NUTS1, 242 NUTS2, and 1264 NUTS3 regions from 1998 to 2010. The study utilized HP and Christiano-Fitzgerald filters, supporting a very high degree of business cycle synchronization within EU countries. The analysis also identified a group of countries within the EU that could form an effectively working monetary union based on business cycle synchronization.

Gadea *et al*. (2017) explored the evolution of regional economic interlinkages in Europe using GDP data for 213 NUTS2 regions from 18 EU countries (covering the period 1980-2011). The study applied regime-switching and dynamic model averaging techniques, along with correlation measures. The findings revealed increased synchronization during the Great Recession, with Ile de France acting as the main channel of transmission for business cycle shocks.

Bandrés *et al*. (2017) utilized European and regional-level data for NUTS 2013 classification, covering 98 regions at NUTS1 level, 276 regions at NUTS2 level, and 1,342 regions at NUTS3 level over 32 years (1980-2011). They employed Finite Mixture Markov Models Clustering based on dynamic regression models, identifying evidence of one cluster among European countries and five distinct groups of European regions. The study also highlighted increased spatial correlation during the convergence process towards the introduction of the euro and the Great Recession.

Camacho *et al*. (2017) focused on 17 Spanish regions, analyzing total security system affiliation as a measure of economic activity from 1983.01 to 2017.05. They employed a Single-equation Markov-switching model and concordance index, finding substantial synchronization of regional business cycles. The study also identified regional leading and lagging performance across different recessions.

Lange (2017) investigated the asymmetric nature of provincial business cycles in Canada using Markov switching methodology and concordance indices, based on total employment data from 1976:5 to 2010:6. The study identified two- and three-regime provincial business cycles, as well as provinces that did not experience explicit cycle phases. Concordance indices showed a close cyclical pattern between most provinces and Canada.

Leiva-Leon (2017) used U.S. state coincident indexes provided by the Federal Reserve Bank of Philadelphia, spanning from August 1979 to February 2016. The study applied a Markov-switching framework to identify periods of synchronous and independent business cycles among US states. The results showed substantial changes over time in cyclical affiliation patterns, emphasizing that the more similar the economic structures of states, the higher the correlation between their business cycles.

Gomez-Losko *et al*. (2019) utilized annual real GDP data for NUTS2 regions corresponding to 16 European countries from 1980 to 2011. The study applied Finite Mixture Markov models to analyze business cycle co-movements, date business cycles, and identify clusters of regions with similar behavior. The findings indicated that co-movement among regions increased during the convergence process prior to the euro cash changeover and after the onset of the Great Recession. The study identified five different groups of European regions and observed heterogeneity in the size of border effects.

Gießler *et al*. (2020) focused on East and West Germany, using real GDP, unemployment rates, and survey data as indicators for business cycles from 1991 to 2017. The study applied a coincident index and factor model, as well as correlations, to assess the degree of business cycle synchronization. The findings suggested that regional

business cycles synchronized over time, with GDP-based indicators and survey data showing higher synchronization than unemployment rate indicators. However, synchronization between East and West German business cycles appeared to weaken recently.

Finally, Cainelli *et al.* (2021) estimated a regression model between a spatial measure of pairwise regional business cycle synchronization and a set of gravity type, industry, labour market and agglomeration measures. For the US states, they showed that the synchronization increases during recessions, and the business cycles are more synchronized between the states with stronger commercial link.

4. Conclusion

The aim of this work is to provide a detailed review of the literature on business cycles synchronization, starting with the studies focused at the country-level to be followed by the review of the studies employing regional approach.

The main conclusions that can be drawn are: 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 most 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.

Though, future research should examine further the regional business cycles synchronization in EU, given that the bulk studies concentrate their attention at country-level, other, beyond EU areas, such as Australia, could attract the interest of research. 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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Conflict of interest

The author claims that the manuscript is completely original. The author also declares no conflict of interest.

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, Cross Correlation
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 Pairwise correlation using GMM
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*. (2003a)	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.
Kose, M.A.*et al*. (2003b)	Macroeconomic aggregates (output, consumption, and investment) in a 60-country sample covering seven regions of the world.	Bayesian dynamic latent factor model

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 coefficients with the Eurozone benchmark
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	VAR-GARCH models,

	Countries: existing EMU, 9 enlargement countries and 3 candidate countries Series: monthly industrial production.	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 Countries: Sweden, Norway, Denmark and selected OECD countries Series: annual GDP	Christiano-Fitzgerald filter, rolling average cross correlations
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 Correlation coefficients
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	Hodrick-Prescott filter, correlations in different sub-periods

	Series: major economic series	
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 world countries	Like Kose *et al.* (2008) econometric methodology.

	Series: quarterly industrial production based on IMF archival data	
Gadea *et al*. (2017)	Period: 1980-2011 Countries: 213 NUTS2 (18 EU countries) Series: GDP	Regime switching, Dynamic model averaging, 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.	Hodrick-Prescott filter, Correlation index
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
Karadimitropoulou (2018)	Period: 1972-2009	Multi-factor dynamic model to a multi-sector setting. Region-specific factor that

	Countries: 5 developed economies (G5) and 19 emerging economies Series: GGDC 10-Sector annual macroeconomic data	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,	He quantified the different channels through which capital mobility affects BCS, considering dynamic panel framework accounting for model uncertainty, reverse causality, and contagion.

	quarterly time series of the real GDP for 1996–2019 were utilized.	
Arčabić and Škrinjarić (2021)	Period: 1975:Q1 to 2018:Q3. Countries: EU countries excluded Ireland, Malta, Bulgaria Series: trade openness, industrial similarity, differences in fiscal deficits and differences in unit labor costs.	HP and Hamilton (2018) filter output gap synchronicity, and output gap similarity

Berger *et al.* (2021)	Period: 1961 –2017, annual data Countries: 60 countries from Europe, North America, Latin America and Asia Series: Penn World Table (PWT) version 9.1	Testing for international business cycles: A multilevel factor model with stochastic factor selection.
Cainelli *et al.* (2021)	Period: 2002-2011 Countries: US states Series: household nominal disposable income, gravity-type variables, industrial structure andlabour market variables, agglomeration economy indicators, indicators of commercial links between states.	The fraction of observations when the cyclical phase is the same for both states in each state pair.
Chionis *et al.* (2021)	Period: 1990q1- 2016q4 Countries: 28 European countries Series: GDP growth andForeign Direct Investments (FDI)	Non-Linear ARDL (Asymmetric) model Hodrick–Prescott, Corbae–Ouliaris, Hamiltov filter
Lopez *et al.* (2021)	Period: 1970–2015 Countries: 89 developed and developing countries Series: GDP	Kalman filter, Dynamic Factor Model
Böhm *et al.* (2022)	Period: 1996 to 2017 Countries: Ten European countries Series: claims of banks in one country towards all sectors in the counterparty country, sectoral GVA, additional global and domestic control variables.	Dynamic spatial model
Fankem *et al.* (2023)	Period: 1981–2019 Countries: East African Community (EAC); the Economic Community of Central African States (ECCAS); the Economic Community of West African States (ECOWAS); the Southern African Development Community (SADC); and the Arab Maghreb Union (AMU). Series: real GDP from Database AFDB.	wavelet power spectra, continuous wavelet approach
Guerini *et al.* (2023)	Period: 2000–2017 monthly frequency Countries: European Union 27 (out of 28) countries Series: industrial production	Band-Pass filter, Principal Component Analysis (PCA),

		Random Matrix Theory (RMT)
Mansour-Ibrahim (2023)	Period: 1995-2016 annual frequency Countries: Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain Series: inflation growth rate, the domestic credit to private sector growth rate and the GDP growth rate, real property prices, credit to the private sector and credit-to-GDP ratio	Maximum Overlap Discrete Wavelet Transform, Continuous Wavelet Transform
Stiblarova (2023)	Period: 2000–2019 Countries: EU-28 countries Series: number of announced FDI projects, value of announced FDI projects trade intensity, specialization, government deficit	Negative absolute value of country pairs' real GDP growth differences, simultaneous equations model

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