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A business cycle synchronization evidence

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Who will be the next in line to join the Euro Area? A business cycle synchronization evidence[1,2]

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Abstract

The aim of this paper is to investigate business cycle synchronization between seven candidate countries to the Euro Area (EA) – Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania and Sweden – and the Euro Area (EA-12/EA-19), France and Germany. The Hodrick-Prescott filter is used to decompose the real Gross Domestic Product into trend and cyclical components for the period 1995Q1-2019Q4. The results point to the existence of a strong business cycle synchronization between Sweden and the Euro Area, Germany, and France. The second highest correlation was observed for the Czech Republic followed by Hungary, Poland and Croatia. In contrast, Bulgaria and Romania show the weakest business cycle synchronization with both the Euro Area and the core economies. We conclude that Sweden is the most prepared country to be the next passenger in the single currency train from the perspective of business cycle synchronization.

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Keywords: Euro Area, candidate countries, Hodrick-Prescott filter, business cycle synchronization.

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1. Introduction

According to Mundell (1961), there are four main criteria so that a monetary area can be considered an optimum currency area: i) high labour mobility throughout the area; ii) capital mobility and price and wage flexibility; iii) a currency risk-sharing or fiscal mechanism to share risk across countries in the area, and iv) similar business cycles. Mundell also defined other criteria as a high volume of trade between countries, more diversified production within economies or homogeneous policy preferences across countries. In this work we will focus the research on the study of the business cycle synchronization between seven candidate countries to the Euro Area (EA) – Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania and Sweden – and the Euro Area (EA-12/EA-19) and between these seven candidate countries and the largest two European core economies, i.e., France and Germany.

The Hodrick-Prescott filter is used to decompose the real Gross Domestic Product (GDP) into trend and cyclical components for the period between 1995Q1 and 2019Q4. This methodology is usually applied to the study of business cycle synchronization, as we will see in the following section. Our empirical formulation encompasses four stages. We first analyse the stationary characteristics of the real GDP time-series using the traditional unit root ADF test and the stationarity KPSS test. Second, we proceed to the selection of the most suitable ARIMA model for predictions in order to avoid the so-called end-points problem associated with the use of the Hodrick-Prescott filter. Third, we identify and characterize similar business cycles from real GDP using the Hodrick-Prescott filter. Lastly, we obtain the correlation coefficients as a measure of business cycle synchronization between countries. Our aim is to reveal, from the perspective of business cycle synchronization, which of the seven candidate countries from the European Union are most prepared to ride along with their Euro Area partners.

We explore a relatively recent research topic in the economic literature but of great importance for public decision-makers and economic agents in general, particularly if candidate countries start to share common policies with Euro Area. Our contribution to the literature stems from the fact that this research strategy is conducted for a set of seven candidate countries to the Euro Area for approximately twenty-five years, when most of the work developed so far has focused exclusively on the founding members of the Euro Area for a short period of time before the introduction of the euro. Some exceptions are, e.g., the works developed by Furceri and Karras (2008), Montoya and Haan (2008), Papageorgiu et al. (2010), Crespo-Cuaresma and Fernández-Amador (2013), Gächter and Ried (2014), Santos and Rodrígues (2016) and Borowiec (2020), that evaluate the patterns of cyclical convergence in European countries for relatively long periods before and after the adoption of the single European single currency. One of the main findings of these researchers was that the adoption of the euro had significantly increased the correlation of business cycles. Even so, the results also suggest the existence of some divergence during the period of the financial crisis and economic recession that happened in 2008-2011.

Our empirical results point to the existence of a relatively strong business cycle correlation between Sweden and the Euro Area, Germany, and France, followed by the Czech Republic, Hungary, Poland and Croatia. In contrast, Bulgaria and Romania show the weakest business cycle similarities with both the Euro Area and the core economies. From the perspective of business cycle synchronization, everything seems to indicate that Sweden is the most prepared country to be the next passenger in the single European currency train.

The paper is organized in five sections. Besides introduction, section 2 sets the stage by briefly reviewing the business cycle synchronization literature. In section 3, we describe the data and the methodology used. Section 4 studies the stationarity characteristics of the series, selects the most suitable ARIMA model, applies the Hodrick-Prescott filter and analyses the business cycles and the correlation coefficients of the cyclical components of the real GDP. Finally, section 5 concludes.

2. Literature review

Dating business cycles and business cycles synchronization between countries is a relatively recent research topic in the economic literature, but of enormous importance particularly for candidate countries to the Euro Area. If these countries wish to integrate a large currency area like the Euro Area, before doing so, they must share not only a common set of policies with its member-countries, but also a high degree of business cycle synchronization.

Wesley Mitchell, founder of the National Bureau of Economic Research (NBER) in 1929, was the pioneer in the development of empirical work for measuring business cycles by dating peaks and troughs for the United States economy. Together with Arthur Burns, in 1946, Wesley Mitchell defined business cycles as *"(…) a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; in duration, business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximately their own."* (Burns and Mitchell, 1946, p. 3).

This definition has implicitly two types of business cycles, the so-called "classic business cycle" and the "growth cycle". The classic cycle refers to alternating periods of contraction and expansion, while the growth cycle refers to interleaved periods of acceleration and deceleration of economic activity. Therefore, dating the peaks and troughs does not necessarily have to coincide in these two types of cycles. While in the classical cycle the identification of peaks and troughs is based on the level of economic activity, in the growth cycle it is fundamentally based on the analysis of deviations from a long-run trend. In this context, it can be said that classic cycles are susceptible to a clearer measurement, whereas growth cycles imply a decomposition into its two unobservable components, the trend component and the cyclical component, which means that these are dependent on the method used to identify that trend (Rua, 2017).

In this work we will focus our research on the study of economic growth (recession) cycles using the Hodrick-Prescott filter. This methodology is usually applied to the study of business cycles synchronization between the Euro area member-countries, although we can also find a few other ways of analysing the similarities of business cycles and the joint movements of real GDP for other countries or regions. Several researchers also refer to a "world business cycle" and, assuming from the beginning that this cycle exists, estimate it and calculate its importance in explaining country specific movements. Some examples are the works of Cogley and Nason (1995), Gregory et al. (1997), Kaiser and Maravall (1999), Bonfim and Neves (2002), Lumsdaine and Prasad (2003), Mansour (2003), Canova et al. (2004), Aguiar-Conraria and Soares (2011), Bruzda (2011), Rua (2012), Tatomir and Popovic (2013), Miles and Vijverberg (2018), Umulisa and Habimana (2018), Si et al. (2019) and Duarte and Silva (2020), which in addition of using the filter approach, also use, e.g., VAR and Markov switching models or the wavelets methodology.

The vast majority of studies on business cycles synchronization using the Hodrick-Prescott filter were published after the introduction of the European single currency on 1 January 1999. The generality sought to examine retrospectively whether the member-countries of the Euro Area are correlated with each other, or whether their synchronization has increased precisely because of the use of the European single currency. We can also find some works on business cycle synchronization between the candidate countries and the member-countries of the Euro Area, but just few have carried out their empirical analysis considering both the period before and after the introduction of the European single currency. A relevant literature also focused its attention on analysing the impact of the recent financial and sovereign debt crises on the increasing convergence process observed in the Euro Area, particularly after the biggest European Union (EU) enlargement to the East in 2004. In this line of research we find, e.g., Santos and Rodrígues (2016), Ertürk et al. (2017) and Kovačić and Vilotić (2017), which concluded that there was a weakening in the Euro Area business cycle correlation during the crisis, and that the correlations also declined even during the post-crisis period.

However, as highlighted by Camacho et al. (2006), the standard paradigm used in the economic literature on business cycle synchronization is the so-called core and periphery scheme, namely to describe the supposed existence of an "European business cycle" (Darvas and Szapáry, 2004). Some countries, which exhibit higher synchronization are typically situated in the business cycle core, whose cycle is recognized as the representation of the 'European business cycle'. The "peripheral" countries are situated around this core and represent economies with more idiosyncratic business cycles.

One of these works was developed by Ormerod (2002), which studied the business cycle synchronization in the core economies of the EU (France, Germany, Italy, and the Netherlands), plus the large economy of Spain, which did not join the EU until 1982 but was a founder member of the Euro, and the United Kingdom (UK), a member of the EU since 1973, that did not join the Euro and has been consistently the least supportive of ideas of further European integration. Using the annual rates of real GDP growth on a quarterly basis over the period 1978Q1-2000Q3, the author found that the business cycle synchronization between the core countries was strong over the whole period. The correlations between the growth rates of France, Germany, Italy, and the Netherlands are stable over time and become even stronger after the signing of the Maastricht Treaty in 1992. Even in the late 1970s and early 1980s, these economies moved together closely over the course of the business cycle. There was a slight loosening at the time of German re-unification, but after this event these economies are even more closely correlated. The Spanish economy also converged with the core countries in terms of its movements over the business cycle. In contrast, the results obtained with a data set of the EU core plus the UK show no such trend. In the late 1970s and early 1980s, the UK economy did exhibit some degree of correlation with those of the EU core countries. However, there is no clear evidence to suggest that the UK business cycle has moved more closely in line with that of the core EU economies over the 1978-2000 period. This result seemed to anticipate the recent decision of the UK to leave the EU, the so-called BREXIT.

Aguiar-Conraria and Soares (2011) also divided European countries into core and "peripheral" to investigate the existence of business cycle synchronization using for this purpose the wavelets methodology. The database consists of twenty-seven member-countries of the EU for the period between July 1975 and May 2010. Surprisingly, the authors found out that it is the French business cycle, not the German business cycle, which has been leading the European cycle. Also, business cycles of Portugal, Greece, Ireland, and Finland do not show statistically relevant degrees of synchronization with the EA-12. Among non-Euro Area members, Denmark is highly synchronized with the Euro Area. On the other hand, among the countries which accessed EU in 2004, the most synchronized is the Czech Republic, which seems according to this criterion the most promising candidate to join it. Also interesting is the finding that countries which already adopted the euro – Cyprus and Slovakia –, and that are not very aligned with the Euro Area.

Focusing the attention on the analysis of the synchronization of business cycles between the candidate countries and the Euro Area, Darvas and Szapáry (2004) use in turn the Hodrick-Prescott filter and the Band-Pass filter to study the similarities of business cycles over the period 1993-2002 in eight new EU members from Central and Eastern European countries (CEECs), for which the next step to be considered in the integration process was the entry into the European Monetary Union (EMU). In contrast to the usually analysed GDP and industrial production data, Darvas and Szapáry (2004) extend their analysis to the major expenditure and sectoral components of GDP, concluding that Hungary, Poland and Slovenia have achieved a high degree of synchronization with the EMU for GDP, industrial production and exports, but not for consumption and services. The other CEECs have achieved less or no synchronization, as was the case in the Baltic countries. It was also detected a significant increase in the synchronization of GDP and its major components in the EMU members since the start of the run-up to EMU, which is good news for the pursuit of common monetary policy. In contrast, the "peripheral" countries (Finland, Ireland, Portugal, and Spain) exhibit lower level of synchronization, particularly for consumption and services.

Following a similar line of research, Traistaru (2004) also investigated the degree of business cycles synchronization between the candidate countries and the Euro Area, having also analysed the similarity of economic structures and bilateral trade intensity as main transmission channels. Considering the period from 1990 to 2003 and using also Band-Pass filtered GDP data, the author found that business cycles between the Central European new EU countries (CE-EU-8) and current Euro Area members are less correlated in comparison to the current Euro Area members. In the group of the CE-EU-8 countries, Hungary, Poland and Slovenia were closer correlated with the economic activity fluctuations in the current Euro Area members. The empirical analysis of Traistaru (2004) also indicates that the similarity of economic structures and bilateral trade intensity were positively and significantly associated with business cycles correlations, suggesting that, to the extent that shocks are country-specific, a common monetary policy might have asymmetric effects in a rushed extended Euro Area to the new EU members. Similar results were found by Siedschlag (2010) when analysing the bilateral correlation of business cycles between the eight countries which access to the EU in 2004 and the EA-10 over the period 1990-2003. New EU-8 countries and the EA-10 have significant asymmetries. Among these countries, average correlations of business cycles with the Euro Area were the highest in the cases of Poland, Slovenia, and Hungary. This result is also similar to the findings of Artis et al. (2003) and Darvas and Szapáry (2004). Authors argue that new EU-8 member countries had lower bilateral trade and less similar economic structure. Their results also suggested that similarity in economic structure and bilateral trade intensity were positively and significantly associated with the correlations of business cycles.

Beck (2013) goes even further in the study of business cycles synchronization (measured by average correlation coefficient of GDP growth rates) in the Euro Area and the EU by introducing in his analysis a broader set of determinants, namely the international trade, the structure of the economy, specialization, convergence and participation in the monetary union. The dataset cover the period over 1991-2011. The results suggest that business cycles synchronization is tighter in the Euro Area then in the EU, but its changes over time exhibit the same tendencies. Due to the monetary integration and increases in international trade, business cycles synchronization has been rising. But in the case of structure similarities of the economy, European countries tend to be less and less similar over time. Moreover, real convergence has a positive impact on economies specialization and structure divergence, particularly in the Euro Area, and lack of trade barriers and the European single currency may have a positive impact on business cycle synchronization. On the other hand, it also has a strong positive impact on specialization, which leads to a lower portion of intra-industry trade in overall trade and further structure divergence.

A broader cross-country research on business cycle co-movements was developed by Camacho et al. (2006), which investigate the eventual existence of a business cycle attractor in the Euro Area. The sample of countries includes all member countries of the EU, Romania, Turkey, Canada, USA, Norway and Japan. Using quarterly seasonally adjusted industrial production for the period 1962Q1-2003Q1, the authors show that there is no evidence of a 'European economy' that acts as an attractor to the other economies of the area. The establishment of the EMU has not significantly increased the degree of co-movements across Euro Area member countries. Nevertheless, Camacho et al. (2006) confirmed that the business cycles of the Euro Area countries are more closely linked than the business cycles of the new members. The differences among the new members and the old members seem to be much more important than the differences that the founding members of the Euro Area exhibited prior to the establishment of the EMU.

Afonso and Furceri (2008) have also not concluded that the European single currency strengthens the synchronization of the business cycles in the Euro Area as a whole. Analysing macroeconomic costs determinants of joining EMU for the new EU member states, and comparing them with those of the EMU members, the authors investigate the business cycle correlation between the candidate countries and the Euro Area, and the ability of insurance mechanisms and fiscal policies to smooth income fluctuations. The dataset covers twenty-eight member of the EU for the period between 1980 and 2005. The results suggest that EMU membership would not be costly for Cyprus, Hungary and Malta, but for other countries it could have relevant costs, at least in the short-run. For some of these countries (e.g., Estonia, Lithuania, and Slovakia), business cycles are not yet well synchronized with the Euro Area's business cycle, and risk-sharing mechanisms do not provide enough insurance against shocks. Negative correlations vis-à-vis the EMU-wide business cycle are also exhibited by two of the three prospective EU members (Romania and Turkey).

To end this literature review, is it also important to mention the interesting findings recently obtained by Adamec (2018), which investigates business cycle synchronization between countries of the so-called Visegrad group, Euro Area, and Germany, as a core economy. Using quarterly GDP data, seasonally and calendar adjusted for the period 1995Q1-2016Q4, Adamec (2018) applied the Hodrick-Prescott filter to broken down GDP to trend and cyclical components to obtain the relative output gap. Results suggest that before 2004, the period previous to the biggest enlargement of the EU, a few business cycles were weakly correlated, many of them were not correlated, and some were even negatively correlated. After this EU enlargement, business cycles became closely synchronized between countries in Visegrad group as well as between the Visegrad group and the Euro Area or Germany. The only exception was Hungary, which showed lower degree of business cycle synchronization with many other EU countries due essentially to prolonged economic havoc. Given this results, the author ends up suggesting that candidate countries should work consciously in order to establish a stable place in the Euro Area club.

3. Methodology and data description

For the analysis of business cycle synchronization, we use the Hodrick-Prescott filter methodology (Hodrick and Prescott, 1997)[3]. With this method we are able determine the cyclical component of the GDP for each country under research. This filter enables us to decompose a time series, in our case the values of real GDP, into two time series. The first time series is the so-called trend component of the GDP, the second one corresponds to the cyclical or random part of the original values, the so-called cyclical component of the GDP:

$$y_t = \tau_t + C_t \tag{1}$$

where y_t is the time series of original values of GDP, τ_t is the trend component and C_t refers to the cyclical component extracted through the Hodrick-Prescott filter. The cyclical component is thus the difference between the original GDP and its trend component. For this purpose, we can extract the trend component by minimizing the following equation:

$$\min\{\sum_{t=1}^{T}(y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1}[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2\} \tag{2}$$

with $t = 1,2,\ldots T$. The first term of equation (2) is the sum of the square of deviations between the values of the original series and the respective values of the trend series, thus representing a measure of the degree of adjustment. The second term is the sum of the square of the second difference between the trend component, indicating a degree of smoothing. The smoothing parameter, λ, controls the variations in the trend component's growth rate and should therefore assume positive values.

For the particular case of $\lambda = 0$, the original series would be equal to the series trend. In turn, the greater the value of the smoothing parameter, the more smoothed

[3] In this section we follow very closely Duarte and Silva (2021).

will be the trend component extracted by the Hodrick-Prescott filter. At the limit, for values of λ close to infinity, the solution of this problem will correspond to the least squares fit of a linear time trend model of the type $y_t = \alpha + \delta_t + \varepsilon_t$, where α is a drift, δ_t is the trend component and ε_t is a residual, meaning that the trend will approach from a straight line.

The value adopted for the smoothing parameter λ is the critical element associated with the use of this filter. Hodrick and Prescott (1997, p. 6) draw attention to the fact that any filter can change the serial correlation properties of the data, which should be interpreted with caution. The suggested values for the smoothing parameter λ for annual, quarterly and monthly data are, respectively, 400, 1600 and 6400. Canova (1998, p. 485) states that the value of λ is debatable, having investigated the issue for quarterly data with λ=1600. In our study, we have used $\lambda = 1600$ as the value for the smoothing parameter, suggested by Gretl software, as appropriate to work with quarterly data.

The data were taken from Eurostat database. We downloaded Gross Domestic Product at market prices – chain-linked volumes with the reference year 2015. The data are expressed in million euros, and they are seasonally, and calendar-adjusted at the quarterly frequency. As we said before, our main aim is to examine the business cycle synchronization between the candidate countries to the Euro Area and the Euro Area as well as with the two European core economies, i.e., France and Germany. The group of candidate countries includes all countries that are member states of EU, but are not part of Euro Area. The sample with candidate countries includes: Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, and Sweden. We analysed the EA-12, which contains the 12 founding members of the Euro Area, and it is referring to the Euro Area in the years 2001-2006. We also analysed the EA-19, which includes the 19 current members of the Euro Area. This is referring to Euro Area from the year 2015. We used data for the longest period available. The first observations are from the first quarter of 1995. Due to the strong disturbances in terms of GDP growth caused by the current Covid-19 pandemic, we decided exclude observations for the available the year of 2020. According to that, our dataset ends with the fourth quarter of 2019. Not all data were available for all selected countries. The exception with incomplete data is the Czech Republic, which has data available only from first quarter 1996. To solve this problem, data from 1996 were used to extrapolate the missing values in the year of 1995. This means, that the value corresponding to the first quarter of 1995 was obtained considering the same value of the first quarter 1996. We repeated this same process also to for the second, the third and the fourth quarter of 1995, respectively.

Table 1 presents the description of variables.

Table 1: Description of variables

Variable	Description of variable
GDP_EA12	Euro Area consisting of 12 original member states - Gross Domestic Product, constant prices
GDP_EA19	Euro Area consisting of 19 actual member states - Gross Domestic Product, constant prices
GDP_Bul	Bulgaria - Gross Domestic Product, constant prices (2015)
GDP_Cro	Croatia - Gross Domestic Product, constant prices (2015)
GDP_Cze	Czech Republic - Gross Domestic Product, constant prices (2015)
GDP_Fra	France - Gross Domestic Product, constant prices (2015)
GDP_Ger	Germany - Gross Domestic Product, constant prices (2015)
GDP_Hun	Hungary - Gross Domestic Product, constant prices (2015)
GDP_Pol	Poland - Gross Domestic Product, constant prices (2015)
GDP_Rom	Romania - Gross Domestic Product, constant prices (2015)
GDP_Swe	Sweden - Gross Domestic Product, constant prices (2015)

Source: Eurostat database.

Note: According to the National accounts indicator (ESA 2010) the variable is Gross Domestic Product at market prices. Unit of measure is Chain linked volumes (2015) million euro. Time frequency is quarterly, and data are seasonally and calendar adjusted.

4. Results

In this section, we first analyse the stationary characteristics of the real GDP time-series and proceed to the selection of the most suitable ARIMA model in order to avoid the so-called end-points problem. Then, we identify and characterize the business cycles in the seven candidate countries, the two core economies, and the Euro Area (EU-12/EU-19) using the Hodrick-Prescott filter. Finally, we obtain the correlation coefficients of the cyclical components of real GDP as a measure of business cycle synchronization between countries and regions.

4.1. Stationarity characteristics of the series

For the analysis of the stationarity characteristics of the real GDP of the nine countries and the aggregate real GDP of the EA-12 and EA-19 we used the traditional unit root and stationarity tests, respectively, the Augmented Dickey-Fuller test, usually known as ADF test (Dickey-Fuller, 1979), and the Kwiatkowski-Phillips-Schmidt-Shin test, well-known as KPSS test (Kwiatkowski et al. 1992). Both the ADF and KPSS tests were implemented considering the logarithm of the variables. Moreover, since we use quarterly data, seasonal adjustments were included in the analysis. Table 2 presents the results of standard ADF and KPSS tests on log-values and first differences of log-values of real GDP (logarithmic rates of change of real GDP) for the seven EU candidate countries to the Euro Area, the EA-12 and EA-19, and the two core economies.

Table 2: Unit root and stationarity tests (1995Q1-2019Q4)

	ADF				KPSS			
	Level		Fist Difference		Level		First Difference	
	T	C	C	NC	T	C	T	C
l_GDP_EA12	-2.204	-1.597	-4.955***	-4.054***	0.366***	1.899***	0.105	0.265
l_GDP_EA19	-2.207	-1.572	-4.934***	-4.019***	0.366***	1.905***	0.104	0.259
l_GDP_Bul	-3.469**	-0.718	-2.049	-1.454	0.162**	1.956***	0.059***	0.060
Δ_l_GDP_Bul	-	-	-3.177**	-3.222***	-	-	0.053***	0.100
l_GDP_Cro	-2.041	-1.484	-2.597*	-2.244**	0.403***	1.692***	0.161**	0.442*
Δ_l_GDP_Cro	-	-	-8.77***	-8.82***	-	-	0.0208	0.021
l_GDP_Cze	-2.303	-0.018	-4.551***	-3.611***	0.183***	2.014***	0.134*	0.152
l_GDP_Fra	-2.321	-2.302	-3.93***	-2.614***	0.415***	1.955***	0.095	0.402*
l_GDP_Ger	-3.809**	-0.494	-7.845***	-4.583***	0.109	2.014***	0.032	0.032
l_GDP_Hun	-1.426	-0.525	-5.97***	-1.407	0.312***	1.86***	0.194***	0.189
l_GDP_Pol	-3.399*	-1.171	-12.78***	-1.95**	0.192***	2.097***	0.080	0.181
l_GDP_Rom	-3.034	0.173	-2.88**	-2.21**	0.140*	2.007***	0.115	0.182
l_GDP_Swe	-2.216	1.973	-5.41***	-1.29	0.337***	2.029***	0.042	0.155

Source: Authors, using the research database of Eurostat.
Notes: The number of lags included in the test regressions was chosen according to the AIC criterion. "T" identifies tests ran with a constant and a trend. "C" identifies tests ran with only a constant. "NC" identifies tests ran without a deterministic term. "Δ" identifies the first difference of the series. The null

hypothesis of the ADF test is the existence of a unit root, while for KPSS under the null the series is (trend-) stationarity. Significance at the 1%, 5% and 10% levels is denoted by "***", "**" and "*", respectively.

According to this analysis we can conclude that only the log-value of real GDP of two countries, Bulgaria and Croatia, need a second differentiation to become stationary. All other logarithmic variables require only a single differentiation to be stationary. In other words, with the exception of the series corresponding to Bulgaria and Croatia, which are I(2), all other series are I(1).

4.2. ARIMA model selection

Once analysed the stationarity characteristics of real GDP series, the next step in our research is to eliminate the so-called end-points problem associated with the use of the Hodrick-Prescott filter. This filter tends to underestimate the cyclical component of the variables, so it is necessary to correct this problem by adding observations to the original series, using forecast models for this purpose, as is the case with the Autoregressive Integrated Moving Average (ARIMA) model. Since we are using data with quarterly frequency we forecast twelve values for each series as suggested by Sorensen and Whitta-Jacobsen (2010). So, each series of the GDP will come with twelve new observations.

For the selection of the most appropriate ARIMA model, we will choose the minimum value of the Schwarz information criterion (BIC)[4]. In the previous section, we have identified the order of the integration (d) for all variables. We conclude that for Bulgaria and Croatia, the order was 2, and for the other economies (d) was 1. Hence, it is still necessary to determine the other two components of the ARIMA model – the autoregressive (AR) and the moving average (MA) model. In this selection, for both cases (series that are I(1) and series I(2)) we have considered nine possible combinations. The results of this analysis are shown in Table 3.

[4] Similar to what was done in the analysis of stationarity, seasonal adjustments were also included in the selection of the most appropriate ARIMA model.

Table 3: ARIMA Model Selection – some possible combinations

Variable	ARIMA Model Selection (AR, d, MA) Schwarz information criterion (BIC)								
I(1)	(0,1,0)	(1,1,0)	(0,1,1)	(1,1,1)	(2,1,0)	(0,1,2)	(2,1,2)	(2,1,1)	(1,1,2)
GDP_EA12	-735.5	-772.9	-760.6	-768.4	-768.4	-764.8	-760.4	-763.9	-764.1
GDP_EA19	-733.7	-771.6	-759.3	-767.2	-767.2	-763.5	-759.1	-762.7	-762.9
GDP_Cze	-660.2	-708.4	-692.5	-703.9	-703.9	-696.5	-694.9	-699.4	-699.5
GDP_Fra	-775.6	-808.3	-793.5	-805.9	-807.2	-807.7	-801.8	-803.6	-806.3
GDP_Ger	-657.1	-657.3	-656.1	-653.8	-654.6	-654.3	-656.9	-650.0	-650.2
GDP_Hun	-634.4	-653.6	-649.7	-649.6	649.3	-646.6	-643.9	-645.9	-646.1
GDP_Pol	-576.4	-578.6	-580.1	-575.5	-577.3	-575.5	-579.2	-572.9	-571.0
GDP_Rom	-547.4	-554.8	-551.6	-552.9	-552.9	-552.7	-557.8	-548.4	-549.1
GDP_Swe	-661.2	-667.2	-664.2	-665.7	-666.8	-663.9	-673.7	-662.6	-669.4
I(2)	(0,2,0)	(1,2,0)	(0,2,1)	(1,2,1)	(2,2,0)	(0,2,2)	(2,2,2)	(2,2,1)	(1,2,2)
GDP_Bul	-354.1	-410.4	-410.5	-411.5	-414.3	-409.9	-412.3	-411.0	-409.9
GDP_Cro	-509.3	-545.2	-564.9	-562.2	-553.6	-562.0	-555.8	-557.8	-556.8

Source: Authors, using the research database of Eurostat.

As can be observed, according to the nine possible combinations considered to select the most appropriate ARIMA model, the order of the autoregressive process (AR) and the moving average (MA) was never greater than 2. As we said before, we have chosen the lowest value of the Schwarz information criterion (BIC), which will correspond to the selected ARIMA model. Results of these selection are summarized in Table 4.

Table 4: ARIMA Model Selection – summary results

Variable	ARIMA Model Selection (AR, d, MA) Schwarz information criterion (BIC)								
I(1)	GDP_EA12 (1,1,0)	GDP_EA19 (1,1,0)	GDP_Cze (1,1,0)	GDP_Fra (1,1,0)	GDP_Ger (1,1,0)	GDP_Hun (1,1,0)	GDP_Pol (0,1,1)	GDP_Rom (2,1,2)	GDP_Swe (2,1,2)
I(2)	GDP_Bul (2,2,2)	GDP_Cro (0,2,1)							

Source: Authors, using research database of Eurostat.

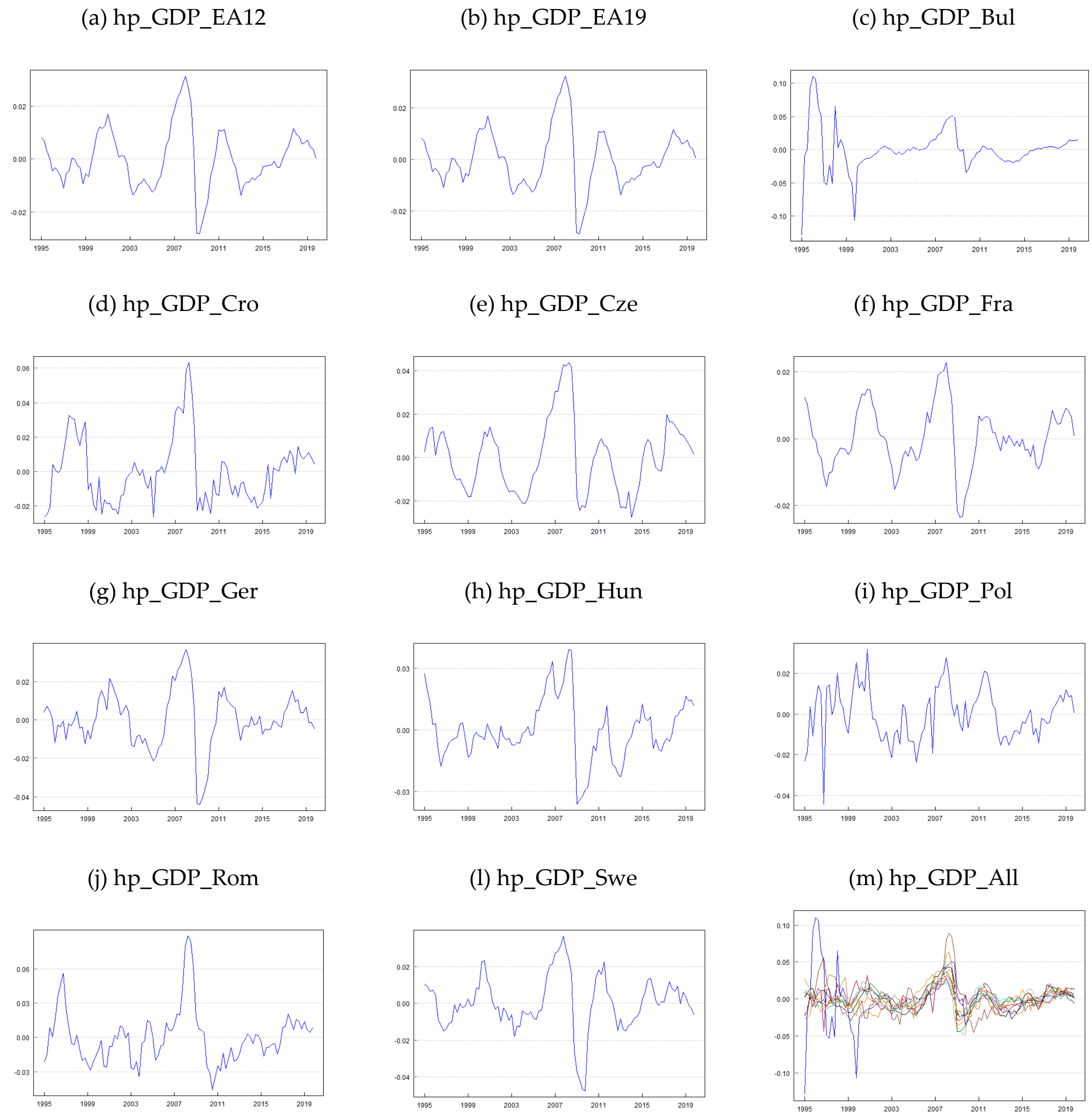
As can be seen, among the economies whose series are I(1), the analysis of the minimum value of the Schwarz information criterion pointed to the choice of an ARIMA forecasting model (1,1,0) for the EA-12, EA-19, Czech Republic, France, Germany, and Hungary. On the other hand, for Poland, we choose an ARIMA model (0,1,1), and for Romania and Sweden the most suitable model was an ARIMA model (2,1,2). Finally, for Bulgaria and Croatia, which real GDP series are I(2), it was selected an ARIMA model (2,2,2) and an ARIMA model (0,2,1), respectively.

Having already eliminated the end-point problem by estimating the twelve new observations using these forecasting models, we are now in conditions to proceed with the application of the Hodrick-Prescott filter to determine the cyclical component of real GDP. The cyclical component allows us to identify and characterize the various business cycles for each of the economies considered in this study, as well as to assess the degree of synchronization between them. Both analyses are performed in the following two sections.

4.3. Dating business cycles

After choosing the most appropriate ARIMA forecasting model, measuring the business cycle chronology became our main goal. In order to proceed with the business cycle identification and characterization, the cyclical components of real GDP were then determined by applying the Hodrick-Prescott filter methodology to the added series (original series plus the twelve observations estimated by the ARIMA model). Figure 1 shows the cyclical components of real GDP for the eleven economies considered in this study – graphs (a) to (l) –, as well as for all the series – graph (m).

Figure 1: Cyclical components of the real GDP



Source: Authors, using research database of Eurostat.

Since our analysis is based on quarterly data, following the suggestions of Hodrick and Prescott (1997), Canova (1998), Ravn and Uhlig (2002) and Dimsdale and Thomas (2019), we chose the value of λ=1600 for the smoothing parameter of the so-called trend component of the real GDP. Applying the Hodrick-Prescott filter we first obtained the trend component of real GDP. Then it was possible to calculate the cyclical components of the real GDP by taking the difference between the trend component and the current GDP.

On the other hand, Table 5 gives a more accurate account of the dating of the various business cycles identified in EA-12, EA-19, Bulgaria, Croatia, Czech Republic, France, Germany, Hungary, Poland, Romania and Sweden in the period from 1995Q1 to 2019Q4, as well as their duration and different phases (expansion vs. recession). We refer specifically to the identification of peaks and troughs in the cyclical component of the real GDP.

Following Burns and Mitchell (1946), business cycles were defined from trough to trough. We can thus identify six economies with four cycles (EA-12, EA-19, France, Germany, Poland and Sweden), three economies with five cycles (Croatia, Czech Republic and Hungary) and two countries (Bulgaria and Romania) with only three cycles. The longest cycle was precisely detected in one of these countries – Bulgaria – with a duration of forty quarters, divided into an expansion phase of thirty-five quarters, from 1999Q4 to 2008Q3, and a recession of five quarters, which was observed after the financial crisis of 2008, specifically between 2008Q3 and 2009Q4. This situation is similarly to what happened in other countries. In fact, everything seems to indicate that the international financial crisis of 2008 has affected all economies in a similar way, including the core economies, so in this perspective we expect some business cycle synchronization between the candidate countries and the Euro Area, as well as with France and Germany. In turn, the shortest cycle was detected for the Czech Republic between 2014Q1 and 2016Q4, thus having a duration of only eleven quarters.

The highest growth cycles happened in Poland (between 2013Q1 and 2019Q4), Bulgaria (from 1999Q4 to 2009Q4) and Hungary (between 2005Q1 and 2009Q1). On the other hand, the biggest slowdown in economic activity took place in Croatia (between 2014Q3 and 2019Q4) and Romania (from 1999Q2 to 2003Q4). Sweden is a curious case, with expansion phases of relatively similar duration as the recession phases, something that also happened in the EA-12 and EA-19, especially in the first part of the sample, a situation which may indicate the existence of a resilient business cycles synchronization between these economies.

A joint comparative analysis of the cyclical components of the real GDP of all countries is shown in Table 5. The results point to the existence of a strong business cycle synchronization between Sweden and the Euro Area (EA-12 and EA-19), Germany and France, followed by Czech Republic, Hungary, Poland and Croatia. In the opposite direction, we find Bulgaria and Romania, which seem to have the weakest business cycle synchronization with both the Euro Area and the core economies.

Table 5: Business cycles identification using Hodrick-Prescott filter

Country	Trough	Peak	Trough	Expansion (A)	Recession (B)	Cycle (A+B)	A/B
EA_12	1997 Q1	2001 Q1	2005 Q1	16	16	32	1
	2005 Q1	2008 Q1	2009 Q1	12	4	16	3
	2009 Q1	2011 Q3	2013 Q1	10	6	16	1,66
	2013 Q1	2017 Q4	2019 Q4	19	8	27	2,375
EA_19	1997 Q1	2001 Q1	2005 Q1	16	16	32	1
	2005 Q1	2008 Q1	2009 Q1	12	4	16	3
	2009 Q1	2011 Q3	2013 Q1	10	6	16	1,66
	2013 Q1	2017 Q4	2019 Q4	19	8	27	2,375
Bulgaria	1997 Q2	1998 Q1	1999 Q4	3	7	10	0,428
	1999 Q4	2008 Q3	2009 Q4	35	5	40	7
	2009 Q4	2011 Q2	2014 Q1	6	11	17	0,545
Croatia	1995 Q2	1998 Q4	1999 Q4	14	4	18	3,5
	1999 Q4	2003 Q2	2005 Q1	14	7	21	2
	2005 Q1	2008 Q2	2009 Q1	13	3	16	4,33
	2009 Q1	2011 Q3	2014 Q3	10	12	22	0,833
	2014 Q3	2015 Q3	2019 Q4	4	17	21	0,235
Czech Republic	1999 Q2	2001 Q1	2004 Q2	7	13	20	0,534
	2004 Q2	2008 Q2	2009 Q2	16	4	20	4
	2009 Q2	2011 Q2	2014 Q1	8	11	19	0,727
	2014 Q1	2015 Q3	2016 Q4	6	5	11	1,2
	2016 Q4	2017 Q2	2019 Q4	2	10	12	0,2
France	1997 Q1	2001 Q1	2003 Q2	16	9	25	1,78
	2003 Q2	2008 Q1	2009 Q2	19	5	24	3,8
	2009 Q2	2011 Q1	2016 Q3	7	22	29	0,318
	2016 Q3	2017 Q4	2019 Q4	5	8	13	0,625
Germany	1998 Q4	2001 Q1	2005 Q1	9	16	25	0,563
	2005 Q1	2008 Q1	2009 Q1	12	4	16	3
	2009 Q1	2011 Q3	2013 Q1	10	6	16	1,67
	2013 Q1	2017 Q4	2019 Q4	19	8	27	2,375
Hungary	1996 Q3	1998 Q3	2005 Q1	8	26	34	0,307
	2005 Q1	2008 Q3	2009 Q1	14	2	16	7
	2009 Q1	2011 Q4	2013 Q1	11	9	20	1,222
	2013 Q1	2015 Q1	2016 Q4	8	7	15	1,143
	2016 Q3	2019 Q1	2019 Q4	10	3	13	3,333
Poland	1996 Q4	2000 Q4	2005 Q2	16	18	34	0,889
	2005 Q2	2008 Q1	2009 Q3	11	6	17	1,833
	2009 Q3	2011 Q3	2013 Q1	8	6	14	1,333
	2013 Q1	2019 Q1	2019 Q4	24	3	27	8
Romania	1999 Q2	2000 Q2	2003 Q4	4	14	18	0,286
	2003 Q4	2008 Q2	2010 Q3	18	9	27	2
	2010 Q3	2013 Q4	2016 Q3	13	11	24	1,181
Sweden	1996 Q4	2000 Q3	2003 Q2	15	11	26	1,363
	2003 Q2	2007 Q4	2009 Q4	18	8	26	2,25
	2009 Q4	2011 Q3	2013 Q3	7	8	15	0,875
	2013 Q3	2015 Q4	2019 Q4	9	16	25	0,562

Source: authors, using the research database.

Although this analysis allows us to have a first glance at the joint movements between the cyclical components of real GDP and, therefore, a possible synchronization between the different business cycles of the economies, the analysis can, however, be complemented with a more particular examination of the values of the correlation coefficients of the cyclical components of real GDP. We develop this task in the following section.

4.4. Business cycles synchronization

The business cycles synchronization developed in this study was carried out by calculating the correlation coefficients between the cyclical components of real GDP between the seven candidate countries and the Euro Area (EA-12/EA-19) and between France and Germany, as shown in Table 6.

Table 6: Correlation coefficients between cyclical components of the real GDP

	EA_12	EA_19	France	Germany
Bulgaria	0.1945*	0.1995**	0.0942	0.1839*
Czech Republic	0.8473***	0.8499***	0.7051***	0.7433***
Croatia	0.4644***	0.4768***	0.2686***	0.4340***
Hungary	0.7075***	0.7145***	0.7012***	0.6359***
Poland	0.5038***	0.5033***	0.4452***	0.3947***
Romania	0.3539***	0.3629***	0.2503**	0.3309***
Sweden	0.8642***	0.8637***	0.8274***	0.8108***

Source: authors, using the research database.
Notes: As usual, "*", "**" and "***" are the 10%, 5% and 1% significance levels of the correlation coefficients, respectively.

As can be seen, the strongest relationship measured in our analysis is between Sweden and EA-12 (Euro Area founding member countries), with a correlation coefficient of 0.8642 for a significance level of 1%. Sweden also shows high business cycle synchronization with EA-19 (Euro Area current member countries), with a very similar value for the correlation coefficient (0.8637), a situation observed in a similar way for all the other candidate countries since the results point to small differences between the EA-12 and the EA-19. This last result is interesting and could also be interpreted as an indicator of great synchronization within the Euro Area members, an aspect that did not guide our main research objective, but which our results still seem to suggest. Regarding the core countries, it appears that Sweden has also a strong business cycle correlation with both of these economies, although somewhat less pronounced with Germany, with a correlation coefficient 0.8108, while with France it is 0.8274, but in both cases for a significance level of 1%. In this context, from the perspective of business cycle synchronization, everything seems to suggest that Sweden is the most prepared candidate country to be the next passenger in the single European currency train.

Still showing a strong correlation of their cyclical components of the real GDP and, therefore an eventually high business cycle synchronization with both the Euro Area and the core economies, we also find Czech Republic and Hungary. In fact, the second highest correlation with the Euro Area (EA-12/EA-19), France and Germany is observed for the Czech Republic followed by Hungary, Poland and Croatia, although in the case of these last two countries the degree of synchronization of their cyclical components can already be considered relatively moderate.

On the other hand, Bulgaria and Romania show the weakest business cycle synchronization with both the Euro Area and the core economies. This finding suggests that in the coming years these two candidate countries will have to run even a little further to get into the carriage of the single European currency. Even so, Romania appears to be slightly better positioned when compared to Bulgaria, with a correlation coefficient of 0.3629 with the EA-19 and a correlation coefficient of 0.2503 and 0.3309 with France and Germany, respectively. The weakest relationship can be seen in the case of Bulgaria, particularly against France, with a correlation coefficient value of only 0.0942, although not statistically significant. In addition to its low synchronization with the other economies, Bulgaria is also the only country for which the degree of business cycle correlation with the Euro Area and Germany is just verified for a significance level of 10%.

A more particular analysis of Table 6, allows us to observe that the cyclical components of the real GDP of three of the seven candidate countries (Hungary, Poland and Sweden) are more synchronized with France than with Germany as a core economy. This result is very intriguing if we take into account the fact that the German economy is usually considered to be the major "locomotive" of economic growth in the European Union. It is also evident that all the candidate countries are relatively more synchronized with the aggregate EA-12 and EA-19 than with either of the two core economies, France or Germany, considered in this study. These results are thus very similar to those found by Ormerod (2002), Darvas and Szapáry (2004), Traistaru (2004), Aguiar-Conraria and Soares (2011) and Adamec (2018), although in some of these works other methodologies of analysis of the business cycle synchronization between countries were used.

5. Conclusion

The aim of this study was to analyse business cycle synchronization between seven candidate countries to the Euro Area – Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania and Sweden – and the Euro Area aggregate (EA-12/EA-19) and between these seven candidate countries and the largest two European core economies – France and Germany – for the period between 1995Q1 and 2019Q4.

We used the Hodrick-Prescott filter methodology to obtain the cyclical component of real GDP of all countries, components from which we dated the business cycles and investigated the existence of synchronization in their behaviour.

Our empirical results point to the existence of a relatively strong business cycle correlation between Sweden and the Euro Area, Germany, and France, followed by the Czech Republic, Hungary, Poland and Croatia. The strongest relationship measured in our analysis was between Sweden and EA-12, with a correlation coefficient of 0.8642 for a 1% significance level. Also, Sweden shows high business cycle synchronization with the core countries, although somewhat less pronounced with Germany. From the perspective of business cycle synchronization, everything seems to indicate that Sweden is the most prepare of the candidate countries to be the next country to join the Euro Area.

In contrast, Bulgaria and Romania showed the weakest business cycle similarities with both the Euro Area and the core economies. The weakest co-movement in the cyclical component of real GDP was observed in the case of Bulgaria, especially between Bulgaria and France, with a correlation coefficient value of only 0.0942, although not statistically significant.

The empirical results also put in evidence that Hungary, Poland and Sweden are more synchronized with France than with Germany, which could suggest that during the period under analysis, the German economy has not exclusively played the role of the European integration process "locomotive". Moreover, candidate countries to the Euro Area seem to be more synchronized with the aggregates EA-12 and EA-19, than with core economies, which could be a good sign that a wider European business cycle could be achieved in the near future.

We consider our analysis as exploratory and the conclusions we have drawn as prospective, since they are supported by a statistical measure for the data set, when the most interesting and advisable would be to measure this same synchronization of economic cycles between countries over (and for) different time horizons, a strategy to be developed in future research.

References

Adamec, Václav (2018), "Synchronization of Economic Cycles in Countries of the Visegrad Group, Germany and Eurozone", *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 66(3): 719-728.

Afonso, António and Davide Furceri (2008), "EMU enlargement, stabilization costs and insurance mechanisms", *Journal of International Money and Finance*, 27(2): 169-187.

Aguiar-Conraria, L. and Soares, M. J. (2011), “Business cycle synchronization and the Euro: A wavelet analysis”, *Journal of Macroeconomics*, 33(3): 477-489.

Artis, Michael; Marcellino, Massimiliano and Tommaso Proietti (2003), “Characterising the Business Cycle for the Accession Countries”, European Forecasting Network, autumn 2003 Report.

Beck, Krzysztof (2013), “Determinants of Business Cycles Synchronization in the European Union and the Euro Area”, *Quarterly Journal of Economics and Economic Policy*, 8(4): 25-48.

Bonfim, Diana and Pedro Duarte Neves (2002), “Comportamento cíclico da economia portuguesa: 1953-1995”, Banco de Portugal, Boletim Económico, 6: 23-40.

Borowiec, Jan (2020), “The convergence and synchronization of business cycles in the European Union and the European Monetary Union”, *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 64(3): 7-20.

Bruzda, Joanna (2011), “Business Cycles Synchronization According to Wavelets - The Case of Poland and the Euro Zone Member Countries”, *Bank I Kredyt*, 42(3): 5-32.

Burns, Arthur F. and Wesley C. Mitchell (1946), Measuring business cycles, National Bureau of Economic Research.

Camacho, Maximo; Perez-Quiros, Gabriel and Lorena Saiz (2006), “Are European business cycles close enough to be just one?”, *Journal of Economic Dynamics and Control*, 30(9-10): 1687-1706.

Canova, Fabio (1998), “Detrending and business cycle facts”, *Journal of Monetary Economics*, 41(3): 475-512.

Canova, Fabio, Ciccarelli, Matteo and Eva Ortega (2004), Similarities and convergence in G7 cycles, CEPR Discussion Paper No. 4534.

Cogley, Timothy and James M. Nason (1995), “Effects of the Hodrick-Prescott Fillter on trend and difference stationary time series Implications for business cycle research”, *Journal of Economic Dynamics and Control*, 19 (1-2): 253-278.

Crespo-Cuaresma, Jesús and Octavio Fernández-Amador, 2013. “Business cycle convergence in EMU: A first look at the second moment”, *Journal of Macroeconomics*, 37(C): 265-284.

Darvas, Zsolts and György Szapáry (2004), “Business Cycle Synchronization in the Enlarged EU: Comovements in the (Soon-To-Be) New and Old Members”, *SSRN Electronic Journal*. DOI: 10.2139/ssrn.508564

Darvas, Zsolts and György Szapáry (2008), Business Cycles Synchronization in the Enlarged EU, *Open Economies Review*, 19(1): 1-19.

Dickey, David and Wayne Fuller (1979), “Distribution of the estimators for autoregressive time series with a unit root”, *Journal of the American Statistical Association*, 74(366): 427-431.

Dimsdale, Nicholas and Ryland Thomas (2019), “Statistical and Econometric Analysis of the Cycle”. In N. Dimsdale and R. Thomas (Eds), *UK Business and Financial Cycles Since 1660*, Palgrave Macmillan, Cham, pp. 35-53.

Duarte, António Portugal and Nuno Baetas da Silva (2020), “Sincronização dos ciclos económicos em alguns países da União Europeia: Uma análise de onduletas”. In A. P. Duarte, M. Simões, P. Bação, and R. Martins (Eds.), *Estudos de Homenagem a João Sousa Andrade*, Almedina, Coimbra, pp. 149-172.

Duarte, António Portugal and Nuno Baetas da Silva (2021), “Exchange Rate Synchronization for a set of Currencies from Different Monetary Areas”, paper presented at the Slovak Economic Association Meeting (SEAM 2021), Online, Nitra, Slovakia, September 2, 2021.

Ertürk, Emin; Yılmaz, Derya and Işın Çetin (2017), “Business Cycle Synchronization in European Economic and Monetary Union (EMU): Testing the OCA during Financial Crisis”, *Ankara Üniversitesi SBF Dergisi*, 4(72): 1157-1183.

Furceri, Davide and Georgios Karras (2008), “Business-cycle synchronization in the EMU”, *Applied Economics*, 40(12): 1491-1501.

Gächter, Martin and Aleksandra Riedl (2014), “One money, one cycle? The EMU experience”, *Journal of Macroeconomics*, 42(C): 141-155.

Gregory, Allan, Head, Allen and Jacques Raynauld (1997), "Measuring world business cycles", *International Economic Review*, 38(3): 677-701.

Hodrick, R. and Prescott, E. (1997), "Postwar U. S. Business Cycles: An Empirical Investigation", *Journal of Money, Credit and Banking*, 29(1): 1-16.

Kaiser, Regina and Agustín Maravall (1999), "Estimation of the business cycle: A modified Hodrick-Prescott filter", *Spanish Economic Review*, 1(2): 175-206.

Kovačić, Zlatko and Miloš Vilotić (2017), "Assessing European business cycles synchronization", MPRA Paper No. 79990, May.

Kwiatkowski, Denis, Phillips, Peter C., Schmidt, Peter and Yongcheol Shin (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root", *Journal of Econometrics*, 54(1-3): 159-178.

Lumsdaine, Robin and Eswar Prasad (2003), "Identifying the common component of international economic fluctuations: a new approach", *Economic Journal*, 113(484): 101–127.

Mansour, Joffrey (2003), "Do national business cycles have an international origin?", *Empirical Economics*, 28(2): 223–247.

Miles, William and Chu-Ping C. Vijverberg (2018), "Did the Euro Common Currency Increase or Decrease Business Cycle Synchronization for its Member Countries?", *Economica*, 85(339): 558-580.

Montoya, Lourdes Acedo and Jakob de Haan (2008), "Regional Business Cycle Synchronization in Europe?", *International Economics and Economic Policy*, 5(1-2): 123-137.

Mundell, Robert (1961), "A theory of optimum currency areas", *The American Economic Review*, 51(4): 657-665.

Ormerod, Paul and Craig Mounfield (2002), "The Convergence of European Business Cycles 1978-2000", *Physica A: Statistical Mechanics and its Applications*, 307(3-4): 494-504.

Papageorgiou, Theofanis; Michaelides, Panayotis G. and John G. Milios (2010), "Business cycles synchronization and clustering in Europe (1960-2009)", *Journal of Economics and Business*, 62(5): 419-470.

Ravn Morten O. and Harald Uhlig (2002), "On adjusting the Hodrick-Prescott filter for the frequency of observations", *Review of economics and statistics*, 84(2): 371-376.

Rua, António (2012), "Wavelets in Economics", Banco de Portugal, Boletim Económico, 6: 71-79.

Rua, António (2017), "Datação dos ciclos económicos em Portugal", Banco de Portugal.

Santos, Sonia and Maria Rodríguez (2016), "Core-Periphery Business Cycle Synchronization in Europe and the Great Recession", *Eastern European Economies*, 54(6): 521-546.

Siedschlag, Iulia (2010), "Patterns and determinants of business cycle synchronization in the enlarged European Economic and Monetary Union", *Eastern Journal of European Studies*, 1(1): 21-44.

Sorensen, Peter Birch and Hans Jørgen Whitta-Jacobsen (2010), *Introducing Advanced Macroeconomics: Growth & Business Cycles*, McGraw-Hill Education, Edinburgh, Berkshire, UK, 2nd edition.

Tatomir, Cristina-Flavia and Oana Cristina Popovic (2013), "Business cycles synchronization in the European Union: truth or challenge?", *Theoretical and Applied Economics*, 20(7): 33-42.

Traistaru, Iulia (2004), "Transmission channels of business cycles synchronization in an enlarged EMU", ZEI Working Paper No. B 18-2004.

Umulisa, Yvonne and Olivier Habimana (2018), "Business cycle synchronization and core-periphery patterns in the East African community: A wavelet approach", *Journal of Economic Integration*, 33(4): 629-658.