I. ARTICLES

Magdalena Osińska[*], *Tadeusz Kufel*[*], *Marcin Błażejowski*[**],
Paweł Kufel[**]

BUSINESS CYCLE SYNCHRONIZATION IN THE EU ECONOMIES AFTER THE RECESSION OF 2007-2009[1]

The aim of the study is to evaluate business cycle synchronization in the EU economies including the determination of the impact of the global financial and economic recession of 2007-2009. In general, the economic recession can be understood as one of the phases of the global business cycle because all countries had suffered somehow from this enormous collapse. However, the depth and length of this phase was different across the countries due to different approaches to the monetary and fiscal policy that was applied to stop it and to start economic recovery. That is why some substantial changes could arise leading to the economic divergence of the economies that might affect not only the stability of particular economies but also periods of their recovery, which in consequence, might spoil the business cycle synchronization that had been observed before the recession. This is particularly important for the future of such economic bodies like the European Union and the Eurozone that experienced both the advantages and the disadvantages of common policy and currency. It is commonly assumed that the GDP series in constant prices measure both business activity and business cycle. In the presented research, seasonally adjusted quarterly GDP series from 1995-2012 were analyzed. To determine how much the recession affected business cycle synchronization, a cross-spectral analysis for the whole analyzed period and for moving windows was implemented. We proposed to apply the tools of cross-spectral analysis such as coherence, phase and amplitude of the specified frequencies taking into account the time window of 48 quarters. Such a procedure allows indicating a rapid change in business cycle synchronization conditionally on the period of the analysis which includes the period 2007-2009. The empirical findings show that the assumption of business cycle synchronization within the EU was confirmed for the strongest economies of the European Union like Germany, Great Britain and France. Moreover, Poland and Spain can also be included in the club of synchronized economies. Other EU economies like the Hungarian, Italian and Portugese, were less synchronized with the EU business cycle, although in the period of crisis they were closer to the whole economic area. For the non-EU countries, a significantly weaker synchronization with the EU was observed. The hypothesis that the financial crisis caused similarities in the business cycle paths of the EU countries and the USA was confirmed, while for Japan and Switzerland it could not be confirmed in the light of the obtained results.

Keywords: business cycle, synchronization, cross-spectrum, moving window, European Union

[*] Department of Econometrics and Statistics, Nicolaus Copernicus University in Toruń
[**] Faculty of Finance and Management, Torun School of Banking

1. INTRODUCTION

Business cycles synchronization is a key criterion of the common monetary policy and monetary union of a group of countries. The process of economic convergence of member-states economies in the European Union has been observed for many years in the last two decades. The efforts to achieve homogeneity of economies and to form a unified economic body, despite the fact that the countries differed specifically in terms of trade and fiscal imbalances have been observed for many years. The outbreak of the global financial and economic crisis in 2007 made the business cycles in some economies more, while in the others less, synchronized. The issue of business cycle synchronization in the European Union group of countries was already the subject of numerous analyses before the last financial and economic crisis outbreak. Adamowicz et al. (2012) provided a brief resume of the attempts to conduct business cycles analysis for Poland and the other EU countries using different methodological approaches. Among the most popular methods the following were indicated: analysis of supply-demand shocks, spectral analysis, VAR models and different filters. The conclusions that came out of the reported research, including the mentioned report (Adamowicz et al., 2012), allow us to state that in general, synchronization between the business cycle in Poland and the EU countries before the crisis had been observed. Skrzypczyński (2006, 2010) provided a wide review of the spectral methods used in business cycle synchronization and the analyzed business cycle in the Polish economy in 1995-2007. He found, among other matters, that taking into account turning points, the business cycle in Poland had been synchronized with the business cycle in the Eurozone and this relation had been quite stable. However, the amplitude of the cycle in Poland had been higher than in the Eurozone. Furthermore, shorter cycles (3 years) had been more synchronized than longer cycles (6-7 years). In the newest literature (Claassen et al., 2013), stronger business cycle synchronization between the US and other economies during the last recession has been emphasized. Stronger co-movements in this period are related to the fact that it was the US financial system which was considered to be the source of the global recession. In general, however, the hypothesis of decoupling between business cycles of the developed and developing countries has become the subject of wide discussion. In the paper of Claassen et al. (2013), it was stated that decoupling between advanced and emerging economies had taken place but in recent years the process of re-coupling has started. Kawa (2011) shows that some arguments support and

some others reject the hypothesis of the existence of decoupling. Nevertheless, it seems obvious that deeper research is necessary to determine the impact of the recession of 2007-2009 on the change of economic forces which drives the economies to different stages of development. In the research published by Stańczyk and Wyrobek (2013), the issue of business cycle synchronization between the USA and emerging economies in 1995-2009 was analyzed. The authors concluded that no evidence was found that emerging economies as a whole and in subgroups had their business cycles synchronized. However, the cycles in many emerging economies had been more synchronized with the US economy, particularly in the time of the global economic crisis. They also stated that unexpected and unusual phenomena like the global crisis had disrupted the relationships between economies observed in a "normal" state of development. Another interesting approach to the synchronization issue is presented in Gächter et al. (2012). The authors analyzed the synchronization based on the output gap. The results of the analysis showed a pronounced desynchronization of business cycles during the recession period. The authors measured the dispersion and correlation of the business cycles.

The aim of the present study is to evaluate business cycle synchronization in the EU economies, including the determination of the impact of the global financial and economic recession of 2007-2009. In general, the economic recession can be understood as one of the phases of the global business cycle because all countries had suffered somehow from this enormous collapse. However, the depth and length of this phase was different across the countries due to the different approaches to the monetary and fiscal policy that was applied to stop it and to start economic recovery. That is why some substantial changes could arise leading to the economic divergence of the economies that might affect not only the stability of particular economies but also periods of their recovery and, in consequence, might spoil the business cycle synchronization that had been observed before the recession. This is particularly important for the future of such economic bodies like the European Union and the Eurozone which experienced both the advantages and the disadvantages of common policy and currency. The effects of the recession that started in 2007 may be observed in at least the medium term and they influence the economic policy of the European Central Bank and the policies of the central banks of the EU member-states. On the other hand, the policy that was adopted in the USA differed from the EU policy that showed quite separate ways of stimulating the economic growth. It is commonly assumed that the GDP series in constant prices measure both: business activity and

business cycle. In the presented research, the seasonally adjusted quarterly GDP series from 1995-2012 were analyzed. The choice of spectral analysis that is made on the basis of the frequency domain is straightforward. The first reason is that there exists full equivalence between time domain and frequency domain (see for example Schoukens et al., 2004). This comes directly from the Fourier transform application that a series observed in time domain can be transformed into frequency domain and vice versa. However in practice, due to the noise effect and different estimators used in both domains, the final findings can differ in particular cases. Usually results based on time domain are more aggregated than those based on frequency domain. The second and more important reason for using spectral analysis to study business cycles synchronization is that it allows the precise partitioning of cyclical periods via spectral frequencies (or frequency bands), and consequently precise inference about the relationships between different economies within these frequencies. Skrzypczyński (2006, 2010) used spectral analysis to describe the business cycle in Poland.

To determine how much the recession affected business cycle synchronization, cross-spectral analysis for the whole analyzed period and for moving windows was implemented. We proposed to apply the tools of cross-spectral analysis such as coherence, phase and amplitude of the specified frequencies taking into account the time window of 48 quarters. Such a procedure allows indicating a rapid change in business cycle synchronization conditionally on the period of the analysis that includes the period 2007-2009. The moving window approach to spectral analysis is the authors' concept and was not presented in the literature. To eliminate the impact of the long period frequencies, the Hodrick-Prescott filter was used at a very early stage of the analysis (Hodrick and Prescott, 1997). The robustness of the applied procedure is discussed in the authors' paper (Osińska et al., 2013), where the application of different frequency filters is thoroughly analyzed. The choice of the countries taken for analysis was limited to the EU states, but to capture the differences between the economies the following countries were additionally included: the USA, Japan and the EFTA member-states.

2. ECONOMIC BACKGROUND

For the past two decades the economic policy in many countries has been founded on the neoclassical liberal economic theory. Visible evidence of such a state of arts was formulated in a document introduced in 1989 which

was called the Washington Consensus (Williamson, 2004). Ten macroeconomic policy prescriptions were formulated to be applied mainly in developing countries, particularly in Latin America. These prescriptions served as the foundation of economic growth policy in this region. In subsequent years they have been interpreted as an appropriate policy model for other developing countries. In fact, the Washington Consensus constituted the basis for macroeconomic policy of both developed and developing countries. The principles of the Washington Consensus were used by such international institutions as the International Monetary Fund, the World Bank and the World Trade Organization. Moreover, this document is in agreement with other policy recommendations such as the Stability and Growth Pact, which was ratified by the European Union in 1997. In its original version it emphasized fiscal discipline, market economy, and the openness to the world economy with respect to trade and foreign direct investment. Two fundamental principles, deregulation principle and trade liberalization, constituted the basis for a common economic policy. Despite its complexity, the Washington Consensus was the subject of deep criticism presented by Stiglitz (1998) and Krugman (2013). Stiglitz noted that using this document in emerging and often unprepared economies had not caused the intended growth effects but had been the reason for the rise of new social and economic problems. Krugman stated, among other points that the deregulation in the banking sector increased banks' inclination to greater risk taking because the market expected higher interest rates for the deposits. To satisfy this expectation, banks had to offer more risky loans. The events that happened in 2007 and 2008 in the USA and, as a consequence in other countries, showed that the policy rules based on the Washington Consensus were no longer valid in the presence of a huge financial and economic collapse. The reasons for such ideas lay in two economic phenomena that appeared simultaneously. The first of them was the liquidity trap, i.e. a case when a decreasing short-term interest rate does not lead to a substantial increase of banking loans. This means that monetary policy fails and can be no longer used as an efficient tool of macroeconomic policy. The second phenomenon is related to the Minsky moment. Minsky (1986) noticed that a sudden major collapse of asset values was a part of the business cycle. This is due to the fact that reactions of entities in the microeconomic scale are debt-ridden and the economic situation, by limiting expenses, does not work where the entire economy is concerned. In the macroeconomic scale it is recommended to use fiscal policy tools such as restricting the scale of taxes to limit the effects of deep recession or to introduce government expenses to

stimulate the economy. During the recession in 2007-2009 and its further continuation in Europe since 2010 (called euro-crisis), these kinds of activities have been bound to the US economy, although Krugman (2013) argued that the scale of public expenses in the USA had not been sufficient. It was visible that the economic recovery of the US economy started in 2010 and in 2014 and it can be stated that it has really succeeded. In Europe, despite some financial support for the banking system observed in the early stage of the crisis, the depreciation of the local currencies and the increase in the obligatory reserves of commercial banks, the policy that restricted both public expenses and public debt was promoted. This has led to institutional changes in the banking and public system. It is worth mentioning that some support for the weaker EU economies from the ECB and the IMF was delivered by means of international loans, for example Greece and Ireland. Nevertheless generally speaking, a policy of belt-tightening has been widely enforced. The basic characteristics of the economic situation in some economies are shown in Table 1.

Table 1

Basic characteristics of selected economies

Basic characteristics	EU27		Spain		UK		USA	
	2007	2012	2007	2012	2007	2012	2007	2012
Long-term interest rates	--	2.96	--	5.34	--	1.6	2.22	2.00
Short-term interest rates	4.0	0.5	4.0	0.5	5.5	0.5	4.25	0.25
General government gross debt (% of GDP)	59.0	85.3	107.4	156.9	44.2	90.0	66.5	106.5

Source: based on Eurostat

The numbers shown in Table 1 indicate that short-term interest rates are very low in almost all the countries, and in consequence central banks are nowadays without any tools to start economic growth and to help in the economies' recovery. It can be seen as well that in the period of the last recession, governments significantly increased their debt which confirms the use of fiscal policy rather than monetary policy. These and other facts show the reasons for decoupling between the developed and developing countries in the European Union: the worsening situation in Greece, changing the policy in Hungary and creating a new union between Slovakia, the Czech Republic and Austria being a side effect of the Ukrainian crisis. The main reason is that the developing economies do not

possess such deep capital resources as the developed ones and this gap is very difficult to narrow. Furthermore, the country-specific problems have made this situation even more complicated. They have increased the gap between the developed and developing countries as the result of both the economic recession and political conflicts. Moreover, these facts confirm another hypothesis that unusual and unexpected phenomena change economic relationships between the countries which were built in a period of stable growth and development.

3. CALENDAR OF THE FINANCIAL AND ECONOMIC CRISIS IN THE EU AND USA

The financial crisis of 2007–2008 was not the first nor last collapse of the global economy. Nevertheless it was the first global financial crisis in the 21st century and the biggest recession since the 1930s. It is hard to say precisely when the crisis started. Some of the researchers take into account the first symptoms of some problems in the financial markets or the first bankruptcies in the subprime mortgage market in 2007, but most of the economists date the start of the financial crisis to when Lehman Brothers went bankrupt in 2008. A great deal of worrying signals in the US financial markets went unnoticed or were simply ignored; even the slowdown in the real estate market in 2005 and 2006 did not instill worries into investors.

The main cause of the financial crisis in 2007–2008 was giving credits to those who did not have sufficient financial potential. Such a situation was directly connected with a very high risk level. Low interest rates and the increasing prices of real estate encouraged the lending of money to poorer families. In 2006, when prices of real estate began to fall, people were unable to acquit their debts, what induced huge losses in both hedge funds and banks. In February 2007, the third biggest bank in the world – HSBC – presented its financial report in which real profits were much lower than estimated. Moreover, the share of high risk subprime mortgage lending increased five times. A month later one of the biggest real estate mortgage creditors announced the possibility of bankruptcy. A similar situation occurred in other financial agencies like Wells Fargo, Lehman Brothers and JP Morgan. Finally, New Century Financial went bankrupt in April 2007. The main banks in the USA (such as Merrill Lynch, Goldman Sachs, Morgan Stanley, Lehman Brothers, Citigroup) were subsidized with billions

of dollars. A sign of the oncoming recession was the bankruptcy of two hedge funds, which accrued to one of the biggest investment banks in the world – Bear Stearns. Most of the assets were invested in high credit risk instruments connected with the real estate market. The bankruptcy of the fourth biggest investment bank in the USA – Lehman Brothers in September 2008 – became the essential moment of the crisis. This investment bank had more than one third of their assets invested in the subprime mortgage sector. Due to this fact, the New York Stock Exchange lost 400 billion dollars.

It is worth noting that the bankruptcy of Lehman Brothers was not the reason for the financial crisis, but it showed the size and the value of the crisis which caused a domino effect. The source of the problems of financial institutions was similar to past situations, i.e. irresistible investments in the sector of high-risk credits. At first, the crisis concerned only the American financial markets, but very soon prices of real estate in Spain fell as well. It became clear that the European banks and the financial agencies had also invested in bad securities. The share of the subprime mortgage sector in the USA and in Europe was so high that the trading in mortgage-based securities decreased, banks were forced to reduce payments and freeze their businesses. Similarly to the FED in the USA, the European Central Bank intervened to stop or to weaken the oncoming crisis. Unfortunately those operations were not sufficient.

To avoid the economic slowdown the U.S., Treasury Secretary Henry Paulson proposed a plan of financial rescue. Its main assumption was about the financial support from the government to the financial institutions. The cost of this plan was transferred to the citizens – the taxpayers. The plan was rejected by the House of Representatives, which caused a huge collapse in the stock exchange markets. Immediately, work on a new version of Paulson's plan began. At the same time the biggest savings and loan associations as well as banks in the US went bankrupt. Meanwhile in Europe, government warranties for bank deposits were increased. The Netherlands capitalized the ING financial group, the International Monetary Fund lent EUR 20 billion to help the Hungarian economy. Similarly to the US, additional financial support for the European banks was delivered.

A positive growth rate of GDP in the United States was observed in September 2009 while in Europe the Eurozone crisis started. This was mainly caused by problems in Greece, gradually in Spain and Portugal, also in Ireland and Italy. The negative effects of the financial crisis spread into all related economies, which determined the slowdown in the GDP growth rates.

4. METHODOLOGY AND THE DATASET

Examination of business cycle synchronization for the EU economies was carried out by using the tools of multivariate spectral analysis for seasonally adjusted processes in the frequency bands corresponding to the business cycle. The research methodology involved the following sequence:

1. Time series seasonal adjustment in order to eliminate the impact of calendar effects.
2. Filtration of the GDP time series in the frequency domain to extract the bands responsible for the cyclical fluctuations of the specified period.
3. Application of cross-spectral analysis in order to verify the hypothesis of cycle synchronization between the economies under study.

The data which were taken for analysis came from Eurostat and they were seasonally adjusted according to Eurostat methodology. Due to the lack of some observations in the Eurostat database we decided to fix the observation period in such a way that it covered those countries and periods (1995-2012) for which the necessary data were available. Filtration of time series aims to isolate the variability of the time series in the specified frequency or in the specified frequency band. In the literature on the analysis of business cycles the following filters are most commonly used: the Hodrick-Prescott (HP) filter, the Butterworth (BH) filter, the Cristiano-Fitzgerald (CF) filter and the Baxter-King (BK) filter. Three of these filters, i.e. HP, BH and CF are frequency-domain filters, while the BK is a time-domain filter (moving average). The properties of the above mentioned filters were discussed in Osińska et al. (2013). The characteristics of the filters are traditionally compared with the ideal filter. Let us consider the time series $\{x_t\}$, $t = 1, 2, \ldots, n$ from which a specified component y_t with a period of fluctuation between p_l and p_u, $(2 \le p_l < p_u < \infty)$ is to be extracted. Then the relation can be written as $x_t = y_t + \overline{x}_t$. The component y_t is involved only in the frequencies of $\{(a, b) \cup (-b, -a)\} \in (-\pi, \pi)$, where $a = \dfrac{2\pi}{p_u}$; $b = \dfrac{2\pi}{p_l}$. The ideal band-pass filter for an infinite number of observations can be defined as:

$$y_t = B(L) x_t, \text{ where } B(L) = \sum B_j L^j; \ L^k x_t = x_{t-k}. \tag{1}$$

The weights B_j in the ideal filter can be defined as: $B_j = \dfrac{sin(jb) - sin(ja)}{\pi j} \wedge B_0 = \dfrac{b - a}{\pi}$. In a finite sample the approximation to the ideal filter has the form:

$$y_t = \hat{B}(L)x_t = \sum \hat{B}_{t,j} x_{t+j} \text{ and } \hat{B}_{t,j} = \arg \min E\left\{\left(y_t - \hat{y}_t\right)^2\right\}. \qquad (2)$$

Each of the considered filters accomplishes this task in a different way. As was indicated in Osińska et al. (2013), the Hodrick-Prescott and Christiano-Fitzgerald filters are the most appropriate for business cycle synchronization analysis. In further analysis, the Hodrick-Prescott filter was applied. Assuming that the time series x_t can be decomposed into a trend component g_t and a cyclical component y_t in such a way that $x_t = g_t + y_t$, $t = 1, 2, \ldots, n$, the HP filter generates the above decomposition by minimizing the following formula:

$$\arg \min\left\{\sum \left(y_t - \hat{y}_t\right)^2 + \lambda \sum \left(\hat{y}_{t+1} - 2\hat{y}_t + \hat{y}_{t-1}\right)^2\right\}, \qquad (3)$$

where the parameter λ is a positive smoothing constant. In empirical analysis, the Hodrick-Prescott filtering methodology was applied with a smoothing parameter determined according to the rule given by Ravn and Uhlig (2002). For quarterly data the value of 1600 corresponds to the period of 10 years. That means that a long-term component longer or equal to 10 years was eliminated from the time series.

Verification of business cycle synchronization by means of cross-spectral analysis was carried out in two variants:
1. For the entire sample (all available observations).
2. For the limited sample (moving windows with 66.7% of observations), for which the cross-spectral analysis was computed separately.

The cross-spectral analysis for the entire sample consisted mainly of the estimation of the coherence coefficient, including the statistical verification of its significance, amplitude and the phase angle for all pairs of selected economies. This approach can be called "static" in the sense that the range of data used in the analysis covered both the period before the financial crisis and within its course. As a consequence this approach did not allow for an assessment of whether the degree of business cycle synchronization has changed as a result of the recession. This type of application of spectral analysis is in line with other publications on the empirical evaluation of business cycle synchronization (Skrzypczyñski (2010); Woitek (1996)).

The cross-spectral analysis carried out for moving windows was based on the fact that the fixed time window (subsample) was moved by one observation (a quarter) to the right and then the coherence coefficient and other characteristics based on cross-spectrum were computed for each shift separately. This approach allowed investigating whether the coherence and

amplitude coefficients as well as the phase changed over time, particularly in the period before the financial crisis and after its outbreak. It is very important to emphasize that the changes in the corresponding coefficients are observed only for one specified frequency. Let us consider the multivariate stationary stochastic process with a zero mean expressed as a vector: $z = [z_{1t}, z_{2t}, \ldots, z_{rt}]$, where $t = \pm 1, 2, \ldots, \quad r \geqslant 2$ (Priestley, 1983; Talaga and Zieliński, 1986). Cross-spectral density function (cross-spectrum) can be expressed in the complex numbers form as:

$$f_{jk}(\omega) = c_{jk}(\omega) - iq_{jk}(\omega) \tag{4}$$

where: $j, k = 1, 2, \ldots, r$; $r \neq k$.

The real part of the function $R : f_{jk}(\omega) = c_{jk}(\omega)$ is called the co-spectrum (co-spectral density) and the imaginary part $I : f_{jk}(\omega) = q_{jk}(\omega)$ the quadratic spectrum (Talaga and Zieliński, 1986; Priestley, 1983). Empirical analysis requires solving the problem of the effective estimation of the cross-spectrum. We applied the discrete Fourier transform taking into account a possible weight system. The following weights called spectral windows are in use: the Bartlett weights, the Hanning weights, the Blackman weights and many others (Priestley, 1983). In the empirical application shown in the next section, the Bartlett weights were taken because there were no substantial differences in the results when other spectral windows were used. It should be noted that in cases of limiting statistical data, the exact estimation method may require some improvement. Unfortunately the exact distribution theory under the small sample may be distorted, thus Grenander et al. (1959) suggested to implement numerical methods to estimate a univariate spectrum using the triangular (Bartlett) window. Unfortunately this method is not exactly applicable to the bivariate case considered in this paper.

The cross-spectrum is the basis for computing further coefficients enabling to analyze the relationships between two processes. The first of them, the coherence coefficient for two processes takes the form:

$$R_{jk}(\omega) = \frac{\left| f_{jk}(\omega) \right|}{\sqrt{f_{jj}(\omega) f_{kk}(\omega)}} = \sqrt{\frac{c_{jk}^2(\omega) + q_{jk}^2(\omega)}{f_{jj}(\omega) f_{kk}(\omega)}} \ . \tag{5}$$

The coherence coefficient takes values in the range [0,1] and indicates the strength of a linear relationship between the processes z_{jt}, $z_{kt+\tau}$ for the frequency ω. In other words, it is the correlation coefficient between the

harmonics of the investigated processes for a given frequency. For the band $[0,\pi]$, the coherence coefficients create a series of values corresponding to those points for which they were computed. It is very important that the coherence coefficient must be statistically significant. The appropriate test formula is presented in Koopmans (1995). The methods of computing equivalent degrees of freedom can be found in Koopmans (1995) and in Priestley (1983).

The phase angle is defined as:

$$\phi_{jk}(\omega) = arc\,tan \frac{-q_{jk}(\omega)}{c_{jk}(\omega)} \tag{6}$$

and it measures the difference in phase between the harmonics of the processes z_{kt} and z_{jt}. This coefficient helps determining the time lags between two orthogonal components for the frequency of the interval $[0,\pi]$. The amplitude coefficient defined as

$$A_{jk}(\omega) = \sqrt{c_{jk}^2(\omega) + q_{jk}^2(\omega)} \tag{7}$$

measures the magnitude of amplitude of cross-spectrum at a given frequency.

5. EMPIRICAL RESULTS

As was mentioned in a previous section, the results of the research were divided into two panels. The first panel is related to the entire period of 18 years from 1995 to 2012 (quarterly data) covered by the time series from the EU countries as well as the EFTA countries and additionally from the USA and Japan. All numerical computations were realized in the gretl (http://gretl.sourceforge.net) software. Due to the fact that gretl does not offer arithmetic for complex numbers (except for basic operations such as absolute value), part of the analysis was carried out in the GNU Octave 3.6.4 environment (http://www.gnu.org/software/octave) through gretl's foreign language mechanism. The relations between the packages are straightforward and do not require any additional operations. Examples of the original and filtered series in the entire period of the analysis are shown in Figure 1.
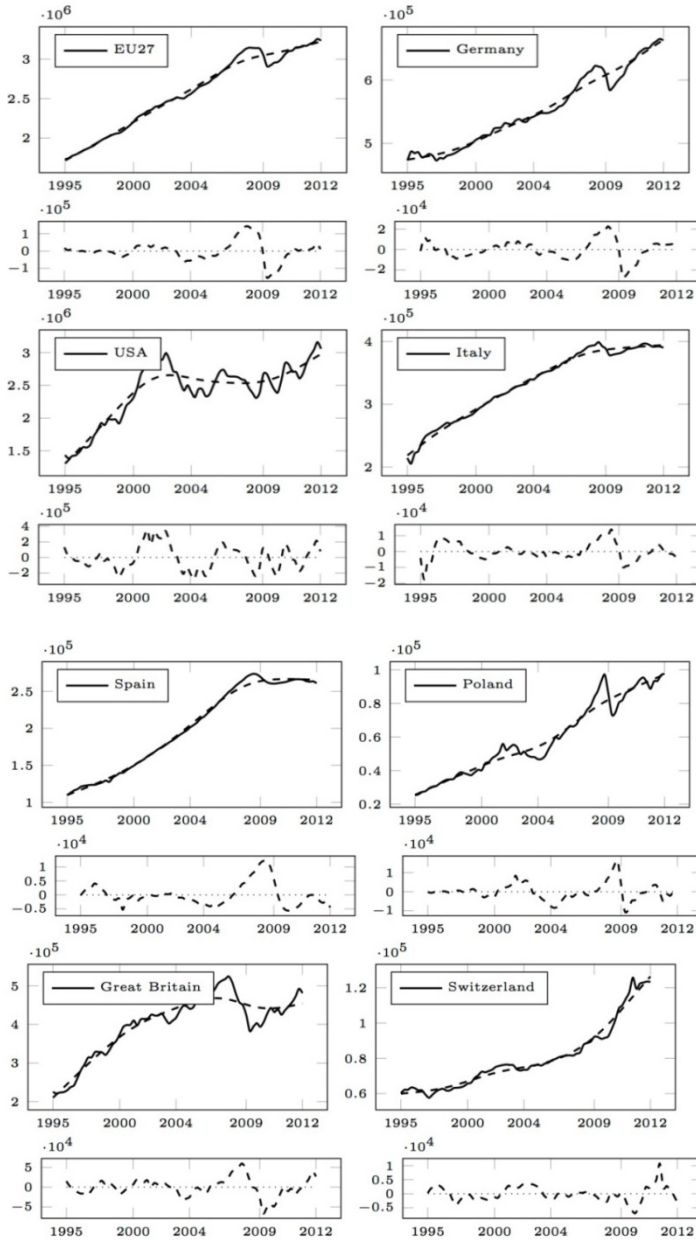
Figure 1. Gross domestic product in the selected countries with the trend component and the cycle component of HP filter

Source: own calculations based on Eurostat data

Despite the relative differences in the growth pattern across countries, the periodical component of GDP shown in Figure 1 was quite similar in the EU27, Germany, Great Britain, Spain, Italy and Poland. The differences are visible for the USA and Switzerland. In Figure 1 original data are presented, while for applying spectral analysis the data were seasonally adjusted and detrended using the HP filter as described below. The transformed time series were checked for stationarity using both the ADF and KPSS tests[2]. All the results indicated stationarity of time series then spectral analysis as appropriate.

PANEL I

The results of the cross-spectral analysis obtained for the entire period of observations show a strong synchronization of business cycles for all the frequencies from the interval $(0, \pi)$ between different subgroups drawn from the EU countries, that is the EU27, the EU15, the Eurozone 17 and the Eurozone 12. When single countries are compared with the EU in the configuration mentioned above, the level of fit of the business cycles differs in both criteria: across countries and across frequencies. To save space in the presentation only selected results[3] are shown in Figure 2.

The general conclusion is that a strong and statistically significant level of synchronization was observed using the coherence coefficient (5). For the confirmed significant coherence values, the coefficients of phase (6) and amplitude (7) were additionally analyzed. Otherwise, a state of no synchronization between given pairs of countries was found. Statistically significant relations were found between the EU27 and the following countries: Germany, Great Britain, Spain, Poland and France. The strongest relation corresponds to the following periods of time: from 24 quarters to 10.29 quarters, i.e. from 6 years to 2.57 years. For such countries as Great Britain, Germany and France, the coherence coefficient was significant at almost all frequencies which confirmed the strong synchronization of business cycles between the EU27 and traditionally its most powerful economies. For the two remaining countries the relation between the changes in output in comparison to the EU27 is concentrated in the period corresponding to the business cycle of 2.5-6 years, which confirms the fact known from literature that the length of business cycles is not stable (see Romer, 2011). Very similar conclusions can be formulated for the EU15 and

---

[2] The results of testing for unit roots / stationarity are available from the authors on request.

[3] The results of analysis presented in the figures are limited to the most typical situations. The full range of results is available from the authors on request.
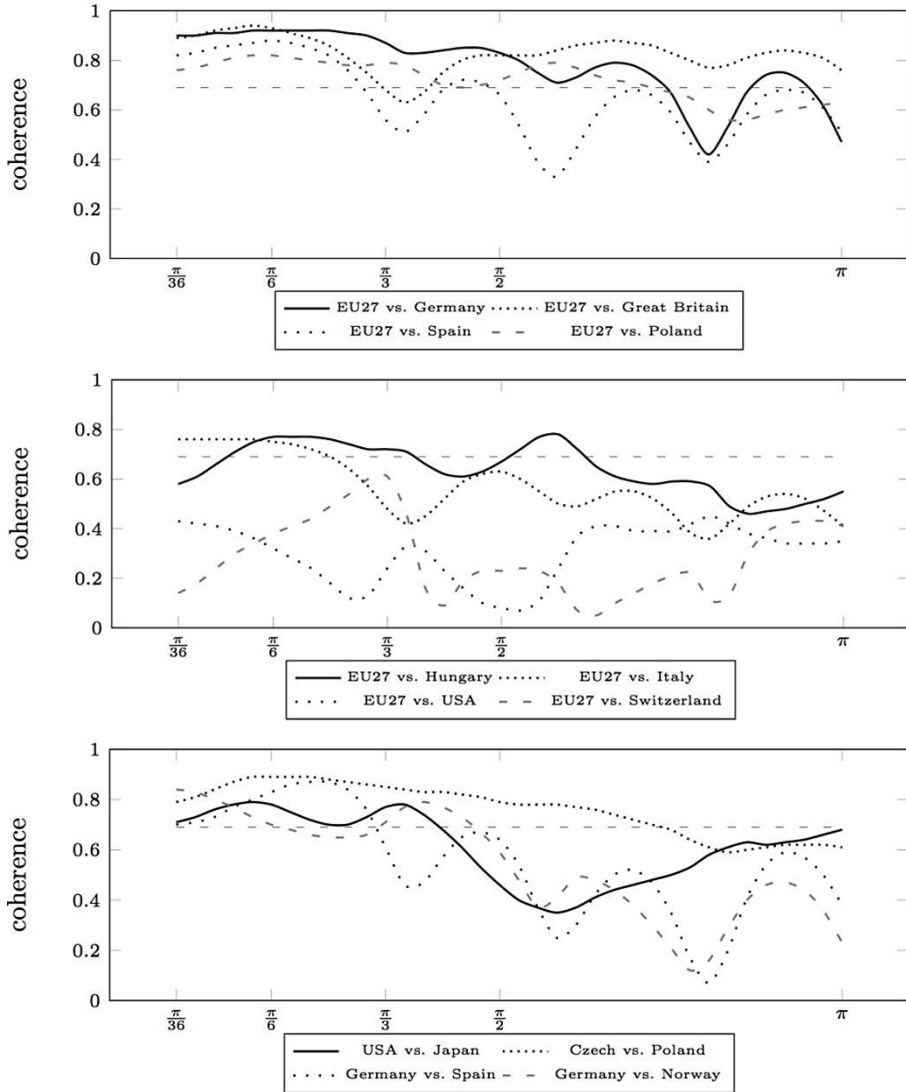
Figure 2. Coherence and its 5% significance level critical value for the selected pairs of economies (full range sample)

Source: own calculations

the mentioned countries. A much weaker synchronization of business cycle was presented for other member countries of the European Union and the EU27 (or EU15), like Hungary, Italy and Portugal. For the non-EU countries

like the USA, Japan and Switzerland, no synchronization with the EU27 was observed. As concerns the Eurozone17 and the Eurozone12 very similar results were obtained, apart from the Czech Republic and Portugal. These two countries had their business cycles synchronized with the Eurozone business cycles. Taking into account pairs of the countries, it was noticed that the following business cycles are related to one another: the USA and Japan; the Czech Republic and Poland; Poland and Norway; Germany and Spain; Germany and France; and in narrower frequencies Germany and Portugal; Germany and Norway; France and Portugal; France and Great Britain as well as Poland and Portugal.

Analysis of the phase coefficient (6) shows that in the pair of EU27 and EU15, the economically stronger EU15 preceded the EU27 in the frequencies corresponding to the period between one and six years. That means that the economic recessions and recoveries started earlier in the countries with a concentration of the majority of human and capital resources as well as technical progress and those capitalized from the higher level of economic development. As far as the EU27 and Norway is concerned, Norway's business cycle preceded the EU27 in three to six years, while in 1.5 to2.5 years the opposite direction was observed. In the pair Germany–the EU27, no difference in phase was observed, while Great Britain preceded the EU27, and the EU27 preceded Spain and Poland. Comparing the Czech Republic and Poland, it can be observed that the business cycle in Poland was preceding the Czech Republic even in a longer time interval i.e. between six months and six years. In the pair the USA–Japan, the latter country was preceding the former in the business cycle (see Figure 3).

The shape of amplitude (7) is presented in Figure 4. It can be seen that in the periods corresponding to the business cycle (three to six years) the magnitude of the amplitude coefficient is much higher than in other frequencies. This fact shows that the analyzed countries were related in the business cycle periods more than in other periods. This impact is visible in the mutual relations in different economic areas including international flows of capital and labour as well as in the intensity of economic cooperation in many fields. It should be emphasized that the results of the phase and amplitude coefficients are interpreted only for those pairs of countries that had significant coherence coefficients.

Looking at the results more generally from the economic point of view, it can be stated that those countries which are traditionally related, like the EU27, the EU15 and Germany, Great Britain and France are more strongly
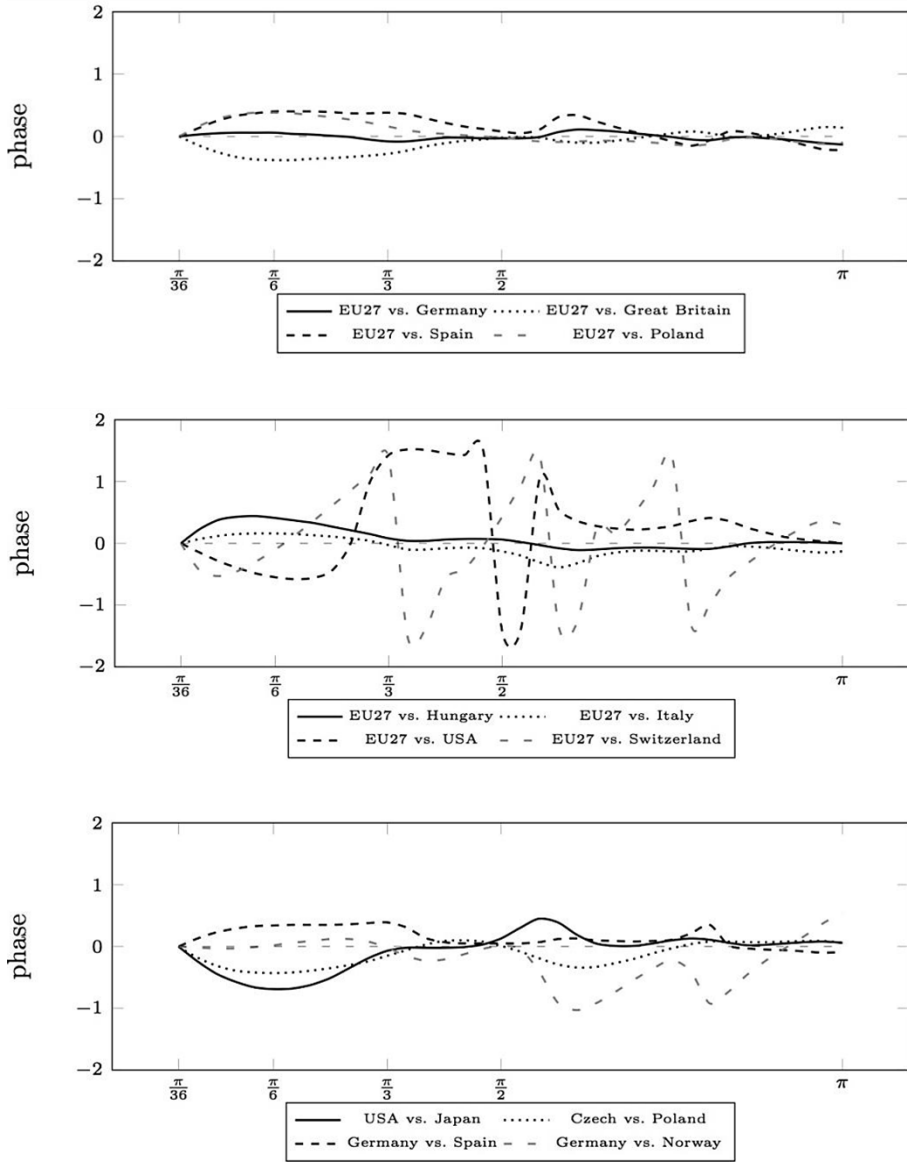
Figure 3. Phase for the selected pairs of economies (full range data)
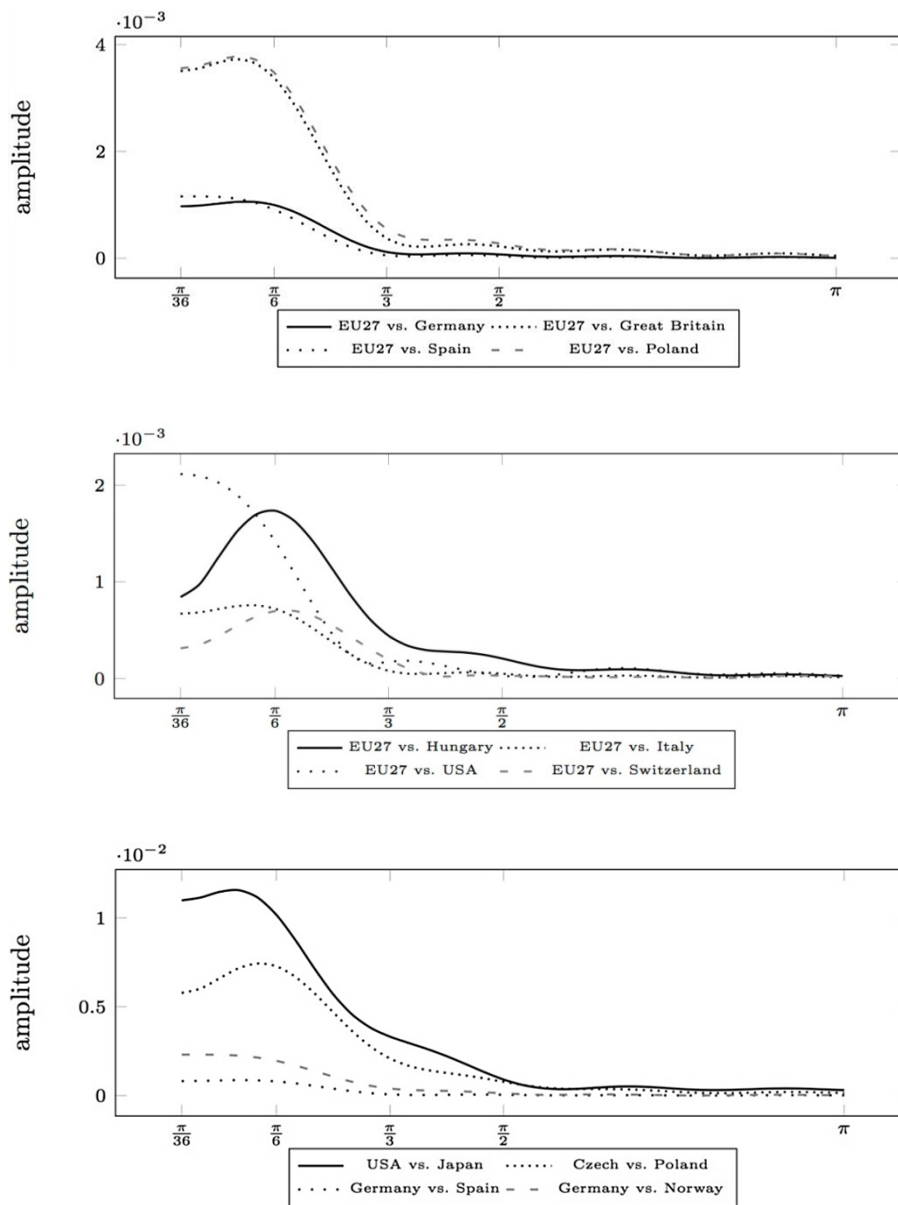
Source: own calculations

Figure 4. Amplitude for pairs of the selected countries (full range data)

Source: own calculation

related than the others. The same regards the USA and Japan. Surprisingly, there is no business cycle synchronization between some European countries and the EU or the Eurozone (in different configurations). Examples of non-synchronized or weakly synchronized countries are Italy, Hungary and Switzerland. While the results concerning Switzerland, due to its position in financial capital accumulation, can be easily explained, it is rather difficult to explain the quite different dynamics in the business cycles in Italy and Hungary which belong to the European Union. The question arises why the Italian economy was so different from the EU economies despite its long membership in the European structures. The answer for this question is related to the Italian GDP growth over past 20 years. The Italian year-by-year growth rate was close to zero and this fact distinguishes Italy from the other European countries where systematic positive growth had been observed before 2009. The position of Hungary is quite different. After a decade of Europeanization process, Hungary changed its policy in 2010 which might affect the results of the research. Another unexpected result is related to the fact that there is no synchronization between the business cycles of the EU and the USA. This can be explained by two facts. The first one is related to the level of economic liberalization and the second one, being the consequence of the first one, reflects the different way of the interventions during the last economic crisis. As is widely known, the level of statism in the EU and its member countries is much wider than in the

Table 2

Values of coherence, phase and amplitude for the selected pairs of countries and the selected frequencies

frequency period (yrs)	Coherence			Phase			Amplitude ($\cdot 10^{-2}$)		
	$\frac{\pi}{12}$ 6.0	$\frac{\pi}{9}$ 4.5	$\frac{\pi}{6}$ 3.0	$\frac{\pi}{12}$ 6.0	$\frac{\pi}{9}$ 4.5	$\frac{\pi}{6}$ 3.0	$\frac{\pi}{12}$ 6.0	$\frac{\pi}{9}$ 4.5	$\frac{\pi}{6}$ 3.0
EU27 vs. GER	0,874	0,877	0,881	0,075	0,090	0,078	0,102	0,105	0,100
EU27 vs. ESP	0,811	0,811	0,789	0,211	0,282	0,355	0,115	0,111	0,091
EU27 vs. ITA	0,584	0,586	0,578	0,125	0,153	0,155	0,072	0,075	0,072
EU27 vs. POL	0,758	0,764	0,762	0,224	0,289	0,333	0,371	0,378	0,347
EU27 vs. GBR	0,886	0,897	0,891	-0,242	-0,309	-0,350	0,366	0,373	0,337
EU27 vs. CHE	0,201	0,250	0,346	-0,143	-0,070	0,181	0,044	0,055	0,070
EU27 vs. USA	0,461	0,436	0,369	-0,233	-0,325	-0,440	0,203	0,190	0,142
EU27 vs. JPN	0,186	0,237	0,250	1,423	1,480	1,556	0,104	0,131	0,122
Euro17 vs. ESP	0,917	0,915	0,911	0,059	0,082	0,115	0,089	0,086	0,072
Euro17 vs. POL	0,720	0,705	0,676	0,094	0,125	0,152	0,240	0,238	0,211
Euro17 vs. GBR	0,712	0,745	0,732	-0,471	-0,586	-0,655	0,201	0,212	0,190
Euro17 vs. CHE	0,264	0,322	0,418	-0,332	-0,315	-0,151	0,039	0,048	0,058
ITA vs. ESP	0,471	0,483	0,504	-0,301	-0,393	-0,474	0,055	0,056	0,053
USA vs. CHE	0,583	0,546	0,441	0,272	0,384	0,555	0,371	0,344	0,251
USA vs. JPN	0,698	0,724	0,738	-0,418	-0,550	-0,658	0,011	0,012	0,010

Source: own calculations

USA (see Dornbusch, 2002; Piketty, 2014). That is why the economic policy and the activity of governments might affect the differences in the lengths and amplitudes of particular phases of business cycles. The second of the mentioned facts, i.e. the different reaction to the recent economic recession in the EU and the USA, discussed in Section 3 will be the subject of further interest in the second panel of the empirical analysis. Apart from the visual analysis of figures, the selected results are also presented in Table 2.

Due to the fact that many combinations were computed, the results are summarized in Table 3.

Table 3

Percentage of significant coherence, positive and negative phase for significant coherence for the selected countries and selected frequencies

frequency	% of significant coherence			% of positive phase			% of negative phase		
	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$
period (yrs)	6.0	4.5	3.0	6.0	4.5	3.0	6.0	4.5	3.0
EU27	72%	84%	84%	52%	64%	72%	20%	20%	12%
EU15	68%	84%	84%	60%	76%	76%	8%	8%	8%
Euro17	80%	88%	88%	48%	52%	52%	32%	36%	36%
Euro12	80%	84%	88%	48%	52%	52%	32%	32%	36%
FIN	68%	76%	80%	32%	40%	44%	36%	36%	36%
FRA	72%	76%	76%	40%	44%	48%	32%	32%	28%
GBR	48%	68%	80%	44%	64%	76%	4%	4%	4%
GER	60%	68%	84%	32%	40%	64%	28%	28%	20%
HUN	8%	16%	40%	4%	8%	16%	4%	8%	24%
ITA	28%	28%	32%	20%	24%	24%	8%	4%	8%
AUS	68%	72%	76%	48%	52%	52%	20%	20%	24%
BEL	64%	72%	80%	52%	60%	64%	12%	12%	16%
CHE	4%	4%	4%	4%	4%	4%	0%	0%	0%
CYP	60%	68%	76%	16%	16%	12%	44%	52%	64%
CZE	48%	72%	80%	8%	8%	8%	40%	64%	72%
DNK	76%	80%	84%	60%	64%	72%	16%	16%	12%
ESP	72%	72%	72%	32%	32%	32%	40%	40%	40%
EST	64%	76%	76%	28%	40%	40%	36%	36%	36%
LTU	84%	84%	84%	24%	24%	24%	60%	60%	60%
LUX	56%	72%	80%	48%	64%	76%	8%	8%	4%
LVA	80%	80%	76%	16%	16%	12%	64%	64%	64%
NLD	68%	76%	80%	20%	20%	28%	48%	56%	52%
NOR	56%	56%	56%	36%	36%	32%	20%	20%	24%
POL	64%	72%	76%	24%	24%	28%	40%	48%	48%
PRT	24%	24%	32%	20%	20%	32%	4%	4%	0%
SVK	36%	56%	76%	0%	4%	4%	36%	52%	72%
SVN	60%	76%	80%	12%	12%	8%	48%	64%	72%
USA	8%	8%	8%	4%	4%	4%	4%	4%	4%
JPN	8%	8%	8%	8%	8%	8%	0%	0%	0%

Source: own calculations

Table 3 is valuable due to the fact that it shows the scale of significant coherence coefficients and the positive and negative phase coefficients when coherence was significant. The analysis of the results confirmed that the business cycles in such countries as Hungary, Switzerland, Portugal, the USA and Japan were rarely synchronized with others even in the frequencies corresponding to the business cycles. Another important observation was that 3-year cycles were more often synchronized in comparison with the 4.5- and 6-year ones which is in line with Skrzypczyński (2010). The results of phase coefficient show that the EU15 preceded other economies by 60% to 76%. The low percentage values of the positive phase for the USA correspond to the fact that the US cycle was weakly synchronized with the others.

PANEL II – the empirical analysis of business cycle synchronization in moving windows

The second panel is related with the analysis of changes in business cycle synchronization at three frequencies corresponding to business cycles, i.e. $\pi/12$, $\pi/9$ and $\pi/6$. The frequencies correspond to 24, 18 and 12 quarters, respectively. The results were computed for coherence, phase and amplitude analyzed in moving windows. Figure 5 shows the selected results of the investigation[4].

The moving window methodology shows three curve lines for each characteristic. It enables deeper insight into the changes of business cycle synchronization. Subsequent years were put at the OX axis. The analysis of the results confirmed the strong and significant synchronization of the cycles in the following pairs of countries: the EU27 and Germany, the EU27 and Great Britain, the EU27 and Italy, the EU27 and Poland in three cyclical frequencies. For the EU27 and the USA, a significant coherence in the period of crisis was observed while for the EU27 and Switzerland a very weak synchronization was observed at the periods of 24 and 12 quarters. In the economic recession period, the USA and Switzerland had their cycles synchronized. The important information flows from the analysis of cycle amplitude. Its highest values correspond to the period of the recession of 2007-2009 which shows its enormous impact on the analyzed economies. It is worth noting that in such pairs as the EU27 and Germany, the EU27 and Great Britain, the EU27 and Italy, the EU27 and Poland, the highest

---

[4] The results of moving windows analysis presented in the figures are limited to the most typical situations. The full range of results is available from the authors on request.
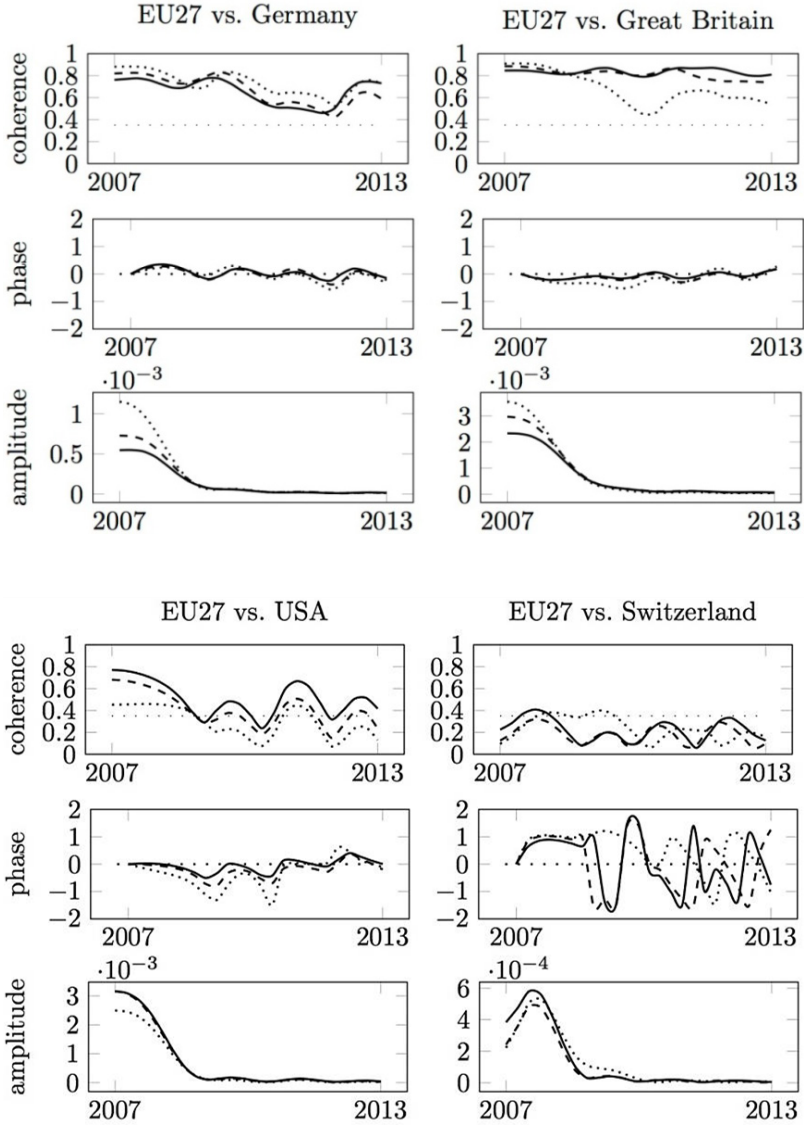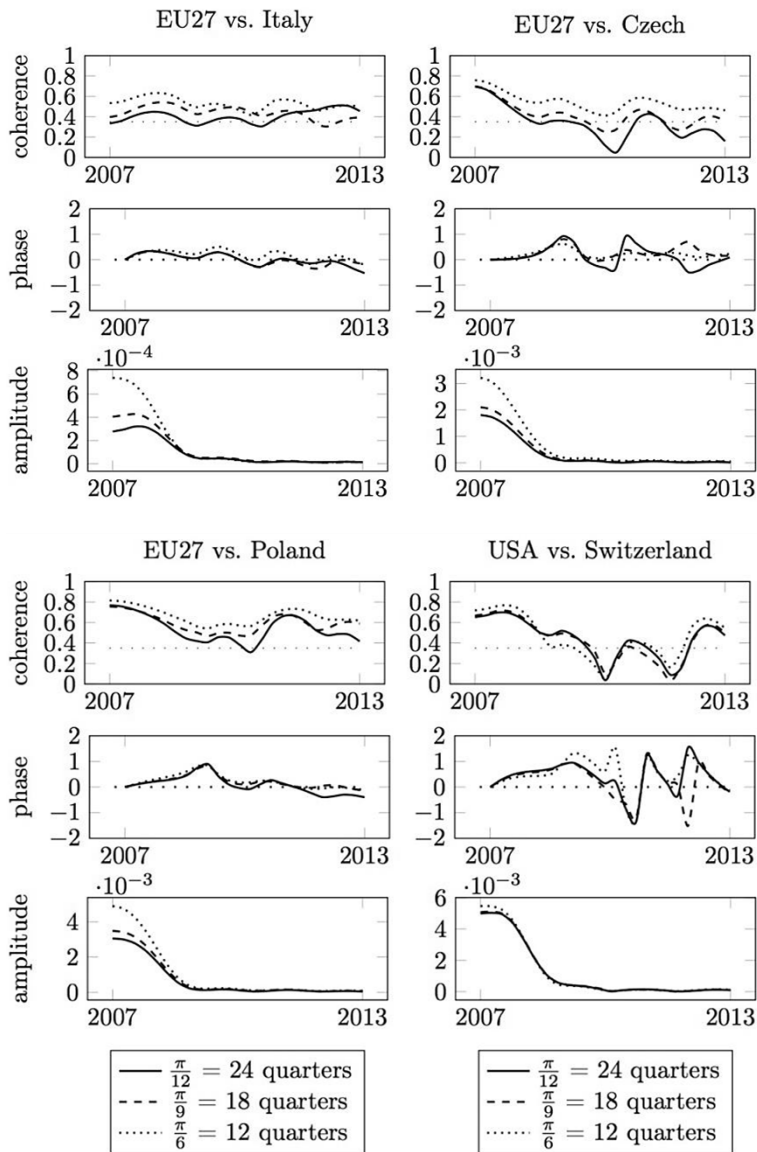
Figure 5. Coherence, 5% critical value for coherence, phase and amplitude in windows for

Source: own calculations

the selected pairs of countries and the selected frequencies

amplitude values correspond to 12 quarters and the smallest values are related with the 24 quarters that support the thesis of short – 3-year cycle in the European countries. For the EU27 and the USA the results were different, i.e. the highest values of amplitude occurred for 24 and 18 quarters and the lowest for 12 quarters. This means that for less economically related states the longer cycles were more important than the shorter ones.

CONCLUSIONS

In the paper, the business cycle synchronization in the EU economies including the determination of the impact of the global financial and economic recession of the period 2007-2009 was evaluated. Firstly, we determined the business cycle synchronization in the entire period of analysis corresponding to the frequency band $[0, \pi]$, and secondly, the procedure in windows was implemented for three selected frequencies related to the business cycle. Such a procedure enabled to capture the changes in the business cycle synchronization conditionally on the period of the analysis that includes the period 2007-2009. The spectral analysis approach for the moving window was proposed by the authors in this paper. The assumption of business cycle synchronization within the EU was confirmed for the strongest economies of the European Union like Germany, Great Britain and France. Moreover, Poland and Spain can also be included to the club of synchronized economies. Other EU economies, like the Hungarian, Italian and Portugese, were less synchronized with the EU business cycle, although in the period of crisis they were closer to the whole economic area. Thus, the hypothesis of decoupling can be partially confirmed for the mentioned countries. For the non-EU countries, significantly weaker synchronization with the EU was observed. In particular, the Swiss business cycle remained isolated from the others but in the period of 2007-2009 it was closer to the global tendency. It should be noted that the impact of the economic recession on business cycle synchronization occurred. The hypothesis that the financial crisis caused similarities in the business cycle paths of the EU countries and the USA was confirmed, while for Japan and Switzerland it could not be confirmed in the light of the obtained results. The fact discussed by Romer (2011), that the length of the business cycles may differ in different countries was confirmed in the light of the empirical results.

REFERENCES

Adamowicz, E., Dudek, S., Pachucki, D., Walczyk, K., *Wahania cykliczne w Polsce i strefie euro* [*Business Cycle in Poland and in Eurozone*]. PiM IRG SGH nr 89, Warszawa 2012.

Claassen, C., Kabundi, A., Loots E., *Decoupling between Emerging and Advanced Economies. An Exploratory Analysis.* Paper presented at the 11th EBES (Eurasia Business and Economics Society) Conference, Ekaterinburg 2013.

Dornbusch, R. *Klucz do sukcesu* [*A Key to Success*]. CeDeWu, Warszawa 2002.

Gächter, M., Riedl, A., Ritzberger-Grünwald, D. *Business Cycle Synchronization in the Euro Area and the Impact of the Financial Crisis,* "Monetary Policy & The Economy', Q2/12 pp. 33–60, 2012.

Grenander, U., Pollak, H.O., Slepian, D., *The Distribution of Quadratic Forms in Normal Variates: A Small Sample Theory with Applications to Spectral Analysis*, "Journal of the Society for Industrial and Applied Mathematics", Vol. 7, no. 4, pp. 374–401, 1959.

Hodrick, R. J., Prescott, E. C., *Postwar, U. S. Business Cycles: An Empirical Investigation*, "Journal of Money, Credit and Banking", Vol. 29, no. 1, pp. 1–16, 1997.

Kawa, P., *Wpływ zaburzeń na rynkach finansowych na wzrost gospodarczy w krajach na średnim poziomie rozwoju* [*The Impact of Shocks on Financial Markets on Economic Growth in Medium Developed Countries*] [in:] Wojtyna, A. (ed.) *Kryzys finansowy i jego skutki dla krajów na średnim poziomie rozwoju* [*Finanacial Crisis and Its Impact on Medium Developed Countries*]. PWE, Warszawa 2011.

Koopmans, L. H., *The Spectral Analysis of Time Series*. Academic Press, San Diego 1995.

Krugman, P., *Zakończcie ten kryzys!* [*End This Depression Now!*]. Helion, Gliwice 2013.

Minsky, H., *Stabilizing an Unstable Economy*. Yale University Press, New Haven 1986.

Osińska, M., Błażejowski, M., Kufel, P., Kufel, T, *Analiza porównawcza wybranych filtrów w analizie synchronizacji cyklu koniunkturalnego* [*Comparative Analysis of Selected Filters in Application to Business Cycle Synchronization*]. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, „Taksonomia" 23, pp. 41–50, 2013.

Piketty, T., *Capital in the Twenty First Century*. The Belknap Press of Harvard University Press, Cambridge, MA, 2014.

Priestley, M. B., *Spectral Analysis and Time Series,* Vol. I and II, "Probability and Mathematical Statistics", Academic Press, 1983.

Ravn, M. O., Uhlig, H., *Notes on Adjusting the Hodrick-Prescott Filter for the Frequency of Observations*, "The Review of Economics and Statistics*, 84(2), pp. 371–380, 2002.

Romer, D., *Advanced Macroeconomics*. McGraw-Hill, New York 2011.

Schoukens, J., Pintelon, R., Rolain, Y., *Time Domain Identification, Frequency Domain Identification. Equivalences! Differences?*, Proceedings of the 2004 American Control Conference, Boston, Massachusetts June 30 – July 2, 2004.

Skrzypczyński, P., *Analiza synchronizacji cykli koniunkturalnych w strefie euro.* [*Analysis of Business Cycle Synchronization in Eurozone*]. *Materiały i Studia*, Narodowy Bank Polski, Zeszyt nr 210, 2006.

Skrzypczyński, P., *Metody spektralne w analizie cyklu koniunkturalnego gospodarki polskiej.* [*Spectral Methods in the Analysis of Business Cycle in Polish Economy*]. *Materiały i Studia*. Narodowy Bank Polski, Zeszyt nr 252, 2010.

Stańczyk, Z., Wyrobek, J., *Zastosowanie analizy spektralnej do weryfikacji hipotezy o rozłączeniu się gospodarek rozwiniętych i wschodzących.*[*Application of Spectral Analysis to Testing the Hypothesis of Developed and Emerging Economies Decoupling*], Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie, pp. 5–21, 2013.

Stiglitz, J. E., *Towards a New Paradigm for Development: Strategies, Policies, and Processes.* Prebisch Lecture at UNCTAD, Geneva, October 19, 1998.

Talaga, L., Zieliński, Z., *Analiza spektralna w modelowaniu ekonometrycznym* [*Spectral Analysis in Econometric Modelling*], PWN, Warszawa, 1986.

Williamson, J., *A Short History of the Washington Consensus,* "From the Washington Consensus towards a New Global Governance," Barcelona, September 24–25, 2004. http://www.iie.com/publications/papers/williamson0904-2.pdf, 2004.

Woitek, U., *The G7 Countries: A Multivariate Description of Business Cycle Stylized Facts* [in:] Barnett, A. W., Gandolfo, G., Hillinger, C. (eds.), *Dynamic Disequilibrium Modelling.* Cambridge University Press, Cambridge 1996.