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2015

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Abstract

The aim of the study is to evaluate business cycle synchronization in the EU economies including determination of the impact of the global financial and economic recession of the years 2007-2009. In general, the economic recession can be understood as one of the phase 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 and, in consequence, might spoil business cycle synchronization that had been observed before the recession. It 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

[1] Financial support from National Center of Science in Poland, grant number 2012/07/B/HS4/02927 is gratefully acknowledged.

commonly assumed that GDP series in constant prices measure both: business activity and business cycle. In the presented research seasonally adjusted quarterly GDP series from the years 1995-2012 were analyzed. 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 years 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 or France. Moreover, Poland and Spain can also be included to the club of synchronized economies. Other EU economies, like Hungarian, Italian and Portugal 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, 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

JEL: C22, E32, F44.

Introduction

Business cycles synchronization is a key criterion of common monetary policy and monetary union of a group of countries. The process of economic convergence of member-states economies in the European Union was observed for many years in the last two decades. The efforts to achieve homogeneity of economies and to form unified economic body, despite of the fact that the countries differed specifically in the terms of trade and fiscal imbalances were observed for many years. Outbreak of 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 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 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 to state that in general synchronization between business cycle in Poland and the EU countries before the crisis had been observed. Skrzypczyński (2006) and (2010) provided a wide review of spectral methods used in business cycle synchronization and analyzed business cycle in Polish economy in years 1995-2007. He found, among others, that taking into account turning points, business cycle in Poland had been synchronized with 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 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 took 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 years 2007-2009 on the change of economic forces which drives the economies to different stage of development. In the research published by Stańczyk and Wyrobek (2013), the issue of business cycle synchronization between the USA and emerging economies in years 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 the unexpected and unusual phenomena like global crisis disrupted the relationships between economies observed in "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 the pronounced desynchronization of business cycles during the recession period. The authors measured the dispersion and correlation of business cycles.

The aim of the present study is to evaluate business cycle synchronization in the EU economies including determination of the impact of the global financial and economic recession of the years 2007-2009. In general, the economic recession can be understood as one of the phase 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 and, in consequence, might spoil business cycle synchronization that had been observed before the recession. It 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. The effects of the recession that started in 2007 may be observed in at least 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 GDP series in constant prices measure both: business activity and business cycle. In the presented research seasonally adjusted quarterly GDP series from the years 1995-2012 were analyzed. The choice of spectral analysis that is made on the basis of the frequency domain in straightforward. The first reason is that there exists full equivalence between time domain and frequency domain (see for example Schoukens et al. (2004)). It 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 basing on time domain are more aggregated than those basing on frequency domain. The second, and more important reason, for using spectral analysis to study business cycles synchronization is that it allows 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 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 years 2007-2009. The moving window approach to spectral analysis is authors' concept and it was not presented in the literature. To eliminate the impact of the long period frequencies the Hodrick-Prescott filter was used at very early stage of analysis (Hodrik and Prescott (1997)). Robustness of the applied procedure is discussed in 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.

Economic background

For recent 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 the document introduced in 1989 which was called the Washington Consensus (Williamson (2004)). There were formulated ten macroeconomic policy prescriptions to be applied mainly in developing countries, particularly in the Latin America. These prescriptions served as foundation of economic growth policy in this region. In sequent 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 recommendation as 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 such as deregulation principle and trade liberalization constituted a basis for 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 reason for the rise of new social and economic problems. Krugman stated, among others that the deregulation in 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 credits with higher risk rate. 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 huge financial and economic collapse. The reasons for such ideas lied in two economic phenomena that appeared simultaneously. First of them is the liquidity trap, i.e. it is a case when a decreasing short-term interest rate does not lead to substantial increase of banking credits. This means that monetary policy fails and can be no longer used as the efficient tool of macroeconomic policy. The second phenomenon is related to Minsky moment. Minsky (1986) noticed that a sudden major collapse of asset values was a part of the business cycle. It is due to the fact that reactions of entities in the microeconomic scale are debt-ridden and economic situation by limiting expenses do not work when 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 years 2007-2009 and its further continuation in Europe since 2010 (called euro-crisis) these kinds of activities have been bounded 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 economic recovery of the US economy started in 2010 and in 2014 and can be stated that it has really succeed. In Europe, despite of some financial support for 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. It has led to institutional changes in banking and public system. It is worth mentioning that some support for the weaker EU economies from ECB and IMF was delivered. It took place by means of international loans, for such as in the example of Greece and Ireland. Nevertheless generally speaking, the policy of tightening the belt has been widely forced. The basic characteristics of economic situation in some economies are shown in table 1.

Table 1.

Numbers shown in table 1 indicate that short-term interest rates are very low in almost all the countries, in the consequent central banks are nowadays without any tool to start the economic growth and to help in economies' recovery. It can be seen as well that in the period of last recession, governments have significantly increased their debt what confirms using 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: worsening situation in Greece, changing the policy in Hungary or creating a new union between Slovakia, Czech Republic and Austria being a side effect of 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 diminish. Furthermore, the country-specific problems made this situation even more complicated. They increase the gap between the developed and developing countries as the result of both 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 the period of stable growth and development.

Calendar of the financial and economic crisis in EU and USA

The financial crisis of the years 2007–2008 was not the first and last collapse of the global economy. Nevertheless it was the first global financial crisis in the 21st century and the biggest recession since 30. in 20th century. It is hard to say precisely when the crisis started. Some of the researchers take into account the first symptoms of some problems on the financial markets or the first bankrupts on subprime credits market in 2007 but most of the economists date the start of the financial crisis when Lehman Brothers went bankrupt in 2008. The great deal of worrying signals at the US financial markets have been unnoticed or simply ignored. Even slow down at the real estate market in 2005 and 2006 did not instilled worries into investors.

The main cause of the financial crisis in years 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 increasing prices of the real estate encouraged lending money to poorer families. In 2006, when prices of the real estate began to fall, people were unable to acquit their debts, what conduced huge losses in both: hedging founds 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 credits increased five times. A month later one of the biggest real estate mortgage creditor announced the possibility of bankruptcy. Similar situation in other financial agencies, like Wells Fargo, Lehman Brothers or JP Morgan occurred. Finally New Century Financial went bankrupt in April 2007. Main banks in the USA (such as: Merrill Lynch, Goldman Sachs, Morgan Stanley, Lehman Brothers, Citigroup) were subsided with billions of dollars. The sign of incoming recession was bankruptcy of two hedging founds, which accrued to one of the biggest investment bank in world – Bear Stearns. Most of the assets were invested into high risk credits connected with the real estate market. Bankruptcy of the fourth biggest investment bank in the USA – Lehman Brothers in September 2008 became an 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 had lost 400 billion dollars.

It is worth noting that 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 the domino effect. The source of the problems of financial institutions was similar to the past situations, i.e. irresistible investments in the sector of high risk credits. At first, the crisis concern only American financial markets, but very soon prices of real estates in Spain fell as well. It became clear that the European banks and the financial agencies also invested in bad securities. The share of subprime mortgage sector in the USA and in Europe was so high, that the turnover of credit instruments decreased, banks were forced to reduce payouts and freeze theirs businesses. Similarly to FED in the USA, the European Central Bank intervened to stop or to weaken incoming 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 ware about the financial support from government to the financial institutions. The cost of this plan was transferred to citizens – taxpayers. The

plan was rejected by the House of Representatives. It caused a huge collapse at the stock exchange markets. Immediately, work on a new version of Paulson's plan began. In the same moment the biggest provident bank in the US went bankrupt. Meanwhile in Europe government warranties for bank deposits were increased. The Netherlands capitalized ING financial group, International Monetary Fund lent 20 billion euro to help Hungarian economy. Similarly to the US, additional financial support for the European banks was delivered.

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

Methodology and the dataset

Examination of business cycle synchronization for the UE 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 that 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 Butherworth (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 time-domain filter (moving average). The properties of the above mentioned filters were discussed in Osińska et al. (2013). Characteristics of the filters are traditionally compared with the ideal filter. Let us consider the time series $\{x_t\}$, t=1,2, … ,n from which a specified component y_t with a period of fluctuation between p_l i p_u, ($2 \leq p_l < p_u < \infty$) is to be extracted. Then the relation can be written as $x_t = y_t + \bar{x}_t$. The component y_t is involved only in the frequencies of $\{(a,b) \cup (-b,-a)\} \in (-\pi,\pi)$, where $a=\frac{2\pi}{p_u}$; $b=\frac{2\pi}{p_l}$. The ideal band-pass filter for an infinite number of observations can be defined as:

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

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

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

Each of the considered filters accomplishes this task in a different way. As it was indicated in Osińska et al. (2013) Hodrick-Prescott and Christiano-Fitzgerald filters are the most appropriate for business cycle synchronization analysis. In further analysis 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, … ,n, the HP filter generates the above decomposition by minimizing the following formula:

$\arg\min\{\sum(y_t - \hat{y}_t)^2 + \lambda\sum(\hat{y}_{t+1} - 2\hat{y}_t + \hat{y}_{t-1})^2\}$ where the parameter λ is a positive smoothing constant. In empirical analysis the Hodrick-Prescott filtering methodology was applied with smoothing parameter determined according to the rule given by Ravn and Uhlig (2002). For quarterly data 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 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 in 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 empirical evaluation of business cycle synchronization (Skrzypczyński (2010); Woitek (1996)).

The cross-spectral analysis carried out for moving windows based on the fact that the fixed time window (subsample) was moved of 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 zero mean expressed as a vector: $z=[z_{1t},z_{2t},\dots,z_{rt}]$, where $t=\pm 1,2,\dots;r\geqslant 2$. (Priestley (1983); Talaga and Zieliński (1986)). Cross-spectral density function (cross-spectrum) can be expressed in the complex numbers form as:

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

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

The real part of the function $R: f_{jk}(\omega)=c_{jk}(\omega)$ is called co-spectrum (co-spectral density) and the imaginary part $I: f_{jk}(\omega)=q_{jk}(\omega)$ quadratic spectrum. (Talaga and Zieliński (1986); Priestley (1983)). Empirical analysis requires solving the problem of effective estimation of cross-spectrum. We applied discrete Fourier transform taking into account a possible weight system. Following weights called spectral windows are in use: Bartlett weights, Hanning weights, Balckman weights and many others (Priestley (1983)). In the empirical application shown in the next section Bartlett weights were taken, because there were no substantial differences in results when other spectral windows were used. It should be noted that in case 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 triangular (Bartlett) window. Unfortunately this method is not exactly applicable to a bivariate case considered in this paper.

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

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

The coherence coefficient takes values in the range $[0,1]$ and indicates the strength of a linear relationship between the processes $z_{\mathrm{jt}}, \mathrm{z}_{\mathrm{kt}+\tau}$ 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 these points for which they were computed. It is very important that coherence coefficient must be statistically significant. The appropriate test formula is presented in Koopmans (1995). Methods of computing equivalent degrees of freedom can be found in Koopmans (1995) and in Priestley (1983).

The phase angle is defined as:

$$\phi_{\mathrm{jk}}(\omega) = \arctan \frac{-q_{\mathrm{jk}}(\omega)}{c_{\mathrm{jk}}(\omega)}$$

and it measures 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 $[0,\pi]$.

Amplitude coefficient defined as

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

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

Empirical results

As it was mentioned in a previous sections 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 the 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 the gretl's foreign language mechanism. The relations between the packages are straightforward and do not require any additional operations. The examples of original and filtered series in the entire period of analysis are shown in figure 1.

Figure 1.

Despite of the relative differences in the growth pattern across countries the periodical component of GDP shown in figures 1 was quite similar in 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 HP filtered as described below. The transformed time series were checked for stationarity using both: ADF and KPSS tests[2]. All the results indicated stationarity of time series then spectral analysis is appropriate.

PANEL I

The results of the cross-spectral analysis obtained for the entire period of observations show strong synchronization of business cycle for all frequencies from $(0;\pi)$ interval between different subgroups drawn from the EU countries, that is EU27, EU15, Eurozone17 and

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

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 of the presentation only the selected results[3] are shown in figure 2.

Figure 2

General conclusion is that strong and statistically significant level of synchronization was observed using the coherence coefficient. For the confirmed significant coherence values the coefficients of phase and amplitude were additionally analyzed. Otherwise, a state of no synchronization between a given pairs of countries was announced. Statistically significant relations were found between EU27 and following countries: Germany, Great Britain, Spain, Poland and France as well. 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 coherence coefficient was significant at almost all frequencies that confirmed strong synchronization of business cycle between EU27 and traditionally its most powerful economies. For two remained countries the relation between the changes in output in comparison to EU27 is concentrated in the period corresponding to business cycle of the period of 2,5-6 years, what 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 EU15 and the mentioned countries. Much weaker synchronization of business cycle was presented for other member-countries of the European Union and EU27 (or EU15), like Hungary, Italy and Portugal. For the non-EU countries like the USA, Japan and Switzerland no synchronization with EU27 was observed. As concerns Eurozone17 and Eurozone12 very similar results were obtained, apart from the Czech Republic and Portugal.

[3] Results of analysis presented in figures are limited to the most typical situations. Full range of results is available from the authors on request.

These two countries had their business cycles synchronized with the Eurozone business cycles. Taking into account pairs of the countries it was noticed that 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 shows that in the pair of EU27 and EU15, economically stronger EU15 preceded EU27 in the frequencies corresponding to the period between 1 year and 6 years. That means that the economic recessions and recoveries started earlier in the countries concentrating majority of human and capital resources as well as technical progress and capitalized from the higher level of economic development. As far as EU27 and Norway is concerned Norway business cycle preceded EU27 in 3-6 years, while in 1,5-2,5 years the opposite direction was observed. In the pair Germany-EU27 no difference in phase was observed, while GBR preceded EU27 and EU27 preceded Spain and Poland. Comparing the Czech Republic and Poland it can be observed that business cycle in Poland was preceding the Czech Republic even in longer time interval i.e. between 0,5 year and 6 years. In the pair the USA-Japan the latter country was preceding the former in the business cycle (see figure 3).

Figure 3.

The shape of amplitude is presented in figure 4. It can be seen that in the periods corresponding to the business cycle (3-6 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 labor as well as in intensity of economic cooperation in many fields. It should be emphasized

that the results of phase and amplitude coefficients are interpreted only for those pairs of countries that had significant coherence coefficients.

Figure 4

Looking at the results more generally from the economic point of view it can be stated that those countries, which are traditionally related like EU27, EU15 and Germany, Great Britain and France are stronger related than others. The same concerns the USA and Japan. Surprisingly, there is no business cycle synchronization between some European countries and the EU or the Eurozone (in different configurations). The examples of non-synchronized or weakly synchronized countries are Italy, Hungary and Switzerland. While results concerning Switzerland, due to its position in financial capital accumulation, can be easily explained, it is rather difficult to explain quite different dynamics in business cycle in Italy and Hungary that belong to the European Union. The question arises whether the Italian economy was so different from 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 differs Italy from the other European countries where the systematic positive growth had been observed before 2009. Position of Hungary is quite different. After a decade of Europeanization process Hungary changed its policy in 2010 that might affect the results of the research. Another unexpected result is related to the fact that there is no synchronization between business cycles of the EU and the USA. It can be explained according to 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 different way of the interventions during the last economic crisis. As it is widely known, the level of statism in the EU and its member countries is much wider than in

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

Table 2.

Due to the fact that many combinations were computed the results were summarized in table 3.

Table 3.

Table 3 is valuable for the fact that it shows the scale of significant coherence coefficients and positive and negative phase coefficients when coherence was significant. The analysis of the results confirmed that business cycle in such countries as Hungary, Switzerland, Portugal, the USA and Japan was rarely synchronized with others even in the frequencies corresponding to the business cycles. Another important observation was that 3 years cycles were more often synchronized in comparison with 4,5 and 6 years that is in line with Skrzypczyński (2010). The results of phase coefficient show that EU15 preceded other economies in 60% - 76%. Low percentage values of the positive phase for the USA correspond to the fact that the US cycle was weakly synchronized with 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. The figure 5 shows the selected results of the investigation[4].

Figure 5.

The moving window methodology shows three curve lines for each characteristic. It enables deeper insight into changes of business cycle synchronization. Sequent years were put at OX axis. The analysis of the results confirmed strong and significant synchronization of the cycles in following pairs of countries: EU27 and Germany, EU27 and Great Britain, EU27 and Italy, EU27 and Poland in three cyclical frequencies. For EU27 and the USA significant coherence in the period of crisis was observed while for EU27 and Switzerland very weak synchronization was observed at period 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 years 2007-2009 that shows its enormous impact on the analyzed economies. It is worth noting that in such pairs as EU27 and Germany, EU27 and Great Britain, EU27 and Italy, EU27 and Poland the highest amplitude values correspond to 12 quarters and the smallest values are related with 24 quarters that support the thesis of short – 3 years cycle in the European countries. For 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 longer cycles were more important than shorter ones.

Conclusions

In the paper business cycle synchronization in the EU economies including determination of

[4] Results of moving windows analysis presented in figures are limited to the most typical situations. Full range of results is available from the authors on request.

the impact of the global financial and economic recession of the years 2007-2009 was evaluated. Firstly, we determined business cycle synchronization it 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 years 2007-2009. Spectral analysis approach for the moving window was proposed by 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 or France. Moreover, Poland and Spain can also be included to the club of synchronized economies. Other EU economies, like Hungarian, Italian and Portugal 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 the years 2007-2009 it was closer to the global tendency. It should be noted that the impact of the economic recession for business cycle synchronization took place. 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. Fact discussed by Romer (2011) that length of business cycles may differ in different countries was confirmed in the light of empirical results.

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Table 1. Basic characteristics of the state 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.

Table 2. Values of coherence, phase and amplitude for the selected pairs of countries and the selected frequencies

	Coherence			Phase			Amplitude ($\cdot 10^{-2}$)		
frequency	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$
period (yrs)	6.0	4.5	3.0	6.0	4.5	3.0	6.0	4.5	3.0
EU27 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

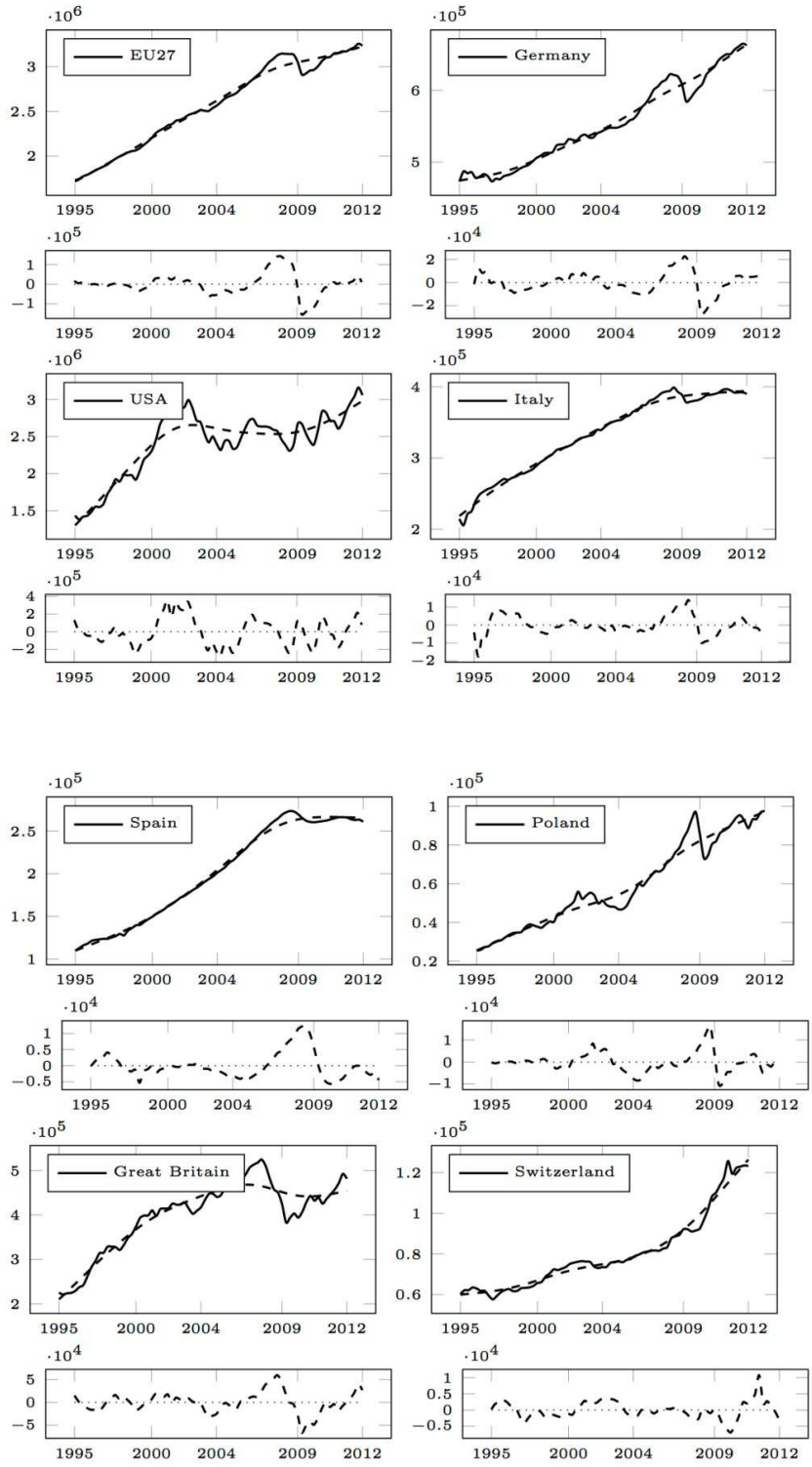
Source: own calculations

Table 3. Percentage of significant coherence, positive and negative phase for significant coherence for the selected countries and selected frequencies

	% of significant coherence			% of positive phase			% of negative phase		
frequency	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$	$\frac{\pi}{12}$	$\frac{\pi}{9}$	$\frac{\pi}{6}$
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%

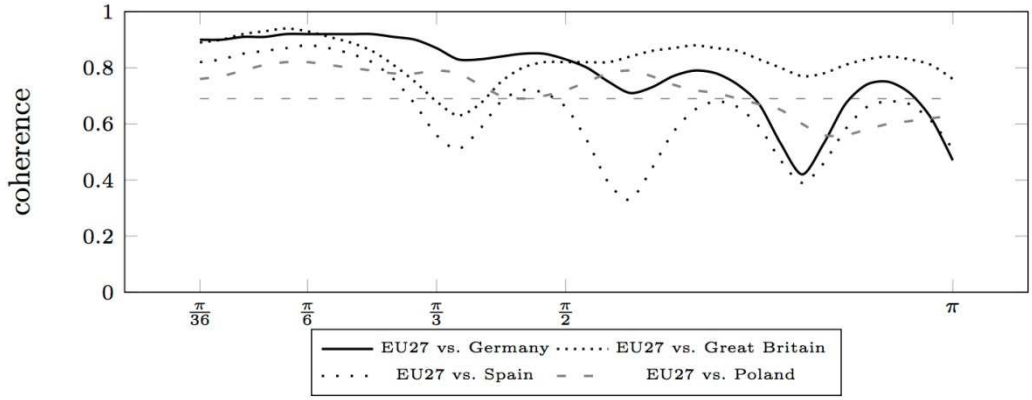
Source: own calculations.

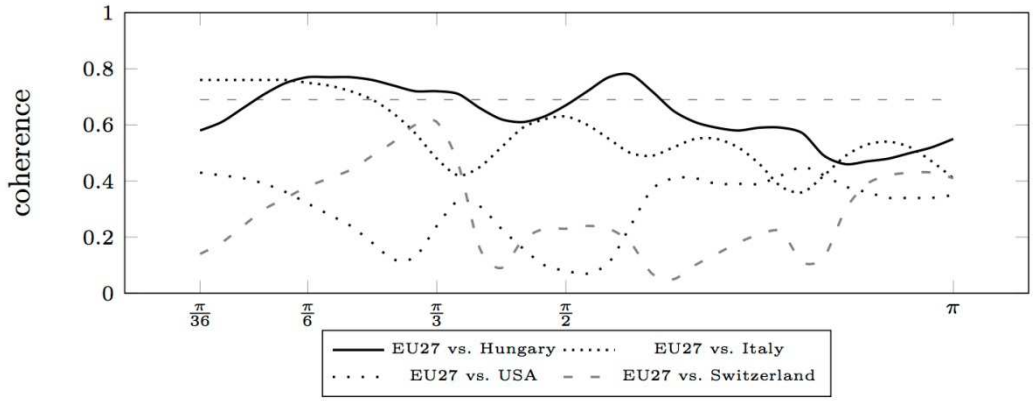
Figure 1: Gross domestic product in the selected countries with the trend component and the cycle component of HP filter

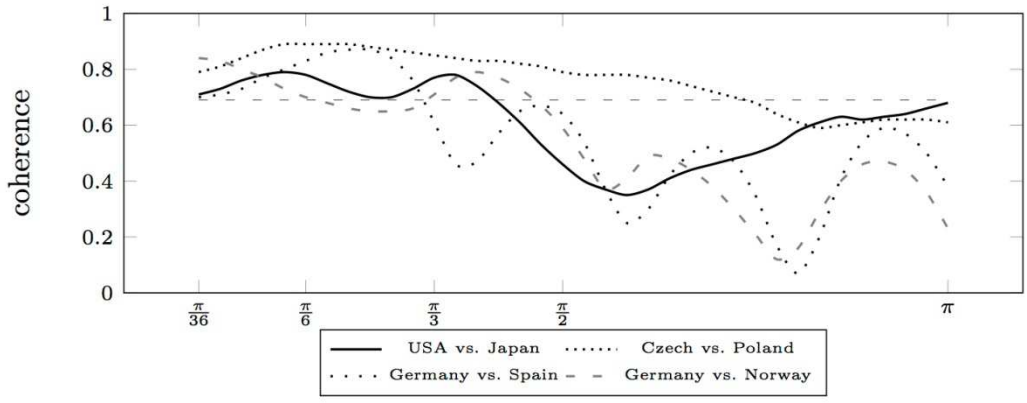


Source: own calculations based on Eurostat data

Figure 2: Coherence and its 5% significance level critical value for the selected pairs of economies (full range sample)

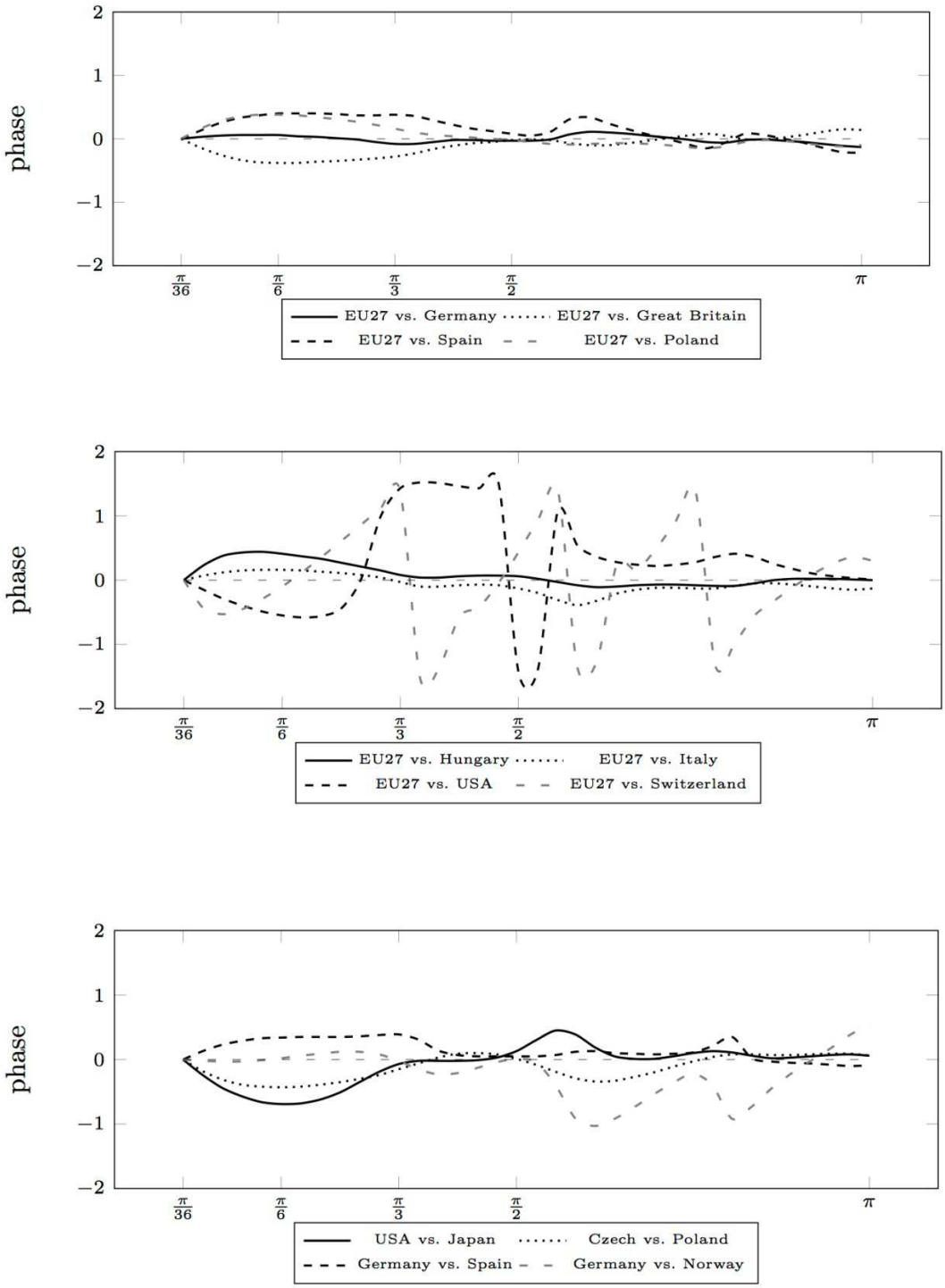






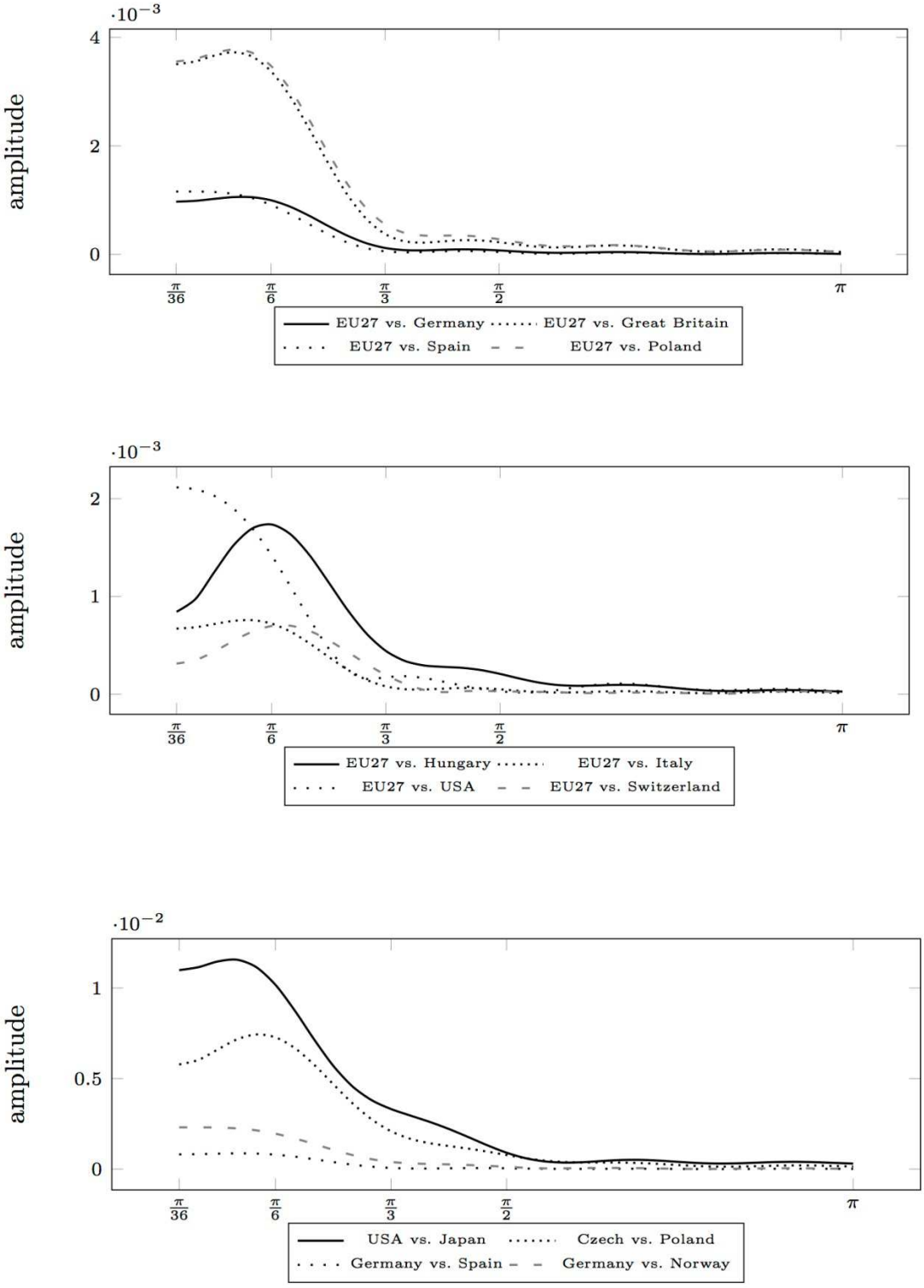
Source: own calculations

Figure 3: Phase for the selected pairs of economies (full range data)



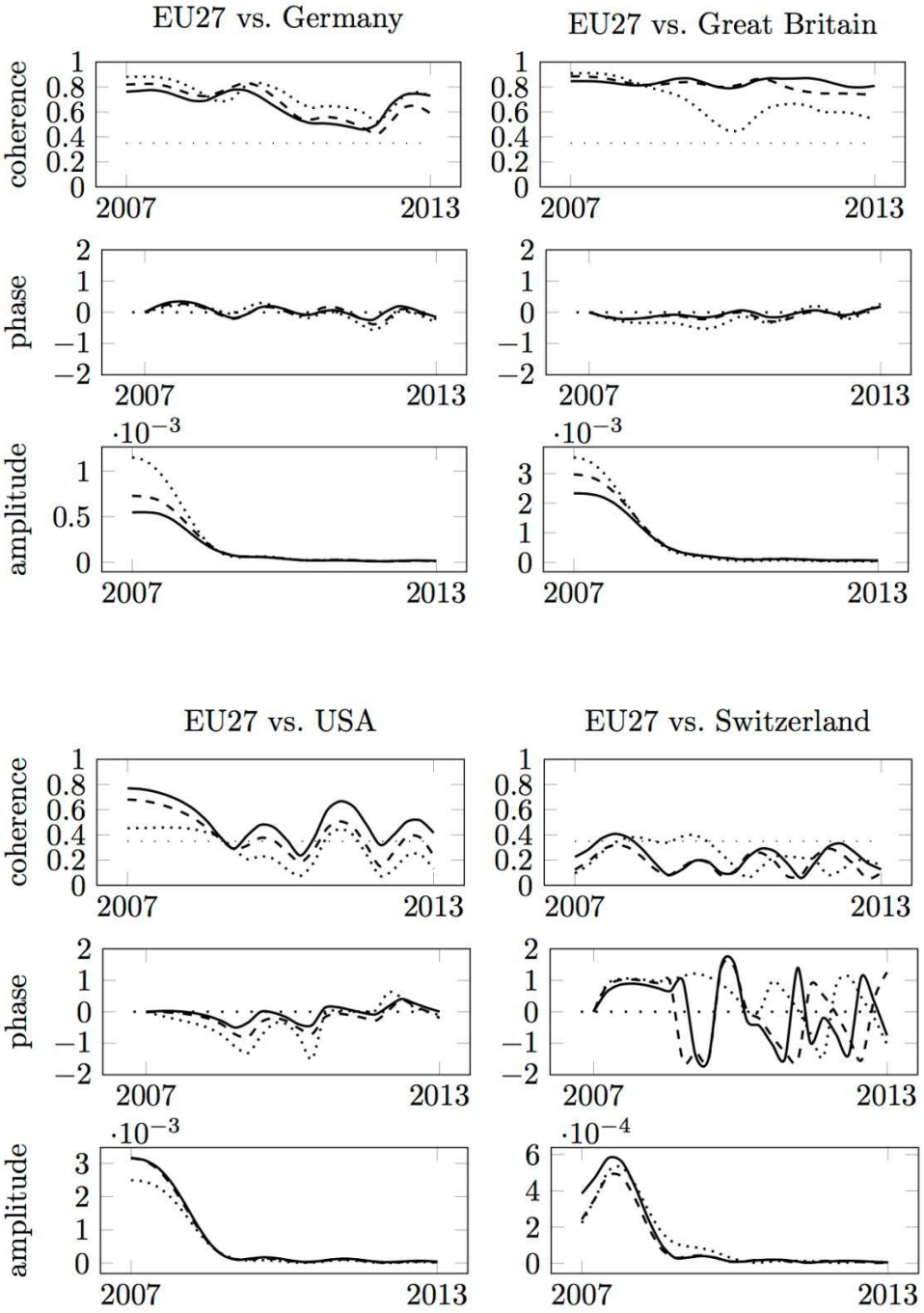
Source: own calculations.

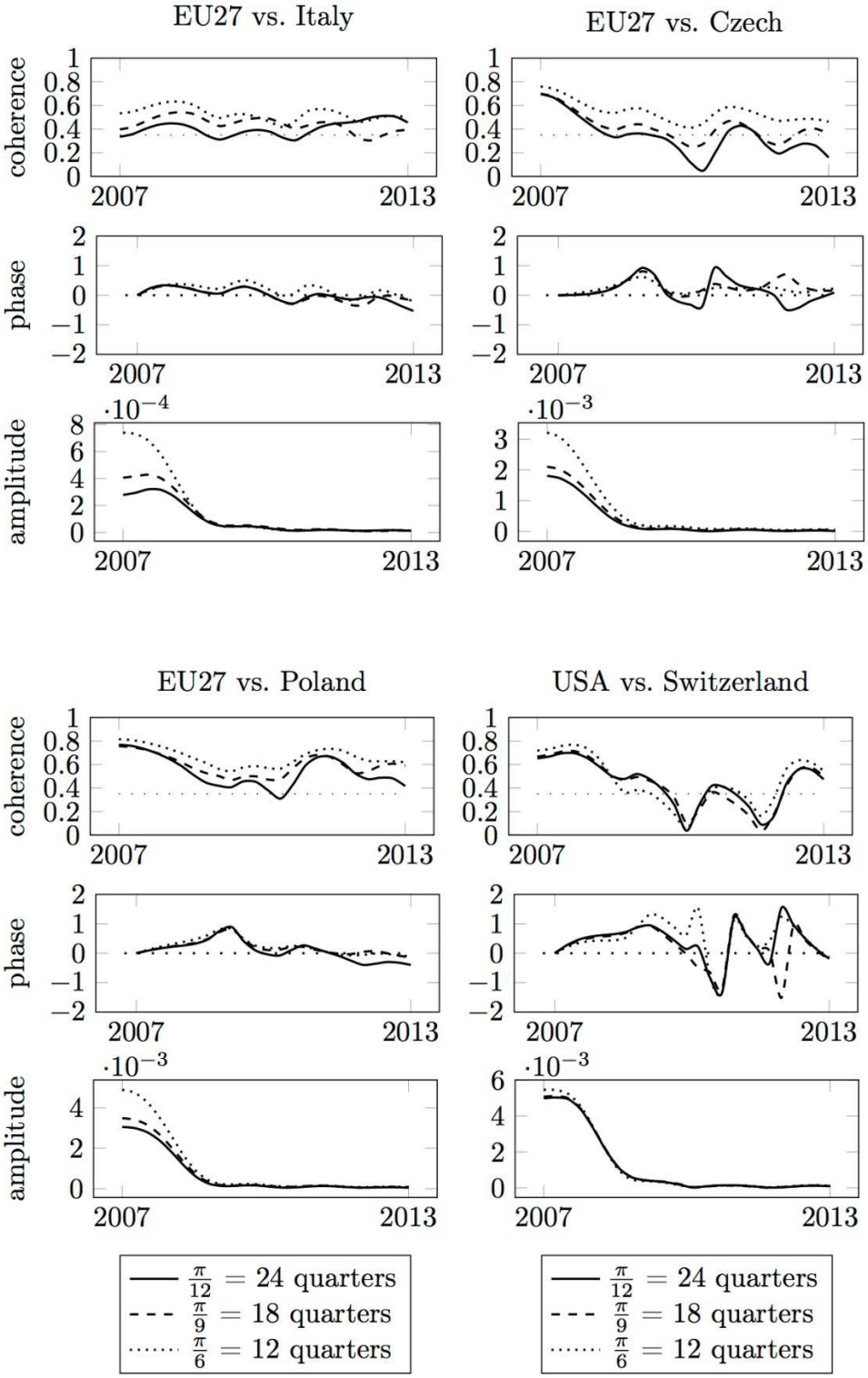
Figure 4. Amplitude for pairs of the selected countries (full range data)



Source: own calculations

Figure 5. Coherence, 5% critical value for coherence, phase and amplitude in windows for the selected pairs of countries and the selected frequencies





Source: own calculations.