Synchronization of business cycles between Poland, the euro zone and the new member states of the European Union

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Abstract. In the following paper, the business cycles between Poland and other members of the European Union are assessed for the purpose of determining their dependence. In order to identify the said dependence, various methods have been employed, primarily a spectral analysis and a co-integration. A special focus is applied to two groups of the member states: the euro zone, due to its significance in the European economy, but also other states that joined the EU with Poland during the same period. Interestingly, the coherence between the Polish and the euro zone business cycles is high, while it is much lower between Poland and the other new member states. The data also proves that Poland had benefited from the accession to the EU, even though this happened during an unfavorable period of the business cycle of the euro zone's countries. The analysis performed illustrates that the Polish business cycle over the years is becoming closer to the euro zone's cycle, while remaining behind it in phase. This conclusion is vital to some companies, as it might help them in mid-term strategy planning.

Keywords: business cycle, euro zone, spectral analysis.

JEL classification: C32, F41
AMS classification: 62M15, 93E11, 91B84

1 Introduction

The purpose of this paper was to analyse the business cycle in Poland and compare it to business cycles of: the euro area (as a whole), the European Union (as a whole), and of selected EU countries, in an attempt to verify if there is an economic evidence of synchronization of the Polish economy with the euro area business cycles which would vindicate Poland's decision to join the euro zone in the nearest future. Business cycle analysis is performed using methods applicable for time-series [5], specifically spectral and co-integration methods are utilised to analyse the business cycles and the relations between them. The results from previous research in this area are briefly described in the second part, and the final part contains the calculations and results of the research conducted by the authors of the paper.

2 Methods used in the article

2.1 Christiano-Fitzgerald band-pass filter

The Christiano-Fitzgerald band-pass filter is used to extract the cyclical part of the time series. The filter was chosen because of its applicability to almost all time series and its advantages over other methods (it takes into account stochastic structure of the decomposed variable, removes all non-seasonal fluctuations, etc.). The Christiano-Fitzgerald filter requires testing of the stationarity of time series (time series can be: stationary I(0), trend stationary or non-stationary I(1)). The filter requires the removal of time-trend (if it is present) and for processes stationary at I(1) one must remove a drift (if it is present) [9].

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The idea of calculating the cyclic component $\hat{y}_t^c$ in the band pass filter is based on the following formula from [8]:

$$\hat{y}_t^c = \hat{B}_t(L)y_t, \quad where: \hat{B}_t(L) = \sum_{j=-(T-t)}^{t-1} \hat{B}_{j,t}L^j \quad for \quad T = 1, 2, ...T \tag{1}$$

A set of weights $\hat{B}_{j,t}$ is the solution of the equation:

$$\underset{\hat{B}_{j,t} = -(T-t),...,t-1}{min} \int_{-\pi}^{\pi} \left| B\left(e^{-i\omega}\right) - \hat{B}_t\left(e^{-i\omega}\right) \right|^2 S_y(\omega)d\omega \quad for \quad t = 1, 2, ...T \tag{2}$$

For the CF filter for the I(1) series there is an additional (limiting) condition that: $\sum_{j=-(T-t)}^{t-1} \hat{B}_{j,t} = 0$ for $t = 1, 2, ..., T$ which provides for removal by filter of a stochastic trend. Further detail on the filter can be found in [8] and [9].

2.2 Single spectrum analysis method

The origin of spectral analysis is based on the idea of representing time series as the sum of sinusoids at various frequencies (cycles). Spectral analysis of cyclic data requires the Fourier transform, which is used to transform the time domain representation of the series into the frequency domain representation of the series. In order to determine the significance of different frequencies in data one calculates a spectrogram. A spectrogram displays the power of a signal as a function of both: time and frequency simultaneously.

According to [9], power spectrum of a stochastic process with discrete time $\{y_t\}_{t=-\infty}^{+\infty}$ with a zero mean and stationary covariance function is defined as the Fourier transform of autocovariance series $\{y_t^v\}_{k=-\infty}^{+\infty}$ of this process and is given as:

$$S_y(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{+\infty} \gamma_k^y \cdot e^{-i\varpi k} \quad for \quad \omega \in (-\pi, \pi) \tag{3}$$

Due to the fact that the spectrogram calculated by using the above method is very "fuzzy", certain methods are used to reduce this variability (smoothing methods), and one of the most popular is the Parzen window. The power spectrum estimator then takes the form:

$$\hat{S}(\omega) = \frac{1}{2\pi} \sum_{k=-H}^{H} w_k \cdot \hat{\gamma}_k^y \cdot e^{-i\varpi k} = \frac{1}{2\pi} \left[W_o \hat{\gamma}_0^y + 2 \sum_{k=1}^{H} w_k \cdot \hat{\gamma}_k^y \cdot cos(\omega k) \right] \tag{4}$$

Where empirical autocovariances are

$$\hat{\gamma}_k^y = \frac{1}{T} \sum_{t=1+k}^{T} (y_t - \bar{y})(y_{t-k} - \bar{y}) \quad for \quad k = 0, 1, .., T-1 \tag{5}$$

and Parzen window weights are:

$$w_k = \left\{ \begin{array}{rl} 1 - 6(k/H)^2 + 6(|k|/H)^3 & for \quad |k| \leq H/2 \\ 2(1 - |k|/H)^3 & for \quad H/2 \leq |k| \leq H \\ 0 & for \quad |k| > H \end{array} \right. \tag{6}$$

Maximum allowable lag time for Parzen window, called the truncation lag is chosen according to the rule $H = int(2\sqrt{T})$.

2.3 Cross-spectral analysis

"Cross spectral analysis allows one to determine the relationship between two time series as a function of frequency. Normally, one supposes that statistically significant peaks at the same frequency have been shown in two time series as that we wish to see if these periodicities are related with each other and, if so, what the phase relationship (time shift) is between them [6]".

There are several methods of calculating the cross-spectrum, one of which is given by Bloomfield [2]. The time series X and Y can first be "combined" in the time domain (before the Fourier transform) by calculating the lagged cross-covariance function. The resulting function is then subjected to a Fourier transform and a cross spectrum periodogram is obtained. Cross-covariance can be written as: $c_{x,y,r} = \frac{1}{n}\sum x_t y_{t-r}$, where t and $t-r = 0,\ 1,\ 2,\ ..,\ n-1$, and r is the time lag of one series relative to the other. The Fourier transform is then carried out to obtain the cross-spectrum periodogram:

$$I_{x,y}(\omega) = \frac{1}{2\pi}\sum_{|r|<n}(c_{x,y,r}\cdot e^{-ir\omega}) \tag{7}$$

Similarly to the single spectrum periodogram (spectrogram), the cross-spectrum periodogram is also smoothed, e.g. by a Parzen window. Applying the cross-spectrum analysis it is possible to calculate the following three measures: squared coherence, gain value and time shift between the series.

According to [9] a stochastic process with discrete time $\{x_t\}_{t=-\infty}^{+\infty}$, with zero mean and stationary covariance function is an independent variable, whereas the similar process $\{y_t\}_{t=-\infty}^{+\infty}$ is the dependent variable, the cross power spectrum (cross-spectral density) of these variables is defined as a Fourier transform of the cross-covariance series of these variables and is given by the formula:

$$S_{yx}(\omega) = \frac{1}{2\pi}\sum_{k=-\infty}^{+\infty}\gamma_k^{yx}e^{-i\omega k} = c_{yx}(\omega) - iq_{yx}(\omega) \quad for \quad \omega \in [-\pi,\pi] \tag{8}$$

where $c_{yx}(\omega) = \frac{1}{2\pi}\sum_{k=-\infty}^{+\infty}\gamma_k^{yx}cos(\omega k)$ is called co-spectrum and is a real part of cross-spectrum, while $q_{yx}(\omega) = \frac{1}{2\pi}\sum_{k=-\infty}^{+\infty}\gamma_k^{yx}sin(\omega k)$, called the quadrature spectrum, is a negative imaginary part of the cross-spectrum. It is possible to calculate three cross-spectral statistics on the basis of cross power spectrum: gain value ($G_{yx}(\omega)$), phase shift ($\Phi_{yx}(\omega)$), and squared coherence ($K_{yx}^2(\omega)$):

$$\begin{aligned} G_{yx}(\omega) &= \frac{\sqrt{c_{yx}^2(\omega)+q_{yx}^2(\omega)}}{S_x(\omega)} \\ \Phi_{yx}(\omega) &= tan^{-1}\left(\frac{-q_{yx}(\omega)}{c_{yx}(\omega)}\right) \\ K_{yx}^2(\omega) &= \frac{c_y^2x(\omega)+q_y^2x(\omega)}{S_y(\omega)S_x(\omega)} \end{aligned} \tag{9}$$

where $S_x(\omega)$ is the power spectrum of the process $\{x_t\}$, while $S_y(\omega)$ is the power spectrum of the process $\{y_t\}$.

2.4 Correction for the Polish time series used in the article

Countries and regions examined in this analysis (data was already seasonally adjusted with Demetra RSA1 [4] method) were subject to the transformations described above; i.e. the time series had time trend removed (or drift removed) if needed. Such data were then used for the Christiano-Fitzgerald filter, and finally for spectral analysis. However, for Poland, an additional adjustment was necessary; i.e. the elimination of an additional business cycle peak resulting from Polish accession to the European Union in 2004 (Fig. 1).

The implementation of the correction for the Polish series was preceded by analysing the results of calculations for an uncorrected series. Adjustments do not distort the picture of cyclical changes in Poland, because except for EU accession, Poland has had the same cyclical troughs and peaks as other EU countries, and therefore the correction erased the only anomaly that could disrupt the spectral analysis.

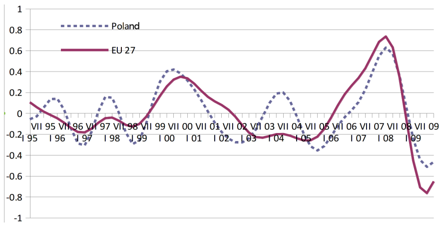

Figure 1 Polish and EU cyclical parts of GDP (percentage changes in real GDP with seasonality and time trend removed, and subjected to the CF filter). Calculations based on the World Bank real GDP data [11].

3 Brief overview of previous studies

The subject discussed in this paper has already received some attention, however the conclusions obtained by researchers differ substantially from each other. This is partly the result of different research methods, and partly due to the use of different underlying data provided by different sources. Several prominent studies and their results has been presented in Table 1.

		Poland		Euro area		Germany	
Authors	method	short cycle	long cycle	Coherence	Phase Shift	Coherence	Phase Shift
Adamowicz [1]	Baxter-King			0.39	-1.26	0.43	-1.17
Adamowicz	Christiano-Fitzgerald			0.47	-0.99	0.46	-0.99
Adamowicz	Hodrick-Prescott			0.35	-1.18	0.41	-0.96
Adamowicz	structural model			0.06	-3.96	0.08	-4.85
Skrzypczyski [9]	Christiano-Fitzgerald	3 y.	6-7 y.	0.52	-1 to -4		
Skrzypczyski [10]	filter CF		6-7 y.				
Skrzypczyski [10]	SVAR		12 y.				

Table 1 Research results on the length of the business cycles in Poland and their relationship to cycles Germany and the euro area (measured on the basis of the cyclical part of GDP)

Other research worth mentioning is [3] who used wavelets for calculating business sycle synchronization and concludes that the Polish business cycle is becoming more and more synchronized with the cycle of the euro area. On the other hand in [7] finds on average a lower degree of synchronization of the euro area cycle with the cycles of the countries of Central and Eastern Europe compared with the cycles of the member countries of the euro area.

4 Strength of the relationship between business cycles in Poland and cycles in other EU countries

The strength of the relationship between cycles (in addition to the length of the business cycle) of a particular country with other countries may indicate a strong relationship between their economies. In the case of spectral analysis, the strength of the relationship between cycles is measured by the squared coherence; the higher the coherence, the stronger the relationship.

As can be seen in Table 2, Polish economy cycles show a strong similarity to cycles in countries such as Finland, the Netherlands, Sweden, the United Kingdom (and also the whole EU). For most of the examined frequencies, coherence ratios were often over 80%. It can be also observed that for all countries there is high coherence in respect of long cycles (longer than 15 quarters).

A surprisingly low coherence exists between Poland and the majority of its neighbors; e.g. the Czech Republic, Slovakia or the Baltic States. It is also interesting to note that in spite of a very strong import-export ties between Poland and Germany, coherence between the two countries (which is quite high) is a little lower than the coherence of the Polish economy with the whole of the European Union and the euro area. These differences are even more apparent when the medians are considered. For the period

1995-2009, the median coherence with Germany is 72.3%, while it is 80% with the euro area and 82.1% with the European Union. The differences, which invite some more research, can be attributed to the effect of Polands accession to the EU in 2004, and to the exceptionally good performance of the Polish economy in 2009.

Country	Average	30	20	15	12	10	8,57	7,5	6,676	6
Austria	51.16	84.80	76.10	72.20	46.70	46.40	60.50	39.00	14.40	20.30
Belgium	49.93	65.10	51.30	57.70	35.40	41.70	63.40	59.90	49.90	25.00
Czech	46.1	63.90	55.20	58.80	50.70	42.40	14.00	1.20	44.70	84.00
Estonia	52.22	63.40	43.70	36.90	64.20	84.70	71.50	14.00	26.20	65.40
Finland	61.61	87.40	82.90	82.00	82.70	83.90	68.20	17.30	6.00	44.10
France	64.97	85.20	80.80	82.30	85.40	87.30	80.10	45.60	9.80	28.20
Germany	64.88	79.60	69.20	72.30	85.00	89.00	74.40	27.30	21.20	65.90
Hungary	63.46	88.40	83.80	73.40	72.70	80.60	65.20	22.50	16.70	67.80
Ireland	58.8	80.00	71.80	73.60	85.80	89.40	77.20	33.80	15.60	2.00
Italy	58.93	76.90	67.50	68.50	81.10	88.50	77.70	33.40	8.60	28.20
Latvia	51.26	77.40	60.00	52.60	62.00	76.70	71.80	33.40	8.40	19.00
Lithuania	45.1	49.90	30.90	33.70	58.60	73.30	59.20	17.80	21.00	61.50
Netherlands	66.67	91.70	88.40	84.60	80.40	77.20	71.00	38.80	8.80	59.10
Portugal	56.98	81.30	72.50	67.80	45.80	43.60	70.60	71.20	30.90	29.10
Slovakia	27.31	37.00	30.10	37.90	45.90	35.10	10.90	6.20	17.60	25.10
Slovenia	55.91	85.20	76.70	72.50	64.90	66.30	63.90	22.20	7.50	44.00
Spain	61.9	90.10	84.90	82.30	72.90	71.60	73.70	50.20	2.80	28.60
Sweden	63.39	90.00	90.40	83.60	77.10	86.50	76.40	25.20	6.00	35.30
UK	65.94	86.30	84.40	84.90	81.30	79.90	70.70	30.20	12.10	63.70
EU 27	67.28	86.50	83.00	82.10	83.80	86.80	76.30	30.00	13.80	63.20
Euro 17	67.66	86.50	81.50	80.00	83.70	87.90	78.40	33.00	14.00	63.90

Table 2 Squared coherence between business cycle in Poland and other European countries, [in %] (for different cycle lengths); years 1995-2009. Based on the World Bank real GDP data [11].

5 Phase shift of the Polish business cycles in relation to business cycles in other EU countries

Table 3 presents the calculated phase shifts (difference in time) between business cycles of the Polish economy and cycles of other countries (for different frequencies). The negative sign means that Poland's cycle is ahead of a particular country. It is important to note that the shifts are expressed in quarters of a year, therefore a shift of 20 means 5 year time difference. As can be seen in this table, Polish cycle is generally behind most of the EU countries, following their cycle pattern. This has changed in recent years, since until 2005 Poland was often ahead of other EU countries. This may be regarded as a proof that Polish economy is strengthening its ties with the rest of the Europe and is more and more influenced by the state of the joined economies.

6 Conclusions

When comparing Poland to the euro area countries, a short cycle for Poland (estimated at 3 - 4 years, or about 10 quarters) is similar to the short cycle of the strongest euro economies (Germany, France, Italy). However, the long cycle for Poland (estimated at 6 - 7 years, approximately 20 - 30 quarters) tends to be a little longer than the long cycle of these strongest euro economies

For the period 1995 - 2009 coherences are significantly high for virtually all countries, and high coherence is observed even for short cycles (even for 6 quarter cycles). A surprisingly low coherence exists between Poland and the majority of its neighbors; i.e. the Czech Republic and Slovakia and the Baltic States.

The amplitudes of fluctuations of the Polish economy are bigger than the amplitudes of fluctuations in the euro zone and in the major economies in the euro zone, but comparing the periods 1991-2005 and 1995-2006 the similarity of the amplitudes have increased. The same applies to most new EU members with the exception of the Czech Republic which had relatively low amplitudes of business cycles.

All the results indicate that the synchronization between the business cycle in Poland and in the euro area is relatively high and appears to be increasing. However, it should be added that the results could be to some extent influenced by the conduct of economies during the last global crisis of 2008.

Country	30	20	15	12	10	8.6	7.5	6.7	6
Austria	-0.06	0.81	1.07	0.43	0.25	0.63	0.89	1.03	0.03
Czech	-1.38	-0.48	-0.17	-0.54	-0.79	-0.04	0.27	-1.23	-0.97
Estonia	1.55	0.75	0.75	0.55	0.28	0.39	0.55	1.62	-1.31
Finland	0.93	0.29	-0.02	-0.09	0.09	0.40	0.65	-1.25	-1.13
France	0.29	0.66	0.73	0.47	0.53	0.73	0.93	0.89	-0.29
Germany	0.01	0.24	0.49	0.32	0.21	0.38	0.44	-0.89	-1.00
Hungary	1.43	0.89	0.59	0.02	-0.04	0.32	0.48	-0.95	-1.07
Ireland	0.78	0.58	0.62	0.51	0.49	0.66	1.11	0.95	-0.49
Italy	0.29	0.39	0.48	0.31	0.17	0.24	0.48	0.72	-0.07
Latvia	0.14	0.24	0.60	0.24	0.01	0.32	0.74	0.32	1.22
Lithuania	-0.25	-0.72	-0.46	-0.46	-0.36	0.16	0.58	-1.50	-1.23
Netherlands	-0.31	-0.09	-0.08	-0.21	0.06	0.51	0.74	-0.06	-0.79
Portugal	-0.50	0.38	0.63	0.46	1.08	1.04	0.83	0.76	0.21
Slovakia	-2.55	-1.59	-0.76	-0.73	-0.46	0.75	1.85	0.91	1.48
Slowenia	-0.74	-0.43	-0.16	-0.29	-0.03	0.47	0.69	-1.06	-1.06
Spain	-0.97	-0.12	0.38	0.32	0.69	0.97	1.03	0.72	-0.94
Sweden	2.46	1.58	1.13	0.47	0.18	0.33	0.47	-0.96	-0.88
UK	1.29	0.65	0.38	0.05	-0.02	0.36	0.63	-1.17	-1.21
EU 27	0.56	0.45	0.43	0.19	0.16	0.38	0.52	-0.73	-0.94
EURO 17	0.35	0.37	0.40	0.20	0.19	0.38	0.50	-0.55	-0.85

Table 3 Phase shifts (in quarters) between business cycle in Poland and other countries (for different frequencies); years 1995-2009. Calculations based on the World Bank real GDP data [11].

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