Central European Journal of Economic Modelling and Econometrics

Cyclical Processes in the Polish Economy

Marta Skrzypczyńska*

Submitted: 19.12.2013, Accepted: 30.07.2014

Abstract

The economic activity indicators in Poland during the years 1995-2011 exhibit various cyclical patterns. Employing the Christiano – Fitzgerald band-pass filter and unobserved components model it is shown that the cyclical processes of Polish economic activity are driven by overlapping higher frequency fluctuations (3-4 years) and longer cycles of 8.5 years. The cyclical fluctuations of construction, transportation and trade are dissimilar to gross value added. Economic activity in transportation leads and in construction lags the fluctuations of gross value added. Cyclical fluctuations of gross value added seem to be determined by industry and construction. Manufacturing, especially capital and intermediate goods fluctuations are responsible for the variation of industry. The production of non-durable consumer goods, energy and production of electric power are relatively the most desynchronized compared to industry. Production of electric power leads industrial production. Capital goods, intermediate goods and energy cycle phases are asymmetric – the slowdown lasts shorter and has higher amplitude compared to expansion. During the last crisis occurred the intensified variation of economic activity in Poland.

Keywords: business cycle, turning points, sectoral analysis, Christiano-Fitzgerald band-pass filter, unobserved components model

JEL Classification: C22, C32, E32

*Szkoła Główna Handlowa; e-mail: marta.elzbieta.skrzypczynska@gmail.com

1 Introduction

The business cycle refers to fluctuations of the economic activity occurring around a long term trend, that recur every 1.5-10 years and are irregular in length and amplitude. There is a comovement of activity among different sectors of the economy. The article concerns the deviation cycles.

Many researchers use the GDP and industrial production to business cycle analysis. However, these economic indicators are highly aggregated. Therefore, it is reasonable to analyze the cyclical behaviour across many sectors of the economy. For Polish economy there is only a few papers concerning the business cycle analysis and still there is a lack of consensus in relation to business cycle chronology. There are several papers exploring stylized facts of Polish business cycle on the basis of wide range of economic indicators (see Fic 2007, Adamowicz *et al.* 2008, Gradzewicz *et al.* 2010, Skrzypczyński 2010, Lenart, Pipień 2013a and Skrzypczyńska 2013). Fic (2007) and Skrzypczyńska (2013) described the main business cycle characteristics in Poland using Markov-switching models and Gradzewicz *et al.* (2010) based on the spectral analysis. These papers contain the dates of the turning points, the cycle phase identification and point that Polish economic activity is determined by shorter cycles lasting about 3-4 years and longer ones (6-10 years). With the latter conclusion agree Lenart, Pipień (2013a) analyzing the almost periodically correlated time series. Gradzewicz *et al.* (2010) explore also the main relations between macrovariables concluding that many of them are similar to those for highly developed countries. Synchronization of business cycle between Poland and the euro zone using the spectral analysis was conducted by Adamowicz *et al.* (2008), Skrzypczyński (2010) and Konopczak (2009) exploiting various econometric methods. The authors of all cited papers unanimously conclude that Polish economy is relatively highly correlated with the euro area countries. Bruzda (2011) exploiting wavelet analysis states also that synchronization of Polish business cycle with the euro zone cycles is slightly higher after the global financial crisis. The same conclude Wyrobek, Stanczyk (2012) using spectral analysis and Konopczak, Marczewski (2011) look for possible explanation for better performance of the Polish economy and the cyclical divergence as a consequence compared to the euro area during recent financial crisis. Fidrmuc, Korhonen (2010) and Hallet, Richter (2012) also investigate its impact on the business cycle characteristics in emerging Asian economies and GIPSI countries respectively.

There are also only a few papers concerning the business cycle analysis in Poland based on different methods of extracting the cyclical component from the data (see Adamowicz *et al.* 2008, Skrzypczyński 2010, Skrzypczyńska 2011) and concerning the impact of the last financial crisis on the business cycle in Poland (see Bruzda 2011, Konopczak, Marczewski 2011, Pietrzak 2014, Wyrobek, Stanczyk 2012). The article fills this gap.

The aim of the conducted analysis is a description of the business cycle in Poland on the basis of sectoral indicators of economic activity using Christiano – Fitzgerald band-pass filter and unobserved components model and an exploration of changes in

business cycle after the last financial crisis.
The structure of this paper is as follows. Section 2 describes the data while Section 3 discusses the econometric methodology. Section 4 provides an empirical results concerning extraction of the cyclical component, dating, turning points analysis, cross-correlations between cyclical components, identification of dominating periodicities of cycles and the influence of the crisis on the business cycle characteristics. Concluding remarks are given in Section 5.

2 The description of the data

The database covered the wide spectrum of the economic activity represented by the chosen sections of the national economy accounting for almost 60% of the gross value added. In addition to national economy data the fluctuations of sold production of manufacturing and industrial production according to Main Industrial Grouping (MIG) covering: durable consumer goods, non-durable consumer goods, capital goods, intermediate goods and energy are employed. The statistical classification in line with MIG is an intermediate level in the statistical breakdown between sections on the one hand, and the divisions and groups on the other. These two latter classifications do not let conduct the fruitful analysis – on the one hand there is an overweight share of manufacturing in the overall industry activity that determines the fluctuations of the latter, on the other hand the 34 industry divisions are too numerous and heterogenous. Furthermore, the industry breakdown according to MIG allows to draw conclusions on the activity of the main entities of the national economy: households and enterprises. The production of durable and non-durable goods accounts for 6% and 20% of the industrial production respectively and is related to sold production of enterprises producing mainly ready-made goods meeting the living needs of people. The production of capital goods covers the machinery and equipment for the production process, whereas the intermediate goods relate to raw materials, semi-finished products and ready-made goods for further production process. The share of these two groups is 20% and 34% respectively and is more meaningful for enterprises than households. The production of energy amounts to about 20% of the overall industrial production and is related to i.a. quarrying of coal, mining of petroleum and gas, electric power production, that are more important in meeting needs of the enterprises than the households. In 2011 the households' consumption of the electric power contributed to almost 20%. The electric power production, which is mostly consumed by the enterprises, is also known as the early warning economic activity indicator.
The database included logarithms of quarterly time series: gross value added, construction, transportation and storage, trade and repair of motor vehicles and monthly indicators: sold production of industry, manufacturing, durable consumer goods, non-durable consumer goods, capital goods, intermediate goods, energy and production of electric power. The quarterly data ranged from the first quarter of

1995 to the fourth quarter of 2011, excluding transportation and storage, trade and repair of motor vehicles – the last observation was the third quarter of 2011. The sample of monthly data included the period from January 1995 to January 2012. The analysis was conducted on seasonally adjusted data, although it may cause a loss of significant information (see Ghysels 1988) and lead to improper business cycle inference concerning peak and through dates (see Franses 1996). Conversely, there is a spectral leakage at the seasonal frequencies while using CF filter. Although UC models give an opportunity to incorporate seasonal patterns, it was chosen not to do so for the sake of comparability with previous research for Polish economy - which uses this attitude extensively. Only a few, such as Lenart, Pipień (2013b), present the alternative to this approach. The time series were seasonally adjusted by TRAMO/SEATS. One disadvantage of this method is the incorrect detection of outliers (see e.g. Grudkowska, Paśnicka 2007, Grudkowska, Nehrebecka 2009). After seasonal adjustment there were additionally removed two outliers of gross value added relating to the fourth quarter of 1996 and the first quarter of 2005 and ten outliers of the production of electric power (2M1996, 1M1997, 4M1997, 10M1997, 10M1998, 9M1999, 1M2001, 1M2005, 7M2007, 3M2008) – the arithmetic mean of two neighbouring observations was calculated. As far as a hypothesis that unit root exists is concerned, the conclusions of ADF test with p-value 0.05 regarding the model with constant and linear trend were mostly not confirmed by the KPSS test (Table 1), conversely to the model with the constant only. With the significance level of 0.05, according to the values of ADF test, we cannot reject the null hypothesis, that the unit root exists almost for all macrovariables (except for trade, energy and production of electric power). The joint ADF-KPSS test was used as an alternative (see Kębłowski, Welfe 2004). Finally, with the significance level of 0.05 the DGP (Data Generating Process) of almost all analysed time series is a random walk with drift, with the exception of the production of energy and electric power – the DGP is stationary and trendstationary respectively. Before filtering the cyclical components, for a non-stationary series a drift was removed by subtracting the mean of the time series first differences, whereas for a trendstationary and stationary process the linear trend and the mean of the time series was removed respectively.

3 Structural decomposition of output growth

Business cycle analysis of Polish economy was conducted on the basis of sectoral indicators of economic activity employing Christiano – Fitzgerald band-pass filter and unobserved components model.

3.1 Spectral analysis and Christiano-Fitzgerald band-pass filter

Spectral analysis assumes that every covariance-stationary process can be represented in a frequency domain requiring to determine the power spectrum, that allows the assessment of the impact of different frequencies on the variability of the time series. Spectral density function is given as a Fourier transform of the autocovariance-generating function. Given the sequence of covariances $\{\gamma_k\}_{k=-\infty}^{\infty}$ of covariance-stationary process, that these autocovariances are absolutely summable, spectral density function is:

$$f_y(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_k e^{-i\omega k} \text{ for } \omega \in [-\pi, \pi], \tag{1}$$

where $\frac{2\pi}{\tau}$ is a frequency related to period τ. Having the finite sample, the estimator of the spectral density function, known as a sample periodogram, refers to empirical autocovariance $\widehat{\gamma}_k$, that can be written (see Skrzypczyński 2008):

$$I_y(\omega_j) = \frac{1}{2\pi} \sum_{k=-(T-1)}^{T-1} \widehat{\gamma}_k^y e^{-i\omega_j k} = \frac{1}{2\pi} \left[\widehat{\gamma}_0^y + 2 \sum_{k=1}^{T-1} \widehat{\gamma}_j^y \cos(\omega_j k) \right]. \tag{2}$$

The periodogram is an even function of nonnegative values, that is why the frequency domain can be limited to $[0, \pi]$. On the one hand the estimator (2) is asymptotically unbiased, on the other hand inconsistent. To reduce the variance associated with ω_j, one can smooth the periodogram with the spectral window. The periodogram allows to determine the portion of the variance of time series that can be attributed to cycles of different frequencies.

Spectral analysis of two covariance-stationary processes $\{x_t\}$ and $\{y_t\}$ relies on cross-spectrum, given the Fourier transform of the sequence of cross-covariance $\{\gamma_k^{yx}\}_{k=-\infty}^{\infty}$ of these variables (see Hamilton 1994):

$$S_{yx}(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{+\infty} \gamma_k^{yx} e^{-i\omega k} = c_{yx}(\omega) + i q_{yx}(\omega) \text{ for } \omega \in [-\pi, \pi]. \tag{3}$$

The formula

$$c_{yx}(\omega) = 2\pi^{-1} \sum_{k=-\infty}^{+\infty} \gamma_k^{yx} \cos(\omega k) \tag{4}$$

is called a co-spectrum and measures the covariance between cycles of two processes of the same phase, when

$$q_{yx}(\omega) = -2\pi^{-1} \sum_{k=-\infty}^{+\infty} \gamma_k^{yx} \sin(\omega k) \tag{5}$$

is a quadrature spectrum and refers to out of phase signal. Cross-spectrum is in general not real-valued, the co-spectrum and quadrature spectrum are its real and imaginary part respectively. Cross-spectral density allows to define coherence, gain and phase shift between two processes. These statistics are as follows (see Sargent 1987):

$$K_{yx}^2(\omega) = \frac{c_{yx}^2(\omega) + q_{yx}^2(\omega)}{S_y(\omega) S_x(\omega)} \text{ for } \omega \in [-\pi, \pi], \tag{6}$$

$$G_{yx}(\omega) = \frac{\left(c_{yx}^2(\omega) + q_{yx}^2(\omega)\right)^{\frac{1}{2}}}{S_x(\omega)} \text{ for } \omega \in [-\pi, \pi], \tag{7}$$

$$\varphi_{yx}(\omega) = tan^{-1}\left(\frac{-q_{yx}(\omega)}{c_{yx}(\omega)}\right) \text{ for } \omega \in [-\pi, \pi], \tag{8}$$

where $S_x(\omega)$ and $S_y(\omega)$ refer to spectrum of $\{x_t\}$ and $\{y_t\}$ respectively. Moreover Croux *et al.* (2001) introduced the dynamic correlation:

$$\rho_{yx}(\omega) = \frac{c_{yx}(\omega)}{\sqrt{S_y(\omega) S_x(\omega)}} \text{ for } \omega \in [-\pi, \pi]. \tag{9}$$

The coherence is ranged between $[0, 1]$ and measures the strength of the linear relationship in a regression of y_t on leads, lags and coincident values of x_t for a given ω. The dynamic correlation ranges between $[-1, 1]$ and in addition allows to inference on the direction of the coincident relationship between variables. The gain is an even function and takes on the nonnegative values. If $G_{yx}(\omega) > 1$, then the variable x_t has the smaller amplitude compared to fluctuations of the reference series y_t and conversely, if $G_{yx}(\omega) < 1$ (see Skrzypczyński 2010). The phase shift is in radians and allows to determine the lags or leads of y_t in reference to x_t for the given frequency ω – the negative (positive) value of $\varphi_{yx}(\omega)$ means the lead (lag).
To extract the components of the desirable frequency one could use the 'ideal' band-pass filter, requiring although the infinite amount of data (see Sargent 1987):

$$y_t^c = B(L) y_t, \tag{10}$$

where $B(L) = \sum_{j=-\infty}^{\infty} B_j L^j$ for $t = 1, 2, \ldots, \infty$, $B_{-j} = B_j$ and $\sum_{j=-\infty}^{\infty} |B_j| < \infty$.
In practice, it is used the approximation of the 'ideal' filter, e.g. BK – Baxter-King (1995) and CF – Christiano-Fitzgerald (2003). In the article, to isolate the cyclical component of the time series the Christiano-Fitzgerald asymmetric band-pass filter was used. The CF filter is similar to HP – Hodrick-Prescott (Hodrick, Prescott 1997) and BK filters. First of all, the common feature with HP is the extraction of the same number of observations of the time series before and after filtering. Secondly, the choice of the band-pass is the same as for BK. To contrast the CF filter with HP and BK, it requires exploration of the DGP of the time series. If the DGP is stationary, before one use CF filter, there is a necessity to remove a mean and if the DGP is I(1),

the drift should be eliminated. In the case of the trend stationarity the trend has to be removed. For a finite sample the estimator of the component $\hat{y}_t^c$ for fluctuations of the specific frequencies is:

$$\hat{y}_t^c = \hat{B}_t(L)\, y_t, \tag{11}$$

where $\hat{B}_t(L) = \sum_{j=-(T-t)}^{t-1} \hat{B}_{j,t} L^j$ for $t = 1, 2, \ldots, T$ (see Christiano – Fitzgerald 2003) and the weights $\hat{B}_{j,t}$ are time varying. The CF filter asymmetry results from the dependence of an index of summation on time, that results in a shift of the $\hat{y}_t^c$ component at the beginning and at the end of the sample in comparison with the time series before filtering (phase shift), that generates the estimation uncertainty at the beginning and at the end of the finite sample. The weights are given as a solution of the following optimization problem:

$$\min_{\hat{B}_{j,t},\ j=-(T-t),\ \ldots,\ t-1} E\left(\left(y_t^c - \hat{y}_t^c\right)^2 \,\middle|\, \{y_t\}_{t=1}^T \right) \tag{12}$$

for $t = 1, 2, \ldots, T$.

3.2 Structural time series model – Watson model

Structural time series models is also known as unobserved components model (UC model) or state space model and allows to decompose time series into unknown (hidden) components, e.g. permanent and transitory components, taking into account its DGP. As far as the business cycle analysis is concerned, the UC model is used to decompose the time series into trend and cycle. Many papers base on the Watson (1986) model:

$$Y_t = T_t + C_t, \tag{13}$$

$$T_t = \mu + T_{t-1} + \varepsilon_t, \tag{14}$$

$$C_t = \phi_1 C_{t-1} + \phi_2 C_{t-2} + \xi_t, \tag{15}$$

where $\varepsilon_t \sim i.i.d.\ N\left(0; \sigma_\varepsilon^2\right)$ and $\xi_t \sim i.i.d.\ N\left(0; \sigma_\xi^2\right)$. In this specification it is assumed that trend T_t is a random walk with drift μ and cyclical component C_t is a stationary AR(2) process. Also the shocks to trend and cycle are independent, that results in getting a smooth trend and a pronounced cycle. It means that innovations to the cycle are more important than shocks to the trend for explaining the business cycle. If σ_ε^2 equals zero, then the resulting trend model is the deterministic linear time trend model. Watson model was used to estimate the unobserved components for GNP of US economy: potential GNP and the output gap. The same specification can be found in Skrzypczyński (2008) for Polish GDP, Adamowicz *et al.* (2008) for industrial production and Skrzypczyńska (2011) for GDP and sold production of industry in Poland. Adamowicz *et al.* (2008) utilized also the Clark (1987) model for GDP, private consumption and investments. The measurement equation and the system of transition equations of Watson model are as follows:

$$Y_t = \begin{bmatrix} 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} T_t \\ C_t \\ C_{t-1} \end{bmatrix}, \tag{16}$$

$$\begin{bmatrix} T_t \\ C_t \\ C_{t-1} \end{bmatrix} = \begin{bmatrix} \mu \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \phi_1 & \phi_2 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} T_{t-1} \\ C_{t-1} \\ C_{t-2} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \xi_t \end{bmatrix}. \tag{17}$$

The parameters μ, σ_ε^2, ϕ_1, ϕ_2, σ_ξ^2 were estimated using the Maximum Likelihood via the Kalman filter – MLE is based on the prediction error decomposition. The sample likelihood:

$$\ln L = -\frac{nT}{2} ln 2\pi - \frac{1}{2}\sum_{t=1}^{T} ln \left| f_{t|t-1} \right| - \frac{1}{2}\sum_{t=1}^{T} \eta'_{t|t-1} f_{t|t-1}^{-1} \eta_{t|t-1}, \tag{18}$$

where $\eta_{t|t-1} = y_t - y_{t|t-1}$ is a prediction error and $f_{t|t-1} = var\left(f_{t|t-1}\right)$ is a conditional variance of the prediction error, can be maximized with respect to unknown parameters.

4 Empirical results

This section presents the extracted cyclical components, turning points analysis, cross-correlations of the cyclical components, identification of the dominating periodicities and the influence of the crisis on the business cycle characteristics.
CF filter was used to extract fluctuations at business cycle frequencies ranging from 1.5 to 10 years. The Watson (1986) model was estimated to extract the business cycle fluctuations using the unobserved components model. The model parameters (see Table 2) were estimated using Maximum Likelihood via Kalman filter in EViews. If $\phi_1 + \phi_2 \approx 1$ the AR(2) process is near nonstationary. In this case the generated cycles might be spurious (see Nelson 1987) and should be taken with some caution. The initial values of the state variables are assumed to be diffuse priors (see Koopman, Shepard, Doornik 1999). The successful estimation of these models depends on proper starting values – a slight change in starting parameters can lead to lack of convergence. Figures 1.a and 1.b presents the estimated trends and cycles. The dots refer to peaks and troughs. Dating of the business cycle turning points was done in the econometric package BUSY (see Fiorentini *et al.* 2003). The peaks and troughs amount to local maxima and minima in the neighbourhood of two and six observations for quarterly and monthly data respectively It was assumed that the cycle phase should last at least 2 quarters whereas the (whole) cycle should be no shorter than 1.5 years.

The estimated periodograms of the cyclical components (isolated from CF filter and unobserved components model) allowed to identify the frequencies determining the variance of analysed variables. The cross-spectral analysis was conducted in Matlab using codes written by Paweł Skrzypczyński. In the article a Parzen window was used to smooth the cross-spectrum while calculating the cross-spectral statistics and the truncation point was matched according to the rule $H = int\left(2\sqrt{T}\right)$ (see Chatfield 1996).

4.1 Reference cycles

The cycles of gross value added and industrial production were the reference series to the cycles of other economic activity indicators. Figure 2 presents the estimated cyclical components. The graph analysis showed that the cyclical fluctuations of gross value added and industrial production measured within two mentioned methods are quite similar with one exception. Gross value added cyclical component of CF filter has a lower amplitude compared to its equivalent of UC model. Industrial production fluctuations seem to be alike. As far as differences between the band-pass filter and UC model are concerned, the same results presents Chagny, Döpke (2001), pointing also that various methods can imply dissimilar turning points and estimated level of the output gap may differ greatly. For detailed specification of cycle phases and turning points see Tables 3 and 4. Figure 3 depicts the turning points moments. The dates of peaks and troughs are not identical.

Within the years 1995-2012 there were revealed 4 cycles of gross value added and industrial production fluctuations lasting approximately 3.5-4 years. One exception is for value added cyclical component of UC model, that showed only 2 cycles lasting on average 6.7 years, but this cycle seems to spurious taking into account results presented in the next section and compared also to other research for Poland. Firstly, cyclical fluctuations of gross value added seem to be determined by industry (medium length cycles). Secondly, the long cycles can be associated with the impact of external economic activity (see Wyrobek, Stanczyk 2012). In the industry the longer cycles, of 6-7 years, play also a crucial role (see Skrzypczyński 2008, Gradzewicz *et al.* 2010). During 1995 to 1999 there occurred two economic activity slowdowns compared to one in the industry. In 1999-2003 the downturn of industrial production was shorter. Between 2008 to 2012 there was one extra cycle in the industry in 2009. Industrial production turning points are similar to earlier research (see Table 5). In the industry the slowdown lasted shorter than expansion conversely to gross value added. Pipień, Lenart (2013) also show that recession in most industrial subsectors is shorter compared to expansion. The downturn in the industry lasted on average 1.5 years in comparison with about 2 years for the gross value added. The average cycle and each phase length are relatively longer for UC model compared to CF filter. Gross value added cycle amplitude is lower in comparison with industrial fluctuations.

4.2 Business cycle analysis

A comprehensive view of business cycle gives the analysis of cyclical components within sectors of the economy. From the sectoral perspective, similarly to gross value added and industrial production, the business cycle measures estimated from CF filter and unobserved components model seem to be alike with exception of construction (see Figure 2). However, the estimated parameters of the UC model (see Table 2) indicate, that the cycles of gross value added, construction and transportation may be spurious (see Nelson 1987), that is why these results should be taken with some caution. Taking into account the determined turning points and the other characteristics of cyclical components (see Table 3 and Figures 3, 4), it can be concluded, that construction is the sector of the lowest periodicity of cycles compared to gross value added, industry, trade and transportation. During 1995-2011 there were three or two cycles in construction, that lasted about 5 and 7 years according to CF filter and UC model respectively. Compared to above mentioned sectors, cycle amplitude in construction is relatively the largest. Construction is asymmetric both in length and amplitude of cycle phases. However, the results depend on the method of measurement of cyclical component. According to UC model the cycle amplitude for expansion is bigger compared to slowdown contrary to results for CF filter. Among sectors under analysis cyclical fluctuations in trade, are the most similar to gross valued added and last on average 3.5 and 6.5 years in line with CF filter and UC model respectively. Similarly to construction the expansion in trade lasts longer to contraction. Cyclical amplitude in trade is similar to deviations of gross value added. CF filter and UC model shows that in transportation cycles last respectively approximately 3.5 and 4.5 years with amplitudes being higher compared to gross valued added and trade, are similar to industry and lower in comparison with construction. Transportation is asymmetric in length of cycle phases. Contraction is shorter compared to expansion. In addition to the analysis on national economy data the business cycle exploration of manufacturing, sold production in industry according to MIG and production of electric power is complementary (see Table 4 and Figures 3, 4). Cyclical component for manufacturing is very similar to its counterpart for industry. In manufacturing the cycle last approximately 3.0-3.5 years. Manufacturing like industry is asymmetric in length of cycle phases concerning shorter length during contraction compared to expansion. Durable consumer goods and industry fluctuations are alike. Expansion lasts longer than slowdown. Durable consumer goods together with capital goods are the most volatile compared to other economic activity indicators. Cycles of durable consumer goods occur more rarely compared to industry and last about almost 3.0 and 4.0 years according to CF filter and UC model respectively. Contrary to UC model, CF filter reveals that for this industrial grouping the slowdown lasts longer than expansion. Deviations of non-durable consumer goods are very similar to energy fluctuations and at the same time lower compared to industry. During expansion the business cycle fluctuations are higher in comparison with contraction. Cyclical component of capital goods is very similar to its counterpart of industrial production

– the periodicity of cycles is similar, cycle phases are asymmetric in length and amplitude. Contraction is more violent than expansion. Business cycle characteristics relating to cycle length are almost identical in this industrial grouping. Together with durable consumer goods the capital goods amplitude is the highest in comparison with fluctuations in industry. Cycles of intermediate goods are very similar to industry deviations. Cycle phases for this industrial grouping are asymmetric. The contraction is shorter and relatively deeper than during expansion in comparison even with industry. Intermediate goods fluctuations amplitude is only a little higher than in industry. Cycles in energy occur more often compared to industry and last about 2.5 and 3.5 years in line with CF filter and UC model respectively and its amplitude is similar to non-durable consumer goods and smaller in comparison with industry fluctuations. Cycles of this industrial group are asymmetric in length and amplitude – expansion lasts longer and its deviations are smaller relatively to slowdown. Fluctuations of production of electric power are different and of smaller amplitude compared to industry. The characteristic of cycle phases depends on the method of measurement of cyclical component. CF filter shows that these fluctuations are symmetric – cycle length and amplitude are similar, whereas UC model reveals very long slowdowns and symmetric cycle phase amplitudes.

The additional source of knowledge about volatility of cycles among sectors is the identification of dominating cycles, that can be conducted on the basis of periodograms of cyclical components. Table 6 shows the summary of cycles that determines business cycle among different sectors of economy. Construction, transportation, non-durable consumer goods, capital goods, energy and production of electric power exibit different cyclical pattern in comparison with other sectors – among dominating cycles are these lasting about 2.5 years (except for construction and transportation) and energy has also additional cycle of 5.5 years. Variability of almost all sectors, excluding intermediate goods and energy, is foremost driven by longer cycles of 8.5 years. Fluctuations of gross value added, industry, manufacturing, durables, non-durables and capital goods are subsequently determined by medium length cycles (3-4 years). For all sectors the short-term fluctuations play also a significant role. Lenart, Pipień (2013a) confirm the same sequence of dominance of cycles for industrial production.

To formulate the lead and lag structure of sectoral cyclical components with respect to gross value added and industry the leads/lags of turning points and cross-correlations were calculated (see Tables 7 and 8 respectively). The cross-correlations are statistically significant at the 0.05 level and vulnerable to the method of measurement of cyclical component. Although there is no regularity in occurring of peaks and troughs in relation to reference cycles (see Table 7), it can be concluded cautiously that the economic activity in transportation leads the fluctuations of gross value added and the production of electric power leads industrial production. Construction seem to be lagging in relation to gross value added fluctuations. The highest cross-correlation with the industrial production is revealed for manufacturing, intermediate and capital goods, whereas the lowest relation is with non-durable consumer goods, energy and production of electric power.

Complementary to the previous inference is the analysis in the frequency domain concerning spectrum and cross-spectral statistics calculated twofold: on the whole sample and excluding the period of the last financial crisis that began in the second half of 2008, called further the crisis. The shorter sample refers to the period 1995-2007. Such a dichotomy allows to describe the influence of the crisis on the cyclical fluctuations among different sectors of the economy. Taking into account the whole sample, if not emphasized, the business cycle characteristics in the time and frequency domain as well are similar. In the article the presented inference refers only to cycle components estimated using CF filter.

Figures 6a-6d present respectively the spectrum among various sectors smoothed with the Parzen window and cross-spectral statistics: coherence, dynamic correlation, gain, phase shift, whereas Table 9 contains the average values of the cross-spectral statistics before and after the crisis. Polish business cycle fluctuations are determined by the longest cycles. The biggest changes in the spectral density after the crisis can be seen especially in the lower frequencies. The spectrum changed the most in construction, then transportation, gross value added and trade. As far as the monthly economic activity indicators are concerned, the greatest revision after the crisis relates to capital and intermediate goods, the moderate to durable goods, industry and manufacturing, the least to non-durables, production of electric power and energy. In construction, trade and transportation the similarity of cycles to gross value added fluctuations measured by the coherence is moderate and statistically significant at the 0.05 level for lower frequency cycles. In trade and construction the coherence is statistically insignificant for cycles lasting less than about 4 years and in transportation for cycles shorter than 3 years. After the crisis the longest cycles in construction were less similar to its counterparts in reference to economic activity, that can be a result of infrastructure investment supported by EU funds, whereas in trade the correlation increased. In transportation the relationship was stronger in the middle frequencies. The correlation in reference to industrial production is very strong among all frequencies in manufacturing, then in the lowest frequency of capital and intermediate goods. In lower frequencies the medium correlation with reference to industry have durables and non-durables. Energy and production of electric power fluctuations have low, not always statistically significant and quite variable among various frequencies correlation with industry. After the crisis the relationship between all variables and industry weakened, except for longer cycles of energy and production of electric power – the relation was strengthened. Dynamic correlation coefficient is positive for all variables indicating their procyclicality and after the crisis the change in their relation with gross value added and industry was similar to revision indicated by coherence. The gain describes the amplitude compared to its counterpart of reference series. Construction fluctuates the most compared to gross value added. After the crisis the amplitude in construction in reference to gross value added increased, especially in high frequencies, whereas the variation of trade stayed bigger compared to gross value added, but the difference of the latter diminished. The earlier analysis using standard deviations of cyclical components indicated that the variability of trade is lower compared to gross value added. In transportation the range of fluctuations before and after the crisis was alike. The amplitudes of all monthly economic indicators are higher compared to industry within the whole frequency domain with the exception of the production of electric power, where the fluctuations of the shortest and longest cycles are lower. In the time domain the results for energy and non-durables were different – the amplitude of cycles was lower in reference to industrial production, whereas in the frequency domain it is higher. The last economic slowdown resulted in bigger amplitudes of higher frequency cycles of all monthly economic indicators compared to industry, whereas the influence on longer cycles was opposite, except for durable goods. However, the average gain for all quarterly and monthly indicators, with the exception of trade and transportation, diminished indicating that the higher variability during the crisis was sustained. Pietrzak (2014) also confirms the intensified variation of economic activity in Poland during the crisis. The phase shift allows to identify the leads and lags of the time series for a given frequency. This statistic had the highest values for the lowest frequencies, which fluctuations in construction and trade are lagged in reference to gross value added. There were no significant changes for these sectors after the crisis. The substantial difference for these frequencies occurred in transportation – the lead in reference to gross value added increased from less than half a quarter to one and a half quarters concerning the longest cycles. In line with the analysis in the time domain the fluctuations of manufacturing are coincident with industrial production. The longest cycles of non-durables, durables, intermediate goods and production of electric power are leading in relation to economic activity in industry, whereas the capital goods and energy are lagging. Cycles lasting less than 3 years are coincident compared to industry. The slowdown of economic activity during the crisis induced mostly the intensification of phase shifts in reference to industrial production for low frequencies of durable and capital goods. The average phase shifts confirm the inference of time domain analysis – construction and energy may be treated as lagging indicators, whereas transportation, non-durables and production of electric power as leading and the economic activity in other sectors as coincident to fluctuations of reference series.

On the basis of the conducted analysis it can be concluded that cyclical fluctuations in construction, transportation and trade are different compared to its counterpart for gross value added. The economic activity in transportation appears to be leading and in construction lagging in comparison with gross value added fluctuations. Construction is a sector of the lowest periodicity of cycles and at the same time of the highest variability. The cyclical component of trade is the most similar to gross value added deviations, whereas the amplitudes in construction and transportation are bigger. In construction cycle phases are asymmetric as far as the length and amplitude are concerned. The economic activity in construction, transportation and trade seem to be invulnerable to external shocks (the Russian crisis and the EU accession) contrary to industry. The volatility of industry, that accounts for about 25% of gross value added, seem to be responsible for fluctuations of the latter. The economic activity in industry is determined by the manufacturing, especially the capital and intermediate goods reflecting the demand of the enterprises. Cyclical components of production of the non-durables, energy and the production of electric power are different from industry fluctuations. The production of electric power leads the industry fluctuations. In relation to industry the production of non-durables is relatively the least periodic, whereas the energy and the production of electric power are the most. The amplitude of durables, capital and intermediate goods is higher and of the production of electric power and non-durables is lower compared to industry. The amplitude of the capital goods is relatively the highest, whereas of the production of electric power is the smallest. The most similar amplitude compared to industry fluctuations has the manufacturing and non-durable goods. Industry cycles are asymmetric in length relating to shorter slowdown compared to the period of expansion. The fluctuations of capital goods, intermediate goods and energy are asymmetric both in length and amplitude. Contraction is shorter and of bigger amplitude compared to expansion. It can be concluded that the contraction is more violent. The analysis in time frequency domain confirms, with some exceptions, the results in time domain.

The crisis influenced the most the longest cycles, whereas the spectrum changed the hardest in construction, capital and intermediate goods. After the crisis the correlation between almost all sectors and reference series diminished, except for transportation and trade, referring mostly to the rise in amplitudes, representing the intensified volatility during the crisis. In trade the correlation in relation to gross value added rose reflecting the reduction in deviations.

During 1995 to 2011 there were revealed 4 cycles. Achieved in 1996 and 1997 the high rate of economic growth slowed down at the beginning of 1998 as a result of lower domestic demand, whereas the external factor deepening the fall of economic activity was the contraction of export that negatively influenced the industry. On the one hand the breakdown of export resulted from our trade partners that were also touched by the economic slowdown following the Asian crisis, and on the other hand from Russian crisis in 1998, that was an unexpected shock.

The trough can be estimated at the first half of 1999 and the expansion lasted to the first half of 2000. Although it was a quite short period, supported by i.a. the series of interest rates cuts in 1998 and at the beginning of 1999 the consumer demand rebound. At the same time the export revival boosted the industrial activity. As a result of a strong investment demand, although there were some signs of hampering of growth, the economic activity in construction was still very solid. In the second half of 2000 the economic growth decelerated. The slowdown was influenced by the external and internal factors. The global economy slipped into recession. The economic slowdown in Poland was driven by the fall in domestic demand, especially of consumer demand (i.a. trade). The negative impact on demand had also the tight monetary and fiscal policy since the second half of 1999. Moreover, in the second half of 2000, when it was clear the economic activity slowed down, the interest rates were risen again, that severely hit the households and enterprises. Furthermore, in April 2000 the exchange rate switched into floating regime. After a period of depreciation the Polish zloty strengthened reducing the competitiveness of Polish exporters. The contraction lasted to the beginning of 2003 in conditions of worsening situation of enterprises and falling investment outlays mirrored in construction. The ignition for recovery were the consumer demand and exports – transportation and industry revived faster than gross value added. The consumption could have been boosted by the rate cuts cycle started in 2001.

The period between the fourth quarter of 2003 to fourth quarter of 2005 was driven by the positive shock such as UE accession. This event was looked forward, that is why its effects influenced the Polish economy before and after EU accession, contrary to Russian shock, which effects were noticed after its appearance. Before the EU accession there were the rise of new orders and inventories. As a result of the foreign direct investments and the EU funds the investment demand revived – although in construction the recovery occurred with some lag compared to the economic activity – there was a trough in the first half of 2004. During one year after joining the EU Polish economic growth decelerated accompanying with decreasing inventories and consumer demand. The economic downturn was a result of appreciating zloty and weakening exports – the external demand was diminished by the problems of euro area.

The economic activity boosted in the half of 2005 thank to rise in public demand. At the same time recovered also the trade and the households' demand was supported by consumer credit. The positive impact on the economic growth had the boost in investments. The expansion in construction was sustained by the better financial conditions of enterprises and housing credit boom. During 2006 to 2007 the rate of economic growth accelerated and reached a relatively high level, that was also supported by expansion at main trade partners of Poland. Unfortunately, the global economic and financial crisis in 2007-2009 did not left untouched the economic activity in Poland. In the second half of 2008 the economic activity slowed down. Although at that time the sale of industry and transportation were touched by the historically biggest falls, Poland was the odd one managed to avoid slipping into recession. During the crisis the fiscal policy was loosened evoking the rise in investment demand enhanced by the EU funds and individual consumption (the fall of PIT in 2009). The undertaken measures delayed the slowdown in trade, that occurred not before the fourth quarter of 2009. At the same time, the economic activity in industry and transportation reached the bottom. The infrastructure investment and the EU funds sustained the expansion in construction, that lasted till the end of 2009.

The conducted analysis allows to formulate a few conclusions concerning the deviation cycles. Firstly, the cyclical component of CF filter and UC model are alike, although the UC model fluctuations were consistently more volatile. The biggest differences relate to gross value added and construction – cycles of UC model show lower periodicity compared to cyclical components of CF filter, so it seems, that not only industry but also construction may mainly be responsible for gross value added fluctuations. Secondly, the periodograms showed, that the deviation cycles are foremost driven by longer cycles lasting about 8.5 years, followed by shorter fluctuations recurring every 3-4 years.

5 Concluding remarks

To sum up, economic activity indicators for Polish economy exibit various cyclical patterns – their fluctuations are different in the amplitude, length of cycle and turning points. The cyclical fluctuations of construction, transportation and trade are dissimilar to gross value added. The economic activity in transportation appears to be leading and in construction lagging the fluctuations of gross value added. It seems the industry fluctuations are responsible for the variation of gross value added. Manufacturing, especially capital and intermediate goods fluctuations are responsible for the variation of industry. Capital goods, intermediate goods and energy cycle phases are asymmetric – the slowdown lasts shorter and has higher amplitude compared to expansion. The production of non-durable consumer goods, energy and production of electric power are relatively the most desynchronized compared to industry. Production of electric power leads industrial production, although with some caution, it may be treated as the early warning indicator of economic activity. In relation to above, it appears the early signals of economic contraction are reflected by the by the production of electric power, then by the slowdown in transportation and in industry afterwards, especially weakening of the enterprise demand for the capital and intermediate goods, following the possible contraction in construction. The economic activity in construction strongly depends on the monetary and credit policy and EU funds inflow. The cyclical processes of Polish economic activity are determined by overlapping higher frequency fluctuations (3-4 years) and longer cycles of 8.5 years. The significant role play also the shortest fluctuations of 1.5-2 years. In 1995-2011 occurred 4 cycles. The economic activity in Poland did not resist the crisis. The biggest changes were related to economic activity of construction, capital and intermediate goods and in most sectors reflected in the longest cycles. After the crisis the correlation between almost all sectors and reference series lowered reflecting the growth in amplitudes, except for trade with the inverse effect.

The conducted analysis let also draw conclusions on the econometric tools used. In relation to business cycle analysis, the cyclical components estimated from CF filter and unobserved components model are alike. However, cyclical component amplitude from UC model were consistently higher compared to those from CF filter. Deviation cycles are foremost driven longer cycles of 8.5 years, subsequently medium length cycles (3-4 years).

References

[1] Adamowicz E., Dudek S., Pachucki D., Walczyk K. (2008), Synchronizacja cyklu koniunkturalnego polskiej gospodarki z krajami strefy euro w kontekście struktury tych gospodarek, Instytut Rozwoju Gospodarczego, Szkoła Główna Handlowa.

[2] Baxter M., King R. G. (1995), *Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series*, NBER Working Paper, No. 5022, National Bureau of Economic Research.

[3] Bruzda J. (2011), Business cycle synchronization according to wavelets – the case of Poland and the euro zone member countries, *Bank i Kredyt*, Vol. 42, No. 3, 5-32.

[4] Chagny O., Däpke J. (2001), Measures of the Output Gap in the Euro-Zone: An Empirical Assessment of Selected Methods, Kiel Working Papers, nr 1053.

[5] Chatfield C. (1996), *The Analysis of Time Series: An Introduction*, Fifth Edition, Chapman & Hall, London.

[6] Christiano L. J., Fitzgerald T. J. (2003), The Band Pass Filter, *International Economic Review*, Vol. 44, No. 2, 435-465.

[7] Clark P. K. (1987), The Cyclical Component of U.S. Economic Activity, *The Quarterly Journal of Economics*, Vol. 102, No. 4, 797-814.

[8] Croux C., Forni M., Reichlin L. (2001), A measure of comovement for economic variables: theory and empirics, The *Review of Economics and Statistics*, 83(2), 232-241.

[9] Fic T. (2007), Cykl koniunkturalny w Polsce. Wnioski z modeli Markowa, 7 Warsztaty doktorskie z zakresu ekonometrii i statystyki, [in:] *Metody ilościowe w naukach ekonomicznych*, SGH, Warszawa.

[10] Fidrmuc J., Korhonen I, (2010), The impact of the global financial crisis on business cycles in Asian emerging economies, *Journal of Asian Economics* Vol. 21, No. 3, 293-303.

[11] Fiorentini G., Planas Ch., Caporello G. (2003), *Busy Program: User Manual*, `http://ipsc.jrc.ec.europa.eu/fileadmin/repository/sfa/finepro/software/BUSY-manual0603.pdf`.

[12] Franses P. H. (1996), Recent Advances in Modelling Seasonality, *Journal of Economic Surveys*, Vol. 10, No. 3, 299-345.

[13] Ghysels E. (1988), A Study Toward a Dynamic Theory of Seasonality for Economic Time Series, *Journal of the American Statistical Association*, Vol. 83, No. 401, 168-172.

[14] Gradzewicz M., Growiec J., Hagemejer J., Popowski P. (2010), Cykl koniunkturalny w Polsce – wnioski z analizy spektralnej, *Bank i Kredyt*, Vol. 41, No. 5, 41-76.

[15] Grudkowska S., Nehrebecka N. (2009), Identyfikacja i usuwanie sezonowości z polskich agregatów monetarnych, Materiały i Studia, Zeszyt nr 237, Narodowy Bank Polski.

[16] Grudkowska S., Paśnicka E. (2007), X-12-Arima i TRAMO/SEATS – empiryczne porównanie metod wyrównania sezonowego w kontekście długości próby, Materiały i Studia, Zeszyt nr 220, Narodowy Bank Polski.

[17] Hallett A.H., Richter C. (2012), Has the financial crisis changed the business cycle characteristics of the GIPSI countries?, Working Paper. International Network for Economic Research, Bonn, Germany

[18] Hamilton J. (1994), *Time series analysis,* Princeton University Press, Princeton, New Jersey.

[19] Hodrick R. J., Prescott E. C. (1997), Postwar U.S. Business Cycles: An Empirical Investigation, *Journal of Money, Credit and Canking*, Vol. 29, No. 1, 1-16.

[20] Kębłowski P., Welfe A. (2004), The ADF-KPSS test of joint confirmation hypothesis of unit autoregressive root, *Economics Letters*, Vol. 85, No. 2, 257-263.

[21] Konopczak K. (2009), Analiza zbieżności cyklu koniunkturalnego gospodarki polskiej ze strefą euro na tle krajów Europy Środkowo-Wschodniej oraz państw członkowskich strefy euro, in: Raport na temat pełnego uczestnictwa Rzeczypospolitej Polskiej w trzecim etapie Unii Gospodarczej i Walutowej. Projekty badawcze, NBP, Warszawa.

[22] Konopczak K., Marczewski M. (2011), Why so different from other CEECs – Poland's cyclical divergence from the euro area during the recent financial crisis, *Bank i Kredyt*, Vol. 42, No. 2, 7-30.

[23] Koopman S. J., Shephard N., Doornik J. A. (1999), Statistical Algorithms for Models in State Space using SsfPack 2.2, *Econometrics Journal,* Vol. 2, No. 1, 107-160.

[24] Kwiatkowski D. P., Phillips C. B., Schmidt P., Shin Y., (1992), Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root, *Journal of Econometrics*, Vol. 54, No. 1-3, 159-178.

[25] Lenart Ł., Pipień M. (2013a), Almost Periodically Correlated Time Series in Business Fluctuations Analysis, *Acta Physica Polonica A*, Vol. 123, No. 3, 567-583.

[26] Lenart Ł., Pipień M. (2013b), Seasonality Revisited – Statistical Testing for Almost Periodically Correlated Stochastic Processes, *Central European Journal of Economic Modelling and Econometrics*, Vol. 5, No. 2, 85-102.

[27] MacKinnon J. G. (1996), Numerical Distribution Functions for Unit Root and Cointegration Tests, *Journal of Applied Econometrics*, Vol. 11, No. 6, 601-618.

[28] Nelson Ch. R. (1987), Spurious Trend and Cycle in the State Space Decomposition of a Time Series with a Unit Root, Technical Working Paper, No. 63, National Bureau of Economic Research.

[29] Pietrzak M. (2014), Opis cykli koniunkturalnych w wybranych krajach Europy Środkowo-Wschodniej oraz ich synchronizacja ze strefą euro, *Bank i Kredyt*, Vol. 45, No. 2, 133-162.

[30] Sargent T. J. (1987), *Macroeconomic Theory*, Second Edition, Academic Press, London.

[31] Skrzypczyńska M. (2011), Pomiar cyklu koniunkturalnego – analiza porównawcza, *Bank i Kredyt*, Vol. 42, No. 4, 11-54.

[32] Skrzypczyńska M. (2013), Cykl koniunkturalny w Polsce – analiza sektorowa, *Bank i Kredyt*, Vol. 44, No. 2, 175-206.

[33] Skrzypczyński P. (2008), Wahania aktywności gospodarczej w Polsce i strefie euro, Materiały i Studia, Zeszyt nr 227, Narodowy Bank Polski.

[34] Skrzypczyński P. (2010), Metody spektralne w analizie cyklu koniunkturalnego, Materiały i Studia, Zeszyt nr 252, Narodowy Bank Polski.

[35] Watson M. W. (1986), Univariate Detrending Methods with Stochastic Trends, *Journal of Monetary Economics*, Vol. 18, No. 1, 49-75.

[36] Wyrobek, J. M., Stanczyk Z., Business Cycle Synchronization in Poland, The Euro Zone and New Member States of the European Union (March 25, 2012). Available at SSRN: `http://ssrn.com/abstract=2028639` or `http://dx.doi.org/10.2139/ssrn.2028639`

A Data description and sources:

gross value added of total, gross value added in construction, gross value added in trade and repair, gross value added in transport and storage – quarterly data, constant average prices of 2005, during 1995-1999 according to NACE Rev. 1.1, since 2000 according to NACE Rev. 2, Central Statistical Office of Poland;

sold production of industry (mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply), manufacturing, MIG- durable consumer goods, MIG - non-durable consumer goods, MIG - capital goods, MIG - intermediate goods, MIG – energy – monthly data, industry production index (2005=100) according to NACE Rev. 2, Eurostat;

production of electric power in GWh – monthly data, Statistical Bulletin, Central Statistical Office of Poland.

Table 1: Unit root tests

Variable	Constant and linear trend				Constant			
	ADF		KPSS	ADF-KPSS	ADF		KPSS	ADF-KPSS
	t-Statistic	*p*-value	LM-Statistic	DGP	*t*-Statistic	*p*-value	LM-Statistic	DGP
Gross value added	-1.961	0.610	0.109	D S	-0.076	0.946	1.075*,**,***	D S
Construction	-1.621	0.774	0.2*,**	D S	-0.105	0.944	0.771*,**,***	D S
Trade	-3.684	0.031	0.133*	D S	-1.986	0.292	1.050*,**,***	D S
Transportation	-3.164	0.101	0.082	D S	-1.165	0.684	1.027*,**,***	D S
Industry	-2.645	0.261	0.083	D S	-0.806	0.815	1.794*,**,***	D S
Manufacturing	-2.636	0.265	0.09	D S	-0.588	0.869	1.792*,**,***	D S
Durable consumer goods	-2.535	0.311	0.179*,**	D S	-0.529	0.882	1.791*,**,***	D S
Non-durable consumer goods	-3.094	0.111	0.129*	D S	-1.483	0.54	1.780*,**,***	D S
Capital goods	-1.985	0.606	0.115	D S	-1.068	0.728	1.759*,**,***	D S
Intermediate goods	-3.035	0.125	0.067	D S	-0.45	0.897	1.778*,**,***	D S
Energy	-3.166	0.094	0.141*	D S	-3.148	0.025	0.369*	S
Production of electric power	-4.973	0.000	0.129*	T S	-2.243	0.192	1.524*,**,***	D S

p-value – MacKinnon (1996) one-sided *p*-values.
LM-Statistic – asymptotic critical values - Kwiatkowski, Phillips, Schmidt, Shin (1992), *,**,*** mean rejecting the null hypothesis of stationarity with *p*-value 0.1, 0.05, 0.01 respectively.
DGP – Data Generating Process is Stationary (S), Trend Stationary (T S) or Difference Stationary (D S) with p-value 0.05 - asymptotic critical values for N=205 (Kębłowski, Welfe 2004), critical values for N=70 sent on request by P. Kębłowski.

Table 2: Estimates of the UC model

Parameter/ Variable	Gross value added	Construction	Transportation	Trade	Industry	Manufacturing
μ	0.01 (0.001)	0.009 (0.004)	0.009 (0.001)	0.009 (0.001)	0.005 (0.0003)	0.006 (0.0006)
$\ln(1000{\sigma_\varepsilon}^2)$	-0.97 (0.23)	1.89 (0.172)	-2.44 (1.41)	-19.87 (4214648)	-30.52 ($127*10^{10}$)	-16.31 (12472395)
ϕ_1	1.80 (0.17)	1.90 (0.044)	1.63 (0.096)	0.81 (0.06)	0.416 (0.056)	0.845 (0.07)
ϕ_2	-0.83 (0.16)	-0.94 (0.04)	-0.71 (0.096)	$-649/10^8$($503/10^8$)	0.459 (0.061)	0.11 (0.06)
$\ln(1000{\sigma_\xi}^2)$	-3.79 (1.62)	-25.42 ($257*10^7$)	-0.064 (0.006)	0.483 (0.137)	2.10 (0.082)	1.27 (0.301)
Log likelihood	211.8	121.8	180.1	175.3	408.2	494.9
Parameter Variable	Durable consumer goods	Non-durable consumer goods	Capital goods	Intermediate goods	Energy	Production of electric power
μ	0.011 (0.0009)	0.004 (0.0005)	0.008 (0.0007)	0.005 (0.0003)		0.0008 (0.0001)
$\ln(1000{\sigma_\varepsilon}^2)$	-8.36 (14835.4)	-1.51 (1.55)	-6.24 (661.1)	-23.14 ($517*10^7$)		
ϕ_1	0.552 (0.086)	0.687 (0.067)	0.899 (0.043)	0.476 (0.063)	0.45 (0.072)	0.61 (0.066)
ϕ_2	0.375 (0.064)	0.225 (0.057)	$616/10^8$ (0.0004)	0.369 (0.07)	0.344 (0.069)	0.192 (0.068)
$\ln(1000{\sigma_\xi}^2)$	3.23 (0.172)	0.97 (0.17)	3.25 (0.106)	2.82 (0.095)	2.27 (0.079)	1.56 (0.114)
Log likelihood	294.9	514.0	300.4	335.7	420.0	462.9

Note: Standard errors are in parentheses.

Table 3: Business cycle characteristics – sectoral overview (quarterly data)

Variable	Method	Turning points		Number of cycles	Average length of cycle (years)	Average length of cycle phase (quarters)		Standard cycle deviation	Standard phase deviation	
		Peak	Trough			Expansion	Slowdown		Expansion	Slowdown
Gross value added	CF	1Q1998 1Q2000 4Q2004 1Q2008	1Q1999 4Q2002 4Q2005 4Q2010	4	3,8	7,6	7,5	1,2	1,3	1,2
	UC	4Q1999 1Q2008	1Q2003 1Q2011	2	6,7	14,3	12,5	1,4	1,5	1,1
Construction	CF	1Q2001 1Q2007 2Q2011	4Q1996 1Q2004 2Q2010	3	4,9	11,0	8,8	4,7	4,5	4,7
	UC	1Q2000 2Q2008	4Q1995 2Q2004	2	7,0	16,5	11,7	6,9	7,2	6,7
Trade	CF	4Q1995 1Q2000 1Q2002 2Q2008	4Q1996 1Q2001 2Q2003 3Q2010	4	3,6	9,0	5,5	1,2	1,3	1,2
	UC	4Q1999 3Q2009	4Q2004 2Q2010	2	6,5	14,7	11,5	3,3	3,6	2,5
Transportation	CF	1Q1996 1Q2000 4Q2002 4Q2007	4Q1996 4Q2001 3Q2004 2Q2009	4	3,6	8,8	5,8	4,0	3,9	3,9
	UC	1Q2000 1Q2003 4Q2007	4Q2001 4Q2004 2Q2009	3	4,6	11,8	6,7	4,4	4,5	4,2

Table 4: Business cycle characteristics – sectoral overview (monthly data)

Variable	Method	Turning points		Number of cycles	Average length of cycle (years)	Average length of cycle phase (quarters)		Standard cycle deviation	Standard phase deviation	
		Peak	Trough			Expansion	Slowdown		Expansion	Slowdown
Industry	CF	12M1997 3M2000 5M2004 11M2007	1M1999 10M2002 5M2005 5M2009	4	3,7	26,2	18,5	3,9	3,7	4,3
	UC	12M1997 12M1999 4M2004 2M2008	2M1999 5M2002 5M2005 1M2009	4	3,7	27,6	16,8	4,8	5,0	4,6
Capital goods	CF	2M1998 6M2000 6M2004 1M2008	4M1999 11M2002 6M2005 8M2009	4	3,7	26,2	18,5	8,6	7,9	9,8
	UC	3M1998 6M2000 4M2004 4M2008	2M1999 12M2002 5M2005 12M2009	4	3,7	26,2	18,5	11,2	10,3	12,0
Intermediate goods	CF	12M1997 4M2000 4M2004 9M2007	10M1995 1M1999 1M2002 4M2005 5M2009	4,5	3,4	25,8	15,2	5,5	5,4	5,6
	UC	1M1998 12M1999 4M2004 3M2007	1M1999 12M2001 3M2005 1M2009	4	3,7	27,2	17,3	6,5	6,2	7,0
Production of electric power	CF	7M1996 8M1998 9M2003 3M2006 12M2007 5M2011	8M1997 4M2002 2M2005 2M2007 2M2009	5,5	2,9	16,3	18,0	2,2	2,4	2,0
	UC	3M1996 2M2004 1M2006 5M2011	3M2002 12M2004 5M2009	3,5	4,3	18,8	32,5	3,3	3,3	3,3
Manufacturing	CF	12M1997 3M2000 5M2004 11M2007	1M1999 9M2002 5M2005 5M2009	4	3,7	26,4	18,3	4,7	4,5	5,0
	UC	2M1998 12M1999 4M2004 2M2008 6M2010	1M1999 2M2003 3M2005 1M2009 7M2011	5	3,1	20,2	16,8	5,4	5,4	5,2
Durable consumer goods	CF	1M1998 11M1999 3M2004 9M2007 4M2010	8M1995 2M1999 4M2002 4M2005 2M2009 6M2011	5,5	2,8	18,5	15,7	6,8	6,6	6,9
	UC	2M1998 3M2004 10M2007 6M2010	9M1995 3M2002 3M2005 12M2008	4	3,8	25,5	20,6	10,3	10,7	9,4
Non-durable consumer goods	CF	12M1997 2M2004 6M2007 5M2010	2M2005 6M2009 2M2002 5M2011	4	3,8	21,4	24,5	3,2	3,4	2,9
	UC	1M1998 7M2007 5M2010	5M2002 11M2008 6M2011	3	4,8	31,0	27,0	4,2	4,7	2,9
Energy	CF	2M1997 5M2001 8M2004 6M2006 2M2008 3M2010	2M1999 9M2002 7M2005 3M2007 3M2009 12M2010	6	2,6	17,6	13,7	3,1	2,9	3,3
	UC	4M1997 5M2001 1M2006 2M2008	6M1996 1M1999 5M2002 2M2007 3M2009	4,5	3,4	25,6	15,4	4,6	4,2	5,2

Table 5: Peaks and troughs – literature overview

Author	Method	Variable	Chronology			
			Expansion		Slowdown	
				Peak		Trough
Adamowicz *et al.* (2008)	CF	Manufacturing		12M1997 6M2000 4M2004 5M2007		8M1995 1M1999 1M2003 5M2005
	UC			1M1998 12M1999 4M2004		12M1998 2M2003 3M2005
Gradzewicz *et al.* (2010)	CF	Industry	2Q1996 2Q1999 4Q2002 3Q2005 3Q2009	4Q1997 2Q2000 1Q2004 4Q2007 4Q2009	1Q1998 3Q2000 2Q2004 1Q2008	1Q1999 3Q2002 2Q2005 2Q2009
		Construction	2Q1996 3Q2003	2Q2000 3Q2007	3Q2000 4Q2007	2Q2003 4Q2009
Skrzypczyńska (2011)	CF	Manufacturing	7M1995 2M1999 10M2002 6M2005 6M2009	12M1997 3M2000 5M2004 11M2007 1M2011	1M1995 1M1998 4M2000 6M2004 12M2007	6M1995 1M1999 9M2002 5M2005 5M2009

Note: The differences in turning points moments may result from distinct dating rules, data revisions and different samples.

Table 6: Dominating cycles periodicity – sectoral overview

Variable	The length of cycle (years)									
	1.5-2.0		2.5		3.0-4.0		5.5		8.5	
	CF	UC	CF	UC	CF	UC	CF	UC	CF	UC
Gross value added	C				B	B			A	A
Construction	B								A	A
Trade	B	B				C			A	A
Transportation	B								A	A
Industry	C	C			B	B			A	A
Manufacturing	C	C			B	B			A	A
Durable consumer goods	C	C			B	B			A	A
Non-durable consumer goods	C	C	D		B	B			A	A
Capital goods		C	C		B	B			A	A
Intermediate goods	C	C			A	B			B	C
Energy	C	C	B	B			A	A		
Production of electric power	C	C	B	B					A	A

Note: A, B, C, D mean in sequence dominating cycles in the variability of cyclical component (from the most to the least dominating).

Table 7: Turning points leads and lags in reference to gross value added and sold production of industry

Method	Reference series	Turning points (P-Peak, T-Trough)	Construction	Trade	Transportation	Reference series	Turning points (P-Peak, T-Trough)	Manufacturing	Durable consumer goods	Non-durable consumer goods	Capital goods	Intermediate goods	Energy	Production of electric power
CF	Gross value added	P 1Q1998	-	-	-8	Industry	P 12M1997	0	+1	0	+2	0	-10	+8
		T 1Q1999	-9	-	-9		T 1M1999	0	+1	-	+3	0	+1	-17
		P 1Q2000	+4	0	0		P 3M2000	0	-4	-	+3	+1	+14	-
		T 4Q2002	+5	+2	-4		T 10M2002	-1	-6	-8	+1	-9	0	-6
		P 4Q 2004	-	-	-8		P 5M2004	0	-2	-3	+1	-1	+3	-8
		T 4Q2005	-	-	-5		T 5M2005	0	-1	-3	+1	-1	+2	-3
		P 1Q2008	-4	+1	-1		P 11M2007	0	-2	-5	+2	-2	+3	+1
		T 4Q2010	-2	-1	-6		T 5M2009	0	-3	+1	+3	0	-2	-2
		extra cycles	-1	0	0		extra cycles	0	1	0	0	0	2	3
UC		P 4Q1999	+1	0	+1		P 12M1997	+2	+2	+1	+3	+1	-8	-21
							T 2M1999	-1	-	-	0	-1	-1	-
		T 1Q2003	+5	+7	-5		P 12M1999	0	-	-	+6	0	+17	-
							T 5M2002	+9	-2	0	+7	-5	0	-2
		P 1Q2008	+1	+6	-1		P 4M2004	0	-1	-	0	0	+21	-2
							T 5M2005	-2	-2	-	0	-2	+21	-5
		T 1Q2011	-	-3	-7		P 2M2008	0	-4	-7	+2	-11	0	-
							T 1M2009	0	-1	-2	+11	0	+2	+4
		extra cycles	0	0	1		extra cycles	1	0	-1	0	0	0	0

Note: + (−) denotes a lag (lead) with respect to reference series.

Table 8: Cross-correlations in reference to gross value added and sold production of industry

Reference series	Method	Lead/lag indicator	Leading indicator				Coincident indicator	Lagging indicator			
			-4	-3	-2	-1	0	1	2	3	4
Gross value added	CF	Construction	0.20*	0.31*	0.41*	0.51*	0.58*	0.62*	**0.63***	0.61*	0.58*
		Trade	0.08	0.26*	0.43*	0.55*	**0.60***	0.54*	0.48*	0.47*	0.49*
		Transportation	0.64*	0.73*	**0.77***	0.74*	0.65*	0.51*	0.35*	0.20	0.07
	UC	Construction	0.10	0.25*	0.41*	0.56*	0.72*	0.78*	**0.81***	0.81*	0.78*
		Trade	0.07	0.21	0.37*	0.54*	**0.70***	0.66*	0.61*	0.65*	0.67*
		Transportation	0.36*	0.43*	0.48*	0.51*	**0.53***	0.48*	0.41*	0.32*	0.25*

Reference series	Method	Lead/lag in relation to reference series	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
Industry	CF	Manufacturing	0.53*	0.62*	0.71*	0.79*	0.86*	0.92*	0.96*	0.98*	**0.99***	0.98*	0.95*	0.91*	0.85*	0.78*	0.70*	0.61*	0.52*
		Durable consumer goods	0.43*	0.50*	0.57*	0.62*	0.67*	0.70*	0.71*	**0.71***	0.70*	0.66*	0.61*	0.55*	0.47*	0.39*	0.30*	0.21*	0.13
		Non-durable consumer goods	0.60*	0.64*	0.67*	0.70*	0.72*	**0.73***	0.73*	0.72*	0.69*	0.66*	0.61*	0.55*	0.50*	0.43*	0.37*	0.31*	0.25*
		Capital goods	0.45*	0.52*	0.60*	0.67*	0.74*	0.79*	0.84*	0.88*	0.90*	**0.91***	0.91*	0.89*	0.87*	0.83*	0.77*	0.72*	0.65*
		Intermediate goods	0.56*	0.64*	0.72*	0.80*	0.86*	0.91*	0.94*	**0.96***	0.96*	0.94*	0.90*	0.85*	0.78*	0.70*	0.60*	0.50*	0.40*
		Energy	-0.13	-0.05	0.04	0.12	0.20*	0.27*	0.33*	0.38*	0.41**	0.43*	**0.44***	0.43*	0.40*	0.37*	0.33*	0.28*	0.23*
		Production of electric power	0.58*	0.61*	0.63*	0.65*	**0.65***	0.65*	0.64*	0.62*	0.59*	0.55*	0.50*	0.44*	0.37*	0.31*	0.23*	0.16*	0.09
	UC	Manufacturing	0.49*	0.55*	0.60*	0.67*	0.72*	0.78*	0.82*	0.86*	**0.95***	0.85*	0.82*	0.78*	0.72*	0.67*	0.60*	0.55*	0.50*
		Durable consumer goods	0.46*	0.45*	0.53*	0.55*	0.53*	0.59*	0.58*	0.56*	**0.68***	0.53*	0.53*	0.53*	0.42*	0.41*	0.39*	0.31*	0.30*
		Non-durable consumer goods	0.37*	0.39*	0.43*	0.46*	0.49*	0.53*	0.55*	0.56*	**0.59***	0.52*	0.49*	0.45*	0.43*	0.39*	0.36*	0.32*	0.30*
		Capital goods	0.46*	0.48*	0.56*	0.61*	0.62*	0.72*	0.74*	0.73*	**0.88***	0.75*	0.77*	0.78*	0.70*	0.70*	0.69*	0.61*	0.60*
		Intermediate goods	0.47*	0.43*	0.57*	0.60*	0.59*	0.73*	0.70*	0.68*	**0.90***	0.67*	0.65*	0.67*	0.49*	0.50*	0.44*	0.30*	0.32*
		Energy	-0.04	-0.02	0.07	0.06	0.07	0.18*	0.14*	0.16*	**0.34***	0.18*	0.24*	0.27*	0.19*	0.21*	0.20*	0.09	0.11
		Production of electric power	0.47*	0.45*	**0.48***	0.45*	0.44*	0.45*	0.44*	0.42*	0.43*	0.38*	0.36*	0.36*	0.28*	0.26*	0.21*	0.13	0.09

Note: the bold values mean the highest correlation within 2 year lead/lag (with exception of energy (CF) - within 1 year lead/lag); *correlation coefficient statistically significant at the 5% level of significance.

Table 9: Average values of cross-spectral statistics before and after the crisis – sectoral overview

Variable	Cross-spectral analysis							
	Coherence		Dynamic correlation		Gain		Phase shift	
	1995-2007	1995-2011	1995-2007	1995-2011	1995-2007	1995-2011	1995-2007	1995-2011
Construction	0.346	0.212	0.530	0.381	0.161	0.120	0.693	0.738
Trade	0.296	0.371	0.460	0.496	0.487	0.537	-0.061	0.140
Transportation	0.346	0.379	0.519	0.478	0.197	0.198	-0.675	-1.177
Manufacturing	0.989	0.984	0.994	0.992	0.880	0.847	-0.047	-0.002
Durable consumer goods	0.801	0.518	0.893	0.702	0.568	0.359	-0.151	-0.243
Non-durable consumer goods	0.493	0.452	0.665	0.646	0.761	0.591	-0.702	-0.629
Capital goods	0.845	0.745	0.917	0.855	0.473	0.428	0.104	0.215
Intermediate goods	0.885	0.710	0.940	0.832	0.796	0.619	-0.800	-0.031
Energy	0.466	0.245	0.612	0.437	0.729	0.553	1.116	0.567
Production of electric power	0.492	0.355	0.641	0.538	1.346	1.025	-0.663	-0.730

Figure 1.a: Trend and cycle decomposition: CF filter

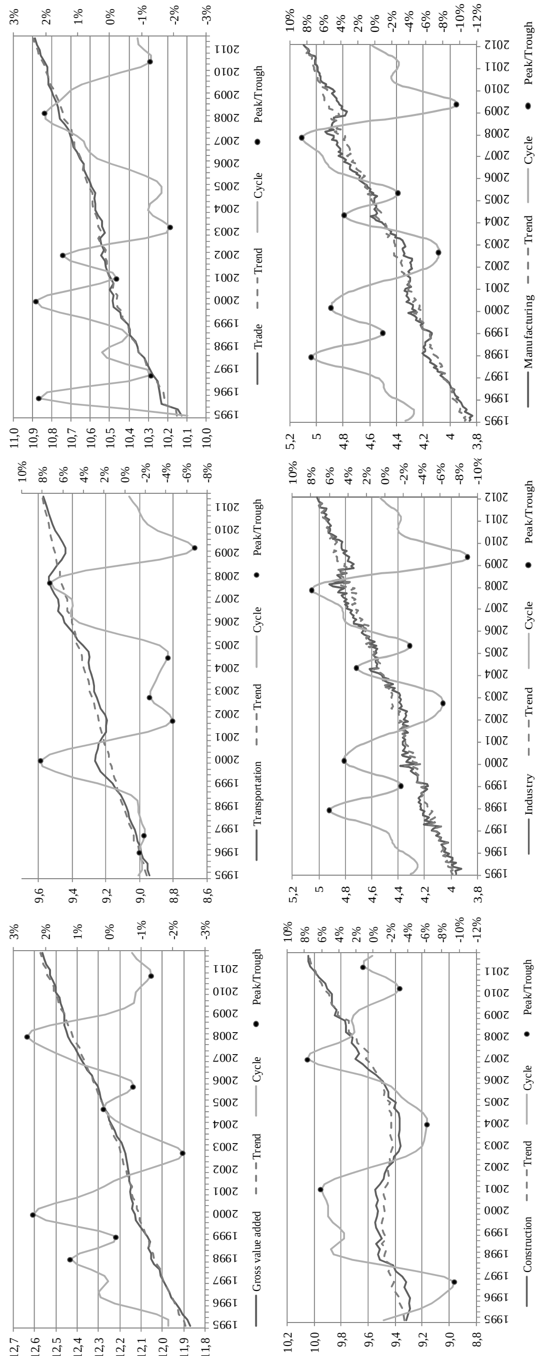

Figure 1.a: Trend and cycle decomposition: CF filter

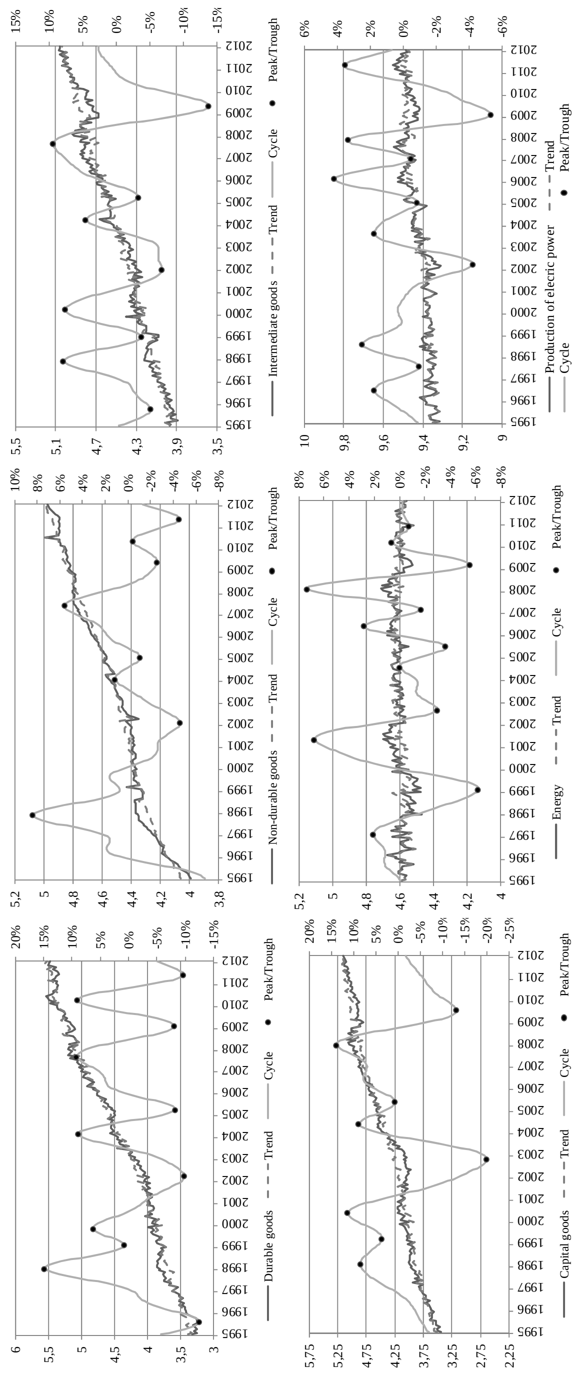

Figure 1.b: Trend and cycle decomposition: UC model

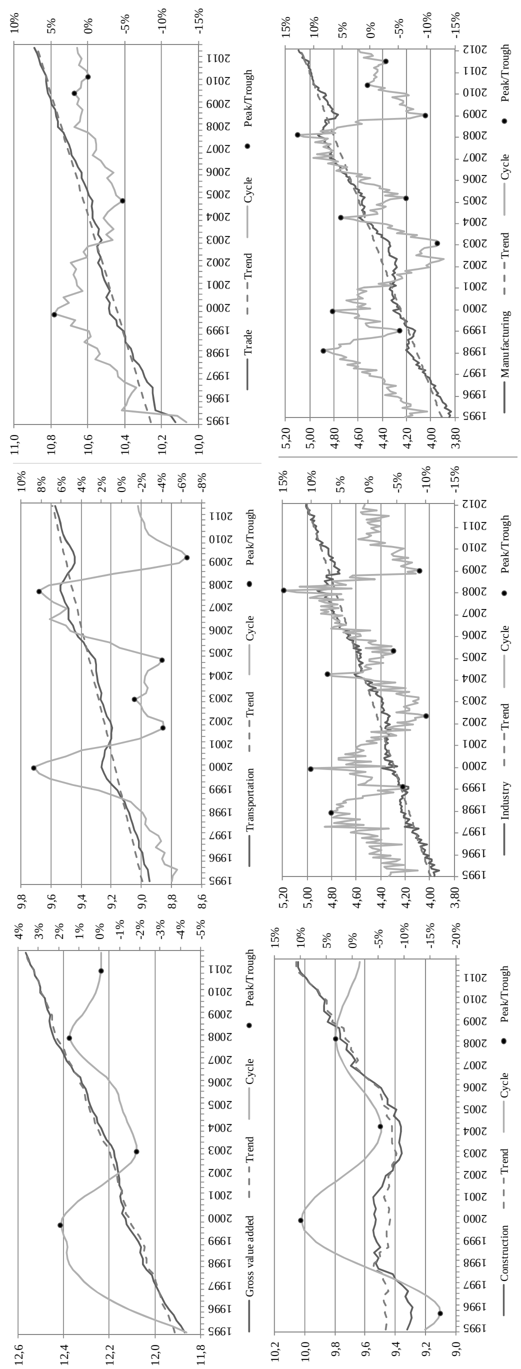

Figure 1.b: Trend and cycle decomposition: UC model

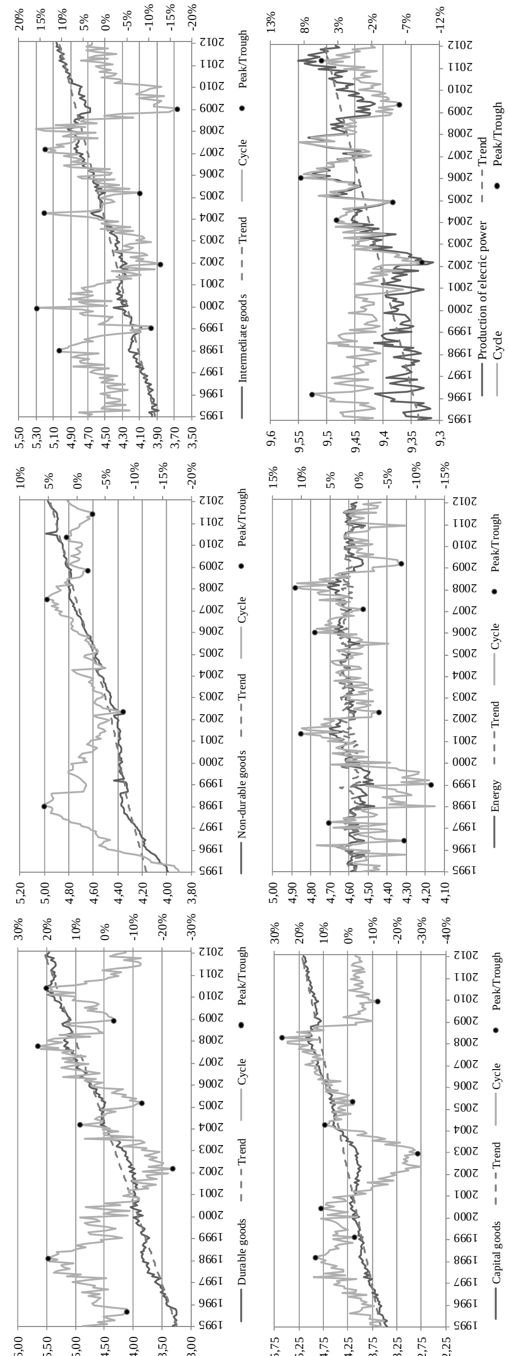

Figure 2: Cyclical components comparison of CF filter and UC model in relation to turning points chronology of gross value added (quarterly data) and sold production of industry (monthly data)

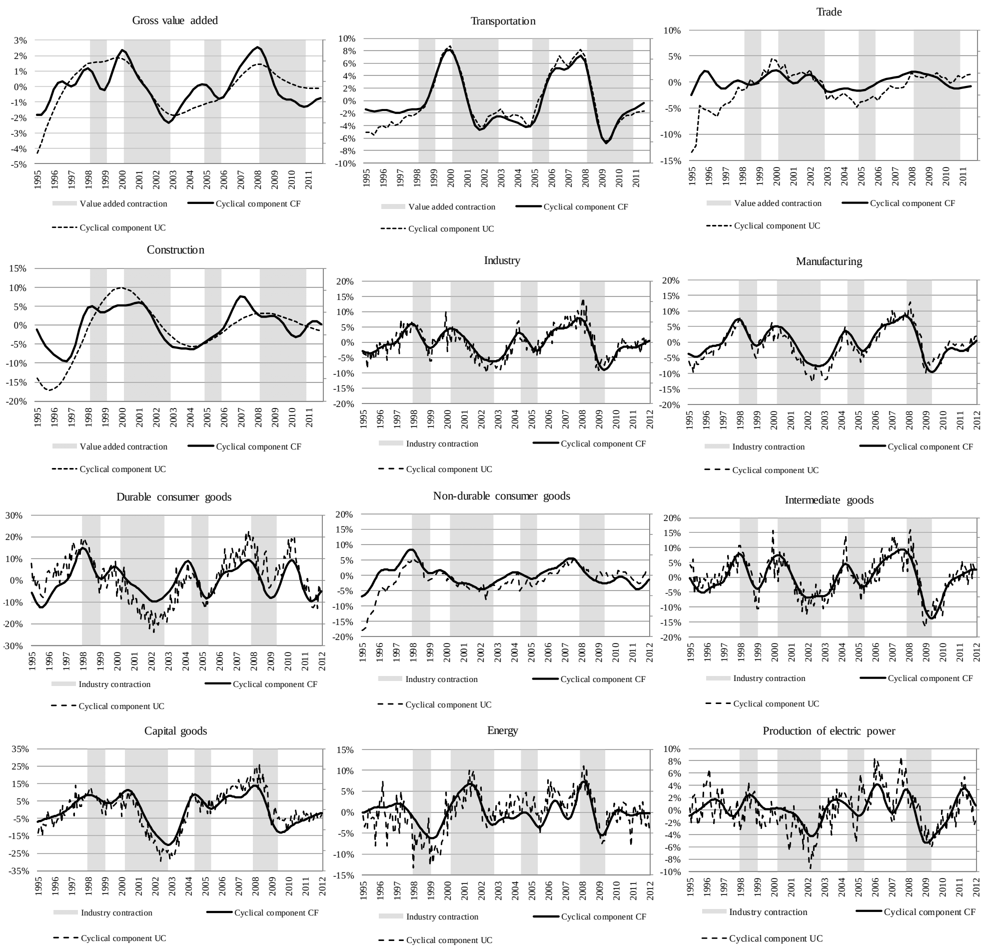

Figure 3: Peaks and troughs of cyclical components in relation to turning points chronology of gross value added (quarterly data) and sold production of industry (monthly data) - sectoral analysis

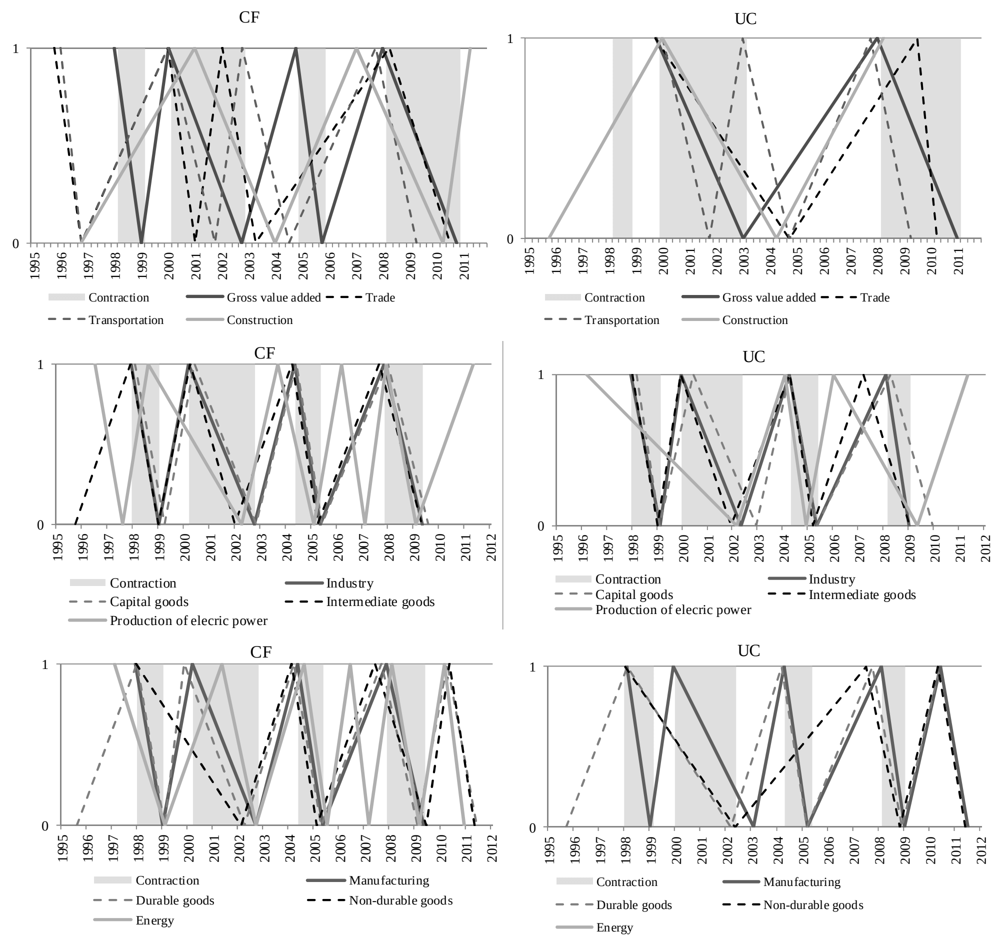

Figure 4: Cyclical components in relation to turning points chronology of gross value added (quarterly data) and sold production of industry (monthly data) - sectoral analysis

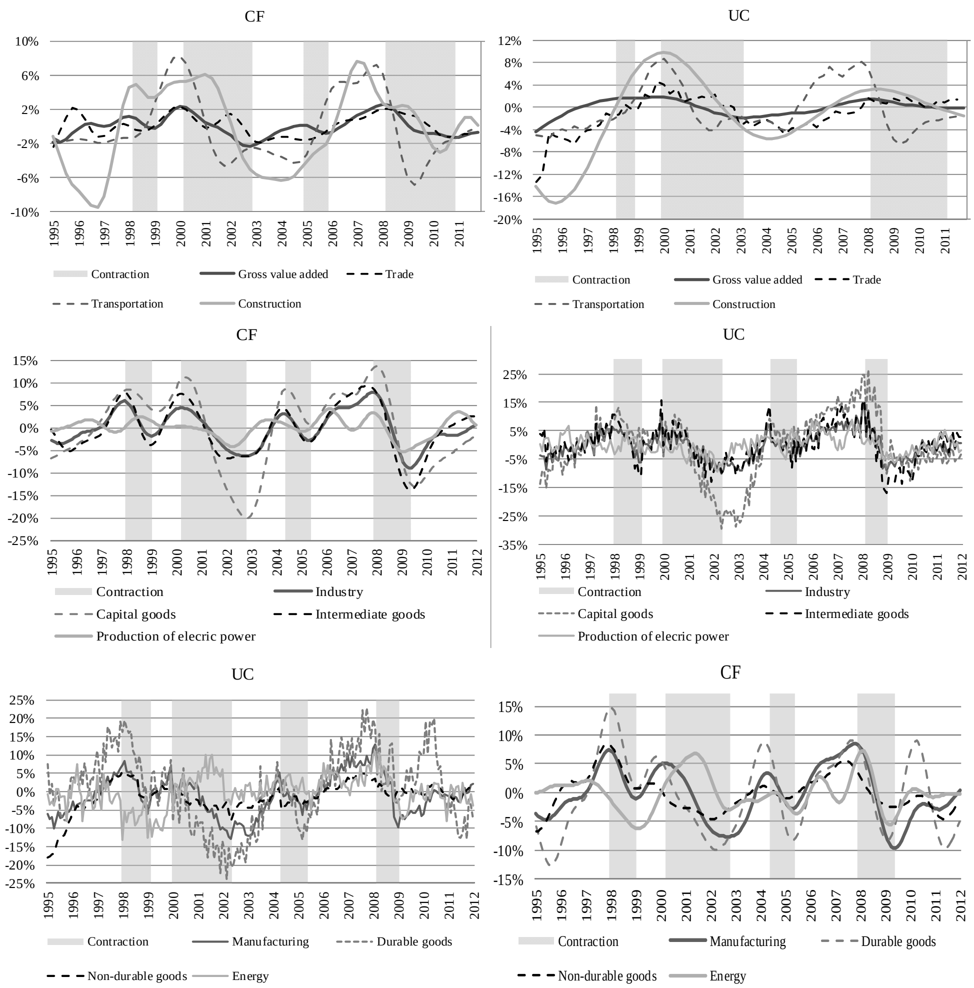

Figure 5: Periodograms of cyclical components - sectoral analysis

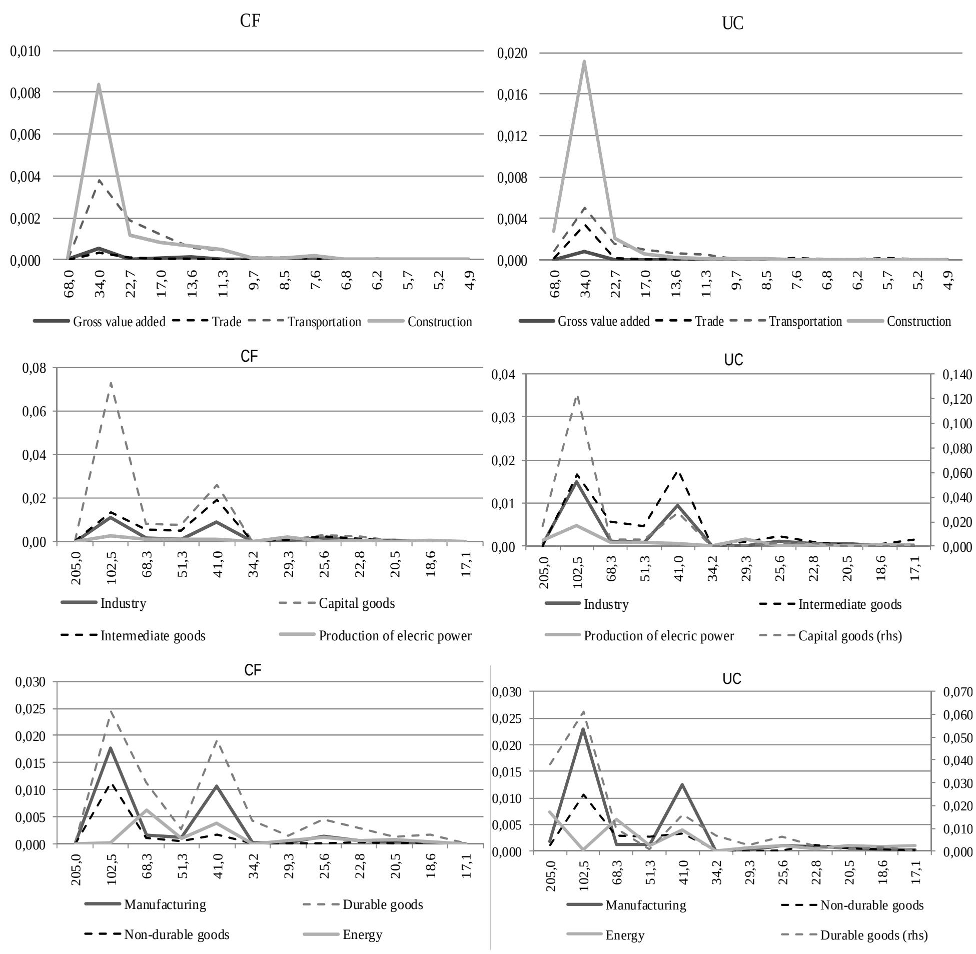

Figure 6.a: Spectral and cross-spectral analysis before and after the crisis – sectoral overwiev: spectrum

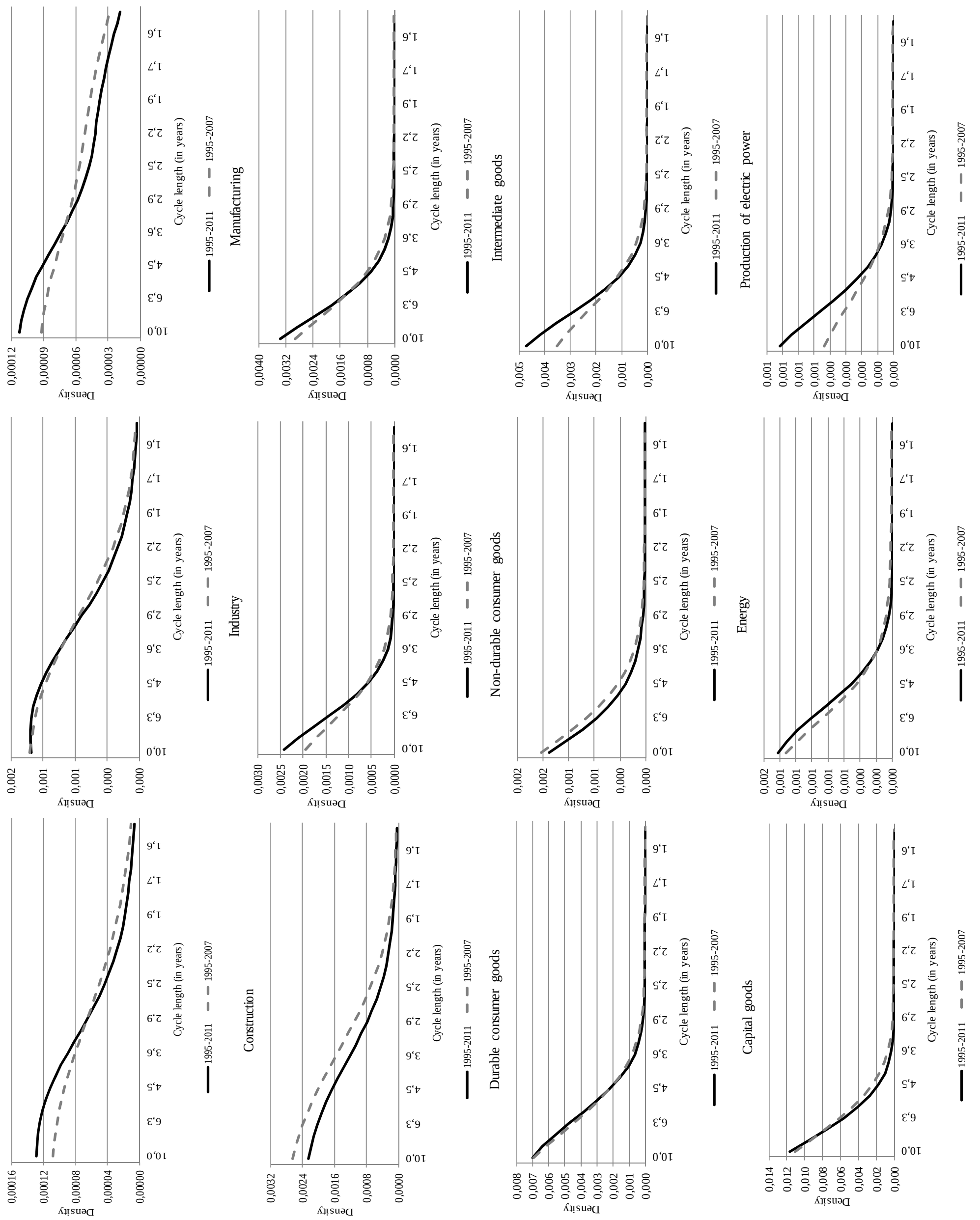

Figure 6.b: Spectral and cross-spectral analysis before and after the crisis – sectoral overwiev: coherence

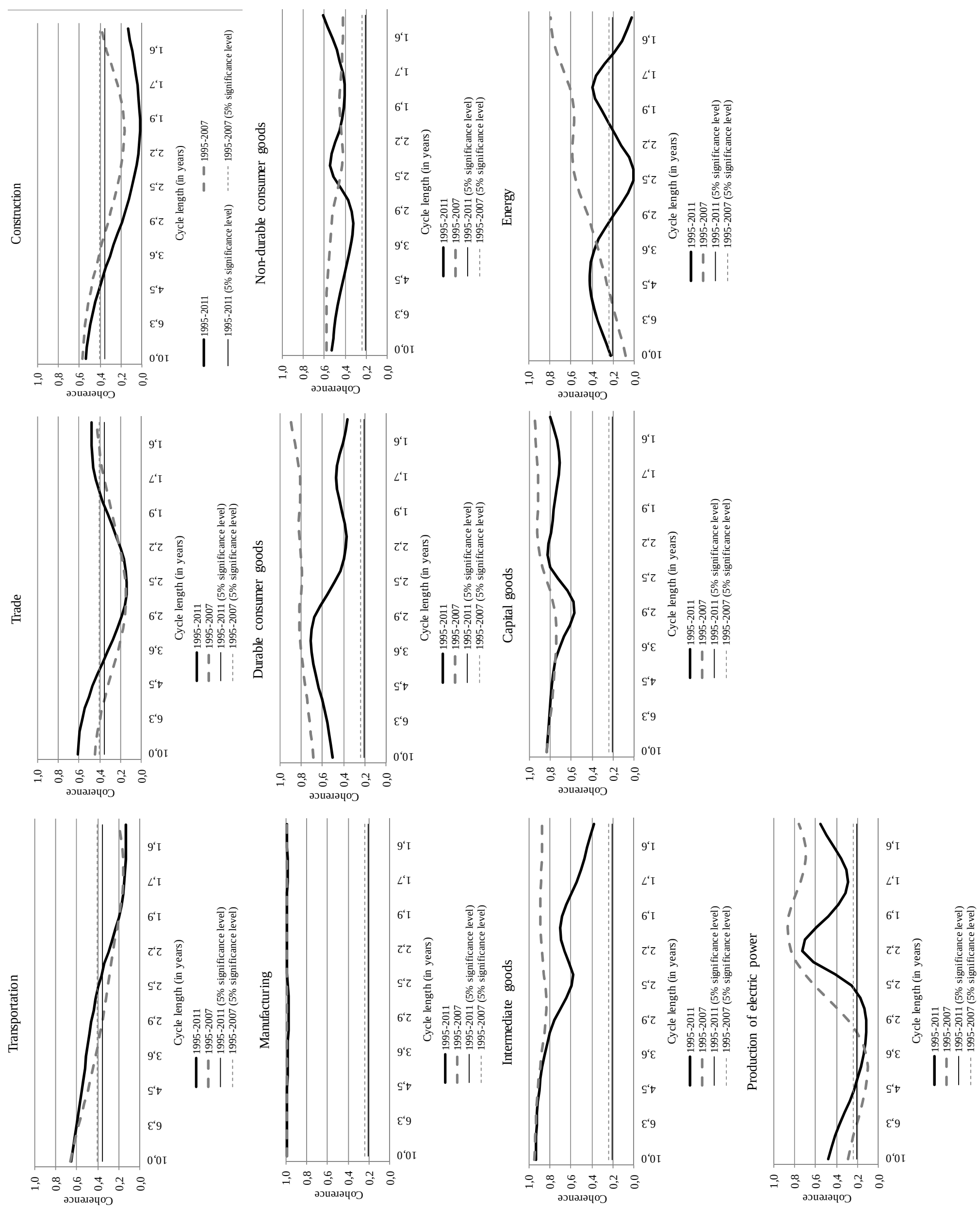

Figure 6.c: Spectral and cross-spectral analysis before and after the crisis – sectoral overwiev: dynamic correlation

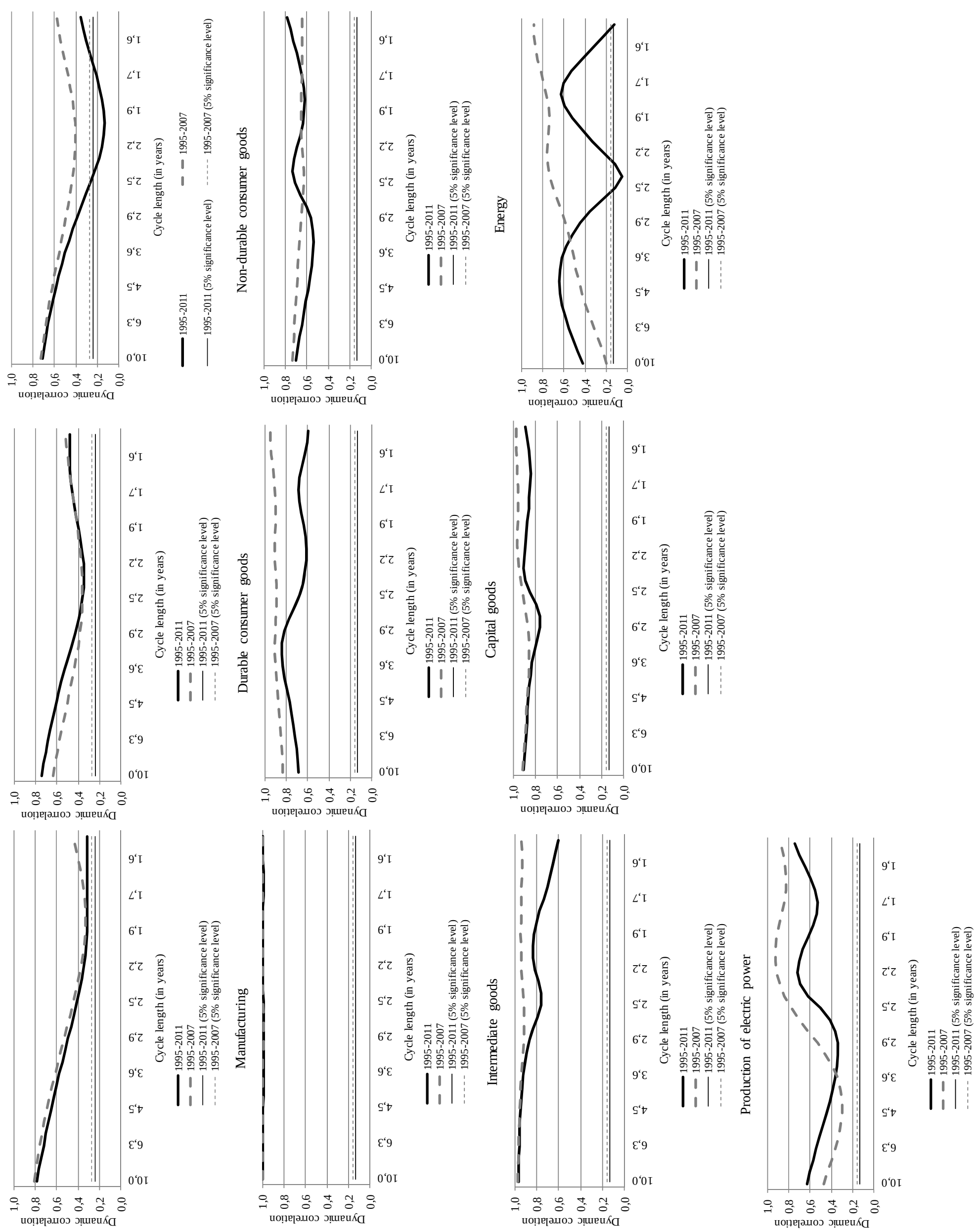

Figure 6.d: Spectral and cross-spectral analysis before and after the crisis – sectoral overwiev: gain