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Summary of Dissertation Research

Cyclical processes in the Polish economy

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1. Study background and significance

The dissertation analyses the economic activity in Poland using three methods: structural time series models, a band-pass filter and Markov-switching models with fixed and time-varying transition probabilities of business cycle phases.

Business cycle comprises fluctuations of economic activity indicators occurring around a long-term trend or growth rate fluctuations 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. This concept of business cycle merges the characteristics considered by Lucas (1997) and Hübner *et al.* (1994). The business cycle is a phenomenon that is still changing (see Mitchell 1927) and every cycle is a result of many factors, having different impact and direction. That is why there is a need to monitor and analyse it constantly. Together with the change of the business cycle morphology, the way of measuring cyclical fluctuations was revised. Before World War II, the business cycle analysis was conducted using levels of economic activity indicators. However Mintz (1970) observed that this approach led to wrong conclusions and she suggested the analysis of growth cycles.

The first aim of the conducted analysis is an extraction of cyclical components employing sectoral indicators of economic activity in Poland using three econometric tools.

The second objective concerns dating business cycle turning points and empirical analysis of business cycle in Poland after 1995, together with assessing the usefulness of chosen econometric tools, in particular the time-varying probabilities Markov-switching models.

Still the reason for analysing the business cycle in Poland is the lack of consensus in business cycle chronology. The turning points chronology for deviation cycle for various economic activity indicators can be found in many papers (see e.g. Adamowicz *et al.* 2008, Gradzewicz *et al.* 2010). The turning points of growth rate cycle were identified by Fic (2007).

For Polish economy there are only a few papers concerning the analysis of cyclical fluctuations using different econometric tools. The cyclical components extracted with different methods were described by Adamowicz *et al.* (2008) and Skrzypczyński (2010).

The structure of the dissertation is as follows. Chapter 1 provides the concept of business cycle and its morphology, business cycle theories, measures of economic activity and the main approaches to analyse cyclical fluctuations, including turning points identification. The next two chapters discusses the econometric methodology used in the empirical part. Chapter 2 concerns econometric tools appropriate for analysing deviation cycle, among others, spectral methods, Christiano-Fitzgerald (2003) filter and unobserved components model (see Watson 1986). Chapter 3 describes the Markov-switching models useful for growth rate cycle analysis. Chapter 4 describes the empirical analysis of cyclical fluctuations in Poland using econometric tools presented in previous chapters. The research on the Polish business cycle and dataset analysis is presented at first. The business cycle analysis involves the extraction of cyclical components, identification of turning points, relations of extracted cyclical components to reference cycles and the investigation of dominant cycles. It is assumed that the business cycle consists of two phases: expansion and contraction. The extraction of deviation cycle was conducted using a structural time series model according to Watson (1986) and the Christiano-Fitzgerald (2003) filter. The measurement of growth rate cycle was done using the Markov-switching model (see Hamilton 1989, Krolzig 1997). Firstly, Markov-switching autoregressive models with fixed transition probabilities (FTP) were estimated as a benchmark. On the basis of FTP model, the characteristics of the business cycle were investigated. The second step was the estimation of time-varying Markov-switching model (TVTP). Firstly, in the TVTP model it was assumed that the transition probabilities could be duration-dependent. To verify this assumption on the basis of turning points dates of gross value added and industrial production, the duration variable was constructed. Secondly, it was assumed that the transition probabilities could vary over time together with the evolution of a Composite Leading Indicator published by OECD. In the last part of empirical investigation, the characteristics of business cycle in Poland were revealed, also from the sectoral point of view. The dissertation ends with concluding remarks.

2. Dissertation theses

The two principal dissertation theses are:

1) It is possible to extract the cyclical components for Polish economy after 1995, in particular business cycle phases and turning points, using the chosen econometric tools.
2) The cyclical fluctuations in Poland are similar to business cycle of highly developed economies. Firstly, the business cycle comprises fluctuations of the economic activity that are not strictly periodic, the amplitude and turning points are different. Secondly, there is a comovement of activity among different sectors of the economy. Thirdly, the longer the business cycle phase lasts, the higher is the transition probability of going from one cycle phase to another.

3. Econometric tools

3.1 Spectral analysis and Christiano-Fitzgerald filter

Time series analysis in the frequency domain is also known as spectral analysis. Spectral analysis assumes that every covariance-stationary process $\{y_t\}$ can be represented in a frequency domain, which requires determining a power spectrum, allowing the assessment of the impact of different frequencies on the variability of the time series. The spectral density function is given as a Fourier transform of the autocovariance-generating function. Given the sequence of covariances $\{\gamma_j\}_{j=-\infty}^{\infty}$ of a covariance-stationary process in which autocovariances are absolutely summable, the spectral density function is (see Hamilton 1994):

$$S_y(\omega) = \frac{1}{2\pi}\sum_{j=-\infty}^{\infty} \gamma_j e^{-i\omega j} \text{ for } \omega \in [-\pi,\pi], \quad (1)$$

where $\frac{2\pi}{\tau}$ is a frequency related to period τ.

For the finite sample, the estimator of the spectral density function, known as a sample periodogram, is based on empirical autocovariance $\hat{\gamma}_j$ and can be defined as (see Hamilton 1994):

$$I_y(\omega) = \frac{1}{2\pi}\sum_{j=-(T-1)}^{T-1} \hat{\gamma}_j e^{-i\omega j} = \frac{1}{2\pi}\left[\hat{\gamma}_0 + 2\sum_{j=1}^{T-1}\hat{\gamma}_j \cos(\omega j)\right] \text{ dla } \omega \in [-\pi,\pi]. \quad (2)$$

The periodogram is an even function of nonnegative values, therefore 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, one can smooth the periodogram with the spectral window (e.g. Bartlett, Parzen). 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 the cross-spectrum, given the Fourier transform of the sequence of cross-covariance $\{\gamma_k^{yx}\}_{k=-\infty}^{\infty}$ of these variables (see Hamilton 1994):

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

The formula $c_{yx}(\omega) = 2\pi^{-1}\sum_{k=-\infty}^{+\infty}\gamma_k^{yx}\cos(\omega k)$ is called a co-spectrum and measures the covariance between cycles of two processes of the same phase, when $q_{yx}(\omega) = -2\pi^{-1}\sum_{k=-\infty}^{+\infty}\gamma_k^{yx}\sin(\omega k)$ 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 being its real and imaginary part, respectively. Cross-spectral density allows to define gain, phase shift, and coherence between two processes. These statistics are as follows (see Sargent 1987):

$$G_{yx}(\omega) = \frac{\left(c_{yx}^2(\omega)+q_{yx}^2(\omega)\right)^{\frac{1}{2}}}{S_x(\omega)} \text{ for } \omega \in [-\pi,\pi], \quad (4)$$

$$\varphi_{yx}(\omega) = \tan^{-1}\left(\frac{-q_{yx}(\omega)}{c_{yx}(\omega)}\right) \text{ for } \omega \in [-\pi,\pi], \quad (5)$$

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

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:

$$\rho_{yx}(\omega) = \frac{c_{yx}(\omega)}{\sqrt{S_y(\omega)S_x(\omega)}} \text{ for } \omega \in [-\pi,\pi]. \quad (7)$$

The gain is an even function and takes on nonnegative values. If $G_{yx}(\omega) > 1$, then the variable x_t has 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). 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 enables inference about the direction of the coincident relationship between variables.

To extract the components of the desirable frequency one could use the 'ideal' band-pass filter y_t^c, which however requires an infinite amount of data (see Sargent 1987):

$$y_t^c = B(L)y_t \tag{8}$$

where $B(L) = \sum_{j=-\infty}^{\infty} B_j L^j$ dla $t = 1,2, \dots, \infty$, $B_{-j} = B_j$ and $\sum_{j=-\infty}^{\infty} |B_j| < \infty$.

In practice, an approximation of the 'ideal' filter is used, e.g. BK – Baxter-King (1995) and CF – Christiano-Fitzgerald (2003).

In the dissertation, 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. Contrasting the CF filter with HP and BK requires exploration of the DGP of the time series. For a finite sample the estimator of the component $\hat{y}_t^c$ for fluctuations of the specific frequencies is:

$$\hat{y}_t^c = \hat{B}_t(L)y_t, \tag{9}$$

$$\text{where } \hat{B}_t(L) = \sum_{j=-(T-t)}^{t-1} \hat{B}_{j,t} L^j \tag{10}$$

for $t = 1,2...,T$ (see Christiano – Fitzgerald 2003) and the weights $\hat{B}_{j,t}$ are time-varying. The CF filter asymmetry arises from the dependence of an index of summation on time. That asymmetry 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), which 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:

$$\min_{\hat{B}_{j,t},\, j=-(T-t),\dots,t-1} E\left(\left(y_t^c - \hat{y}_t^c\right)^2 \middle| \{y_t\}_{t=1}^T\right), \tag{11}$$

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

3.2 Structural time series models – Watson model

Structural time series model is also known as unobserved components model (UC model) or state-space model and allows to decompose time series into unknown (hidden) components taking into account its Data Generating Process. The UC model is used to decompose the time series into trend and cycle. The conducted analysis in the dissertation bases on the Watson (1986) model:

$$\begin{aligned} Y_t &= T_t + C_t \\ T_t &= \mu + T_{t-1} + \varepsilon_t \\ C_t &= \phi_1 C_{t-1} + \phi_2 C_{t-2} + \xi_t, \end{aligned} \tag{12}$$

where ε_t ~i.i.d. N(0; σ_ε^2) and ξ_t ~i.i.d. N(0; σ_ξ^2).

In the above specification it is assumed that 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. In the dissertation the parameters $\mu, \sigma_\varepsilon^2, \phi_1, \phi_2, \sigma_\xi^2$ were estimated using the Maximum Likelihood via the Kalman filter – MLE is based on the prediction error decomposition.

The sample likelihood:

$$lnL = -\frac{nT}{2} ln 2\pi - \frac{1}{2}\sum_{t=1}^{T} ln\left|f_{t|t-1}\right| - \frac{1}{2}\sum_{t=1}^{T} \eta'_{t|t-1} f_{t|t-1}^{-1} \eta_{t|t-1}, \tag{13}$$

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.

3.3 Markov-switching models

Markov-switching model is a nonlinear model that can be used for business cycle analysis. Hamilton (1989) presented the Markov-switching model with fixed transition probabilities between business cycle phases (FTP):

$$y_t = \begin{cases} \mu_0 + \Phi(L)\left(y_{t-1} - \mu_{S_{t-1}}\right) + \varepsilon_t \text{ if regime } 0 \\ \mu_1 + \Phi(L)\left(y_{t-1} - \mu_{S_{t-1}}\right) + \varepsilon_t \text{ if regime } 1, \end{cases} \tag{14}$$

where $\phi(L) = \phi_1 + \phi_2 L + \cdots + \phi_r L^{r-1}$ is a lag operator, $\mu_{S_t} = \mu_0 + \mu_1 S_t$ and $\varepsilon_t \sim N(0, \sigma^2)$. Together with the latent regime (state) variable $S_t \in \{0,1\}$ changes only the mean of the process, whereas the lag polynomial and the variance of errors are unaffected. The driver of regime change is a first-order Markov chain:

$$P(S_t = s_t | S_{t-1} = s_{t-1}, \ldots, S_1 = s_1) = P(S_t = s_t | S_{t-1} = s_{t-1}). \tag{15}$$

The dissertation covers the Markov-switching model with two states reflecting the contraction and expansion of economic activity. The state variable evolves in line with the Markov chain with fixed transition probabilities:

$$P(S_t = s_t | S_{t-1} = s_{t-1}) = \begin{bmatrix} q & 1-q \\ 1-p & p \end{bmatrix}, \tag{16}$$

where p and q describe probabilities of staying in the current business cycle phase, expansion and contraction, respectively, and $1-p$ and $1-q$ the probabilities of going from one state to another. This specification indicates that the expected duration of business cycle phases is constant.

The model parameters were estimated according to Hamilton (1989), using the maximum likelihood estimation. To assess that the sample observation comes from the specific business cycle phase, the smoothed probabilities according to Kim (1994) backward filter were used. In that filter, the smoothing algorithm starts from the last point of the sample:

$$P(s_t|s_{t+1},Y_T;\boldsymbol{\theta}) = P\left(s_t|s_{t+1},Y_t,Y_{t+1,T};\boldsymbol{\theta}\right) = \frac{f(Y_{t+1,T}|s_t,s_{t+1},Y_t;\boldsymbol{\theta})P(s_t|s_{t+1},Y_t;\boldsymbol{\theta})}{f(Y_{t+1,T}|s_{t+1},Y_t;\boldsymbol{\theta})} = P(s_t|s_{t+1},Y_t;\boldsymbol{\theta}). \quad (17)$$

When the assumption that the transition probabilities are fixed is changed (see Diebold, Lee, Weinbach 1994, Filardo 1994), allowing them to evolve over time (TVTP, time-varying transition probabilities) together with the changing economic conditions, then the state variable S_t is driven by the Markov process:

$$P(S_t = s_t|S_{t-1} = s_{t-1}, Z_{t-1} = z_{t-1}) = \begin{bmatrix} q(z_{t-1}) & 1-q(z_{t-1}) \\ 1-p(z_{t-1}) & p(z_{t-1}) \end{bmatrix}, \quad (18)$$

where the variable Z_{t-1} is an economic indicator and the transition probabilities $p(z_{t-1})$ and $q(z_{t-1})$ evolve according to the logistic function:

$$p(z_{t-1}) = \frac{exp(p_0+p_1z_{t-1})}{1+exp(p_0+p_1z_{t-1})} \ , \quad (19)$$

$$q(z_{t-1}) = \frac{exp(q_0+q_1z_{t-1})}{1+exp(q_0+q_1z_{t-1})}. \quad (20)$$

The parameters p_0 and q_0 describe the fixed, wheras p_1 and q_1 varying parts of probabilities, that the specific state will survive for expansion and contraction respectively. If the parameters p_1 and q_1 have opposite signs, then the probabilities of surviving of the expansion and contraction respectively change in the opposite direction in reference to fluctuations of Z_{t-1}. This interpretation is intuitive.

The business cycle analysis concerns also the duration dependence (see Durland, McCurdy 1994, Layton, Smith 2007). In this case, the variable Z_{t-1} depicts the survival time of current business cycle phase. The negative sign of the p_1 and q_1 parameters means that the transition probabilities increase for expansion and contraction, respectively (the longer the current phase lasts, the shorter is the survival time).

4. Chosen empirical results

4.1 Introduction

The database covered the wide spectrum of the economic activity represented by the chosen sections of the national economy. In addition to national economy data covering the quarterly national accounts, the more sensitive, monthly sectoral economic activity indicators were employed. The criteria of selection were: availability of the time series since 1995 and data cohesion within the accessible sample.

The database included the 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, with the exception of 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. Besides the mentioned time series, other indicators were also taken into account, although did not meet the criteria.

4.2 Deviation cycles (quarterly data)

The analysis of cyclical components within sectors of the economy gives a comprehensive view of business cycle. Figure 1 presents the estimated trends and cycles of CF filter and UC model against the chronology of gross value added.

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 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. For detailed specification of cycle phases and turning points see Table 1.

Figure 1: Cyclical components extracted from the Christiano-Fitzgerald filter (CF) and unobserved components model (UC) in relation to turning points chronology of gross value added – sectoral analysis

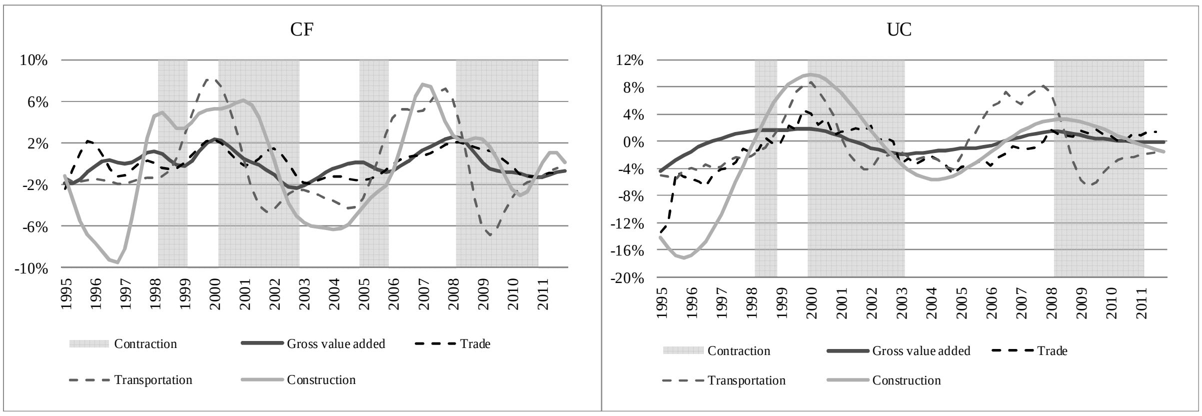


Table 1: Business cycle characteristics – sectoral overview (quarterly data)

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	Contraction		Expansion	Contraction
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

Taking into account the cyclical components of CF filter it can be concluded, that 4 cycles of gross value added fluctuations lasting approximately 3.8 years within the years 1995-2012 were revealed. The cyclical component of gross value added of UC model showed only 2 cycles lasting on average 6.7 years, but these cycles seem spurious, taking into account other results presented in the dissertation 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).

Interestingly, cyclical fluctuations vary across sectors with respect to turning points (local minima and maxima) and amplitudes, which are given as deviations on the percentage scale (see Table 1 and Figure 1).

Taking into account the determined turning points and the other characteristics of cyclical components, it can be concluded that construction is the sector of the lowest periodicity of cycles compared to gross value added, industry, trade and transportation, that lasted about 5 and 7 years – according to CF filter and UC model, respectively. Cycle amplitude is relatively the largest and the fluctuations are 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 contraction, contrary to the results for CF filter.

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 lasts longer than contraction. Cyclical amplitude is similar to deviations of gross value added.

CF filter and UC model show that in transportation, cycles last respectively approximately 3.5 and 4.5 years with amplitudes being higher compared to gross valued added and trade, while being lower in comparison with construction. Both for CF filter and UC model fluctuations are asymmetric in length of cycle phases - contraction is shorter compared to expansion. The contraction according to UC model has a smaller amplitude compared to expansion, whereas the amplitude according to CF filter is symmetric.

The cyclical fluctuations in Poland are determined foremost by the longest cycles. The 2008 financial crisis influenced the longest cycles the most, whereas the spectrum changed the hardest foremost in construction and transportation, followed by gross value added and trade.

4.3 Growth rate cycles (quarterly data)

Firstly, in the framework of growth rate cycles, the parameters of the FTP models were estimated for gross value added and sectoral indicators (see Table 2). The Parameters $\mu_{0,}$ $\mu_{1,}$ ϕ_i and σ^2 describe the average growth rate of contraction and expansion, i-order autoregressive parameter and variance of error term. In the brackets are the standard errors of estimated parameters.

Table 2: The parameter estimates of FTP models and the characteristics of sectoral economic activity – quarterly data

Parameter/Variable	Gross value added	Construction	Transportation	Trade
μ_0	2,80 (0,40)	-2,20 (1,93)	-4,69 (1,46)	2,38 (0,50)
μ_1	6,24 (0,53)	9,23 (1,62)	5,76 (0,62)	5,68 (0,35)
ϕ_1	0,12 (0,16)	0,38 (0,12)	-0,05 (0,14)	0,12 (0,14)
ϕ_2	0,02 (0,14)			-0,19 (0,14)
ϕ_3	0,40 (0,14)			-0,03 (0,13)
ϕ_4				-0,27 (0,12)
σ^2	1,29 (0,15)	5,60 (0,54)	4,42 (0,42)	2,04 (0,21)
q	0,88 (0,05)	0,94 (0,05)	0,80 (0,12)	0,91 (0,07)
p	0,73 (0,11)	0,98 (0,02)	0,96 (0,03)	0,94 (0,05)

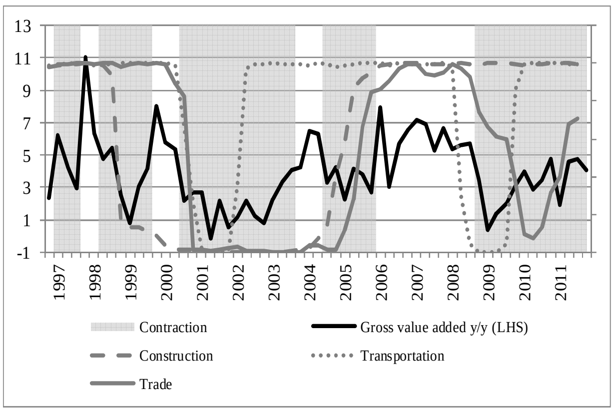
NOTE: The average phase and cycle duration were calculated taking into account the dating rules – these durations may be slightly different from expected duration for business cycle phases that may be calculated from the transition probabilities.

The yearly growth rate of gross value added during contraction is 2.8%, whereas for expansion amounts to about 6.2%. The busienss cycle is clearly visible, because the probability that the contraction (expansion) follows a contraction (expansion) are high (the parameters q and p respectively). For the gross value added, the probabilities that the contraction follows a contraction is higher compared to expansion and amounts to 0.88 and 0.73 respectively. Trade and gross value added have very similar amplitudes for both cycle phases. In contraction, the yearly growth rate of economic activity in trade decelerates on average to almost 2.4% compared to 5.7% for expansion. Similar phenomena occur for construction and transportation, although the amplitude is higher compared to gross value added fluctuations. In a contraction, the level of economic activity indicators for these two sectors falls by 2.2% and 4.7% yearly, in construction and transportation, respectively.

The probabilities of transition to expansion (contraction) from expansion (contraction) are quite high. Not only in construction, but also in transportation and trade these probabilities are higher for expansion than contraction. The highest transition probability of going from contraction to expansion is for transportation. There is 20% chance of switching the regime. For trade the duration of cycle phases does not differ significantly, whereas for construction and transportation there is asymmetry. In construction the contraction lasts on average 25 quarters, in transport only 6 quarters, whereas the expansion lasts almost 19 and 17 quarters respectively. These conclusions are drawn also from the measures of the average duration of business cycle phases determined after the identification of turning points of the analysed economic indicators.

Figure 2 shows the probability that the sectoral economic activity indicators were in expansion. The shadowed area reflects the period of economic activity deterioration of gross value added. Interestingly, the probabilities are different and depend on the sector of economy. The turning points chronology and descriptive statistics among sectors are presented in Table 3. The economic activity was determined to be in a contraction when the probability was less than 0.5. Otherwise, expansion of the economic activity was assumed. In addition, the conditions for duration of cycle and phases were the same as for CF filter and UC model – the business cycle phase should last no shorter than 2 quarters and the whole cycle no less than 1.5 years.

Figure 2: The probabilities of expansion against yearly differences of natural logarithms and economic contraction of gross value added



Taking into account the identified turning points (see Table 3) and the probabilities of slowdown and expansion (see Figure 2), it can be concluded that in 1996-2012 there were almost 5 cycle of gross value added fluctuations lasting nearly 3.5 years. The economic contraction of gross value added lasts on average about 2 years and is longer compared to expansion. The cycles of construction are of the lowest periodicity – in 1996-2012 there were almost only 2 cycles (11-years), whereas in transportation and trade almost 3 cycles occured (5.5-6 years). Also, the transportation, construction and trade seem to be immune to external economic shocks like the 1990's Russian crisis and the EU accesssion.

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

Variable	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	Contraction		Expansion	Contraction
Gross value added	1Q1998 2Q2000 2Q2004 3Q2008	3Q1997 3Q1999 3Q2003 4Q2005 4Q2011	4,5	3,3	4,8	8,4	2,2	1,6	1,4
Construction	3Q1998 4Q2011	4Q2004	1,5	11,0	19,0	25,0	8,4	6,3	5,6
Trade	3Q2000 3Q2009 3Q2011	2Q2005 1Q2011	2,5	6,0	11,3	12,5	2,7	2,0	2,3
Transportation	3Q2000 1Q2008 3Q2011	1Q2002 3Q2009	2,5	5,7	16,7	6,0	6,0	4,6	3,2

Table 4: Estimates of the TVTP duartion dependence models – quarterly data

Parameter/Variable	Gross value added	Construction	Transportation	Trade
μ_0	2,38 (0,55)	-2,5 (1,97)	-6,15 (3,66)	1,98 (0,76)
μ_1	5,02 (0,61)	9,74 (1,81)	4,16 (1,86)	4,99 (0,74)
ϕ_1	0,21 (0,19)	0,36 (0,16)	0,68 (0,10)	0,63 (0,17)
ϕ_2	0,17 (0,16)			-0,02 (0,26)
ϕ_3	0,00 (0,15)			-0,38 (0,20)
ϕ_4				0,39 (0,14)
σ^2	1,37 (0,17)	5,85 (0,61)	4,35 (0,44)	1,82 (0,19)
q0	20,59 (0,76)	5,38 (71,16)	18,1 (192,78)	-30,6 (15885,0)
q1	-14,87 (413,82)	-8,09 (202,79)	23,34 (348,01)	-36,69 (19734,04)
p0	2,58 (0,61)	5,25 (35,42)	42,85 (683,67)	113,37 (1117,2)
p1	0,68 (0,76)	-5,43 (100,99)	16,09 (256,96)	-169,95 (1660,2)
LR*	6,3	1,5	32,0	9,2

NOTE: *$\chi 2$ =5.99 – chi-square statistic for test with two restrictions, p-value of 0.05.

The estimated parametres of TVTP models of duration dependence are shown in Table 4. The likelihood ratio test allowed to reject the null hypothesis of fixed transition proababilities and accept the alternative, that for gross value added, transportation and trade these probabilities are time-varying. However, for none of these time series the parameters of duration dependence were statistically significant (the parameters p_1 and q_1). For Polish economy it can not be confirmed that there is duration dependence in business cycle.

There are different empirical results for the US economy. Durland, McCurdy (1994) stated that there is a duration dependence for recessions but not for expansions. Layton, Smith (2007) incorporated in the model both duration variable and fluctuations of two leading indices. They found that the current duration is not only a significant determinant of transition out of recessions, but also weakly significant in the case of expansions.

4.4 Business cycle in Poland – comparative analysis (monthly and quarterly data)

The database covered a wide spectrum of economic activity represented by 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 conclusions about economic activity in Poland in relation to deviation cycle and growth rate cycle are quite similar.

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 shortest fluctuations of 1.5-2 years play also a significant role. Economic activity indicators for Polish economy exhibit various cyclical patterns – their fluctuations are different in the amplitude, length of cycle and turning points.

On the basis of the conducted analysis it can be concluded that cyclical fluctuations in construction, transportation and trade are different compared to those of gross value added. The economic activity in transportation appears to be leading the fluctuations of gross value added, whereas the activity in construction appears to be lagging those 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.

As far as the growth rate cycles are considered, in the contraction, the fluctuations in construction and transportation drop in absolute level, conversely to gross value added fluctuations, where only the growth rate decelerates. In construction, cycle phases are asymmetric as far as the length and amplitude are concerned. The economic activity in construction, transportation and trade seems to be immune to external shocks (the Russian crisis and the EU accession), contrary to industry. The volatility of industry accounts for about 25% of gross value added and seems to be responsible for its fluctuations.

The economic activity in industry is determined by manufacturing, especially of the capital and intermediate goods (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 particular for the deviation cycle. 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 the highest, whereas the amplitude of the production of electric power is the lowest. Manufacturing and energy have the most similar amplitude compared to industry fluctuations. The deviation cycle fluctuations of capital goods, intermediate goods and energy are asymmetric both in length and amplitude – the contraction is more violent than expansion. The growth rate cycle fluctuations have the same pattern of asymmetry in industry, manufacturing and capital goods.

The analysis in time frequency domain confirm, with some exceptions, the results in time domain. In the framework of growth rate cycles, it was verified that the Polish business cycle phases were not duration dependent – we should not expect the transition out of the current phase the longer this phase lasts.

The crisis influenced the longest cycles the most, whereas the spectrum changed the most 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.

The conducted analysis allows to formulate a few conclusions concerning the deviation and growth rate cycles. Firstly, the growth rate cycles have bigger amplitudes compared to deviation cycles. Secondly, deviation cycles of the cyclical component of CF filter and UC model are similar, although the UC model fluctuations were consistently more volatile. The biggest differences relate to gross value added and construction. Thirdly, the periodograms showed that the deviation cycles were foremost driven by longer cycles lasting about 8.5 years, followed by shorter fluctuations recurring every 3-4 years, whereas for the growth rate cycles, the impact of the longer and shorter cycles is more balanced.

5. Conclusions

Various econometric tools together with accurately chosen economic activity indicators were used to conduct a complete analysis of business cycle in Poland. The empirical investigation covers the extraction of the business cycle components, turning points dating and identification of the stylized facts of business cycle in Poland since 1995 and can be concluded, that the business cycle characteristics are similar to their counterparts in the developed economies.

Economic activity indicators for Polish economy exhibit various cyclical patterns – their fluctuations are varied in amplitude, length and turning points of the cycle. The cyclical fluctuations of construction, transportation and trade are dissimilar to those of gross value added. The economic activity in transportation appears to be leading the fluctuations of gross value added, whereas the activity in construction appears to be lagging those fluctuations. It seems the industry and construction fluctuations are responsible for the variation of gross value added. Manufacturing fluctuations, especially of capital and intermediate goods, 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 than expansion. The production of non-durable consumer goods, energy and production of electric power are the most desynchronized with the industry fluctuations. Production of electric power leads industrial production and it may be treated as an early warning indicator of economic activity, albeit with some caution.

It appears that early signals of economic contraction are reflected first by the production of electric power, then by the slowdown in transportation, followed by weakening in industrial production, especially in enterprise demand for capital and intermediate goods. Finally, a contraction in construction may occur.

The cyclical processes of Polish economic activity are determined by overlapping higher frequency fluctuations (3-4 years), longer cycles of 8.5 years and the longest cycles (even 10 years) in construction. The shortest fluctuations of 1.5-2 years play also a significant role. Four cycles occurred between 1996 and 2011. The economic activity in Poland did not resist the 2008 financial crisis. The biggest changes occurred in economic activity of construction, capital and intermediate goods and for most sectors were reflected in the longest cycles. After the crisis, the correlation between almost all sectors and reference series fell, reflecting the growth in amplitudes.

6. The structure of dissertation

Preface

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Appendix 3. Economic activity indicators and the reason for omitting them in the analysis

Appendix 4A. Cross-spectral analysis (CF filter)

Appendix 4B. Cross-spectral analysis (UC model)

Abstract. Cyclical processes in the Polish economy

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