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Statistical Analysis of Business Cycle Fluctuations in Poland Before and After the Crisis**

Abstract: *The main objective of the paper is to investigate properties of business cycles in the Polish economy before and after the recent crisis. The essential issue addressed here is whether there is statistical evidence that the recent crisis has affected the properties of the business cycle fluctuations. In order to improve robustness of the results, we do not confine ourselves to any single inference method, but instead use different groups of statistical tools, including non-parametric methods based on subsampling and parametric Bayesian methods.*

We examine monthly series of industrial production (from January 1995 till December 2014), considering the properties of cycles in growth rates and in deviations from long-run trend. Empirical analysis is based on the sequence of expanding-window samples, with the shortest sample ending in December 2006. The main finding is that the two frequencies driving business cycle fluctuations in Poland correspond to cycles with periods of 2 and 3.5 years, and (perhaps surprisingly) the result holds both before and after the crisis. We, therefore, find no support for

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the claim that features (in particular frequencies) that characterize Polish business cycle fluctuations have changed after the recent crisis. The conclusion is unanimously supported by various statistical methods that are used in the paper, however, it is based on relatively short series of the data currently available.

Introduction

The global financial crisis, with its origins in August 2007, has addressed the need of a major rethinking in macroeconomics, changing substantially directions of the frontier research. In particular, abrupt, strong and omnipresent effects of the crisis in the US subprime market affecting the global economic growth, prompted new studies on the nature of the procyclicality of the financial system, which has existed in macroeconomics through decades as a topic of secondary importance; see Woodford (2003). Therefore, the analysis of the empirical properties of the financial cycle is one of the most important issues of the empirical macroeconomics nowadays; see Borio *et al.* (2011), Borio (2014) and Drehman *et al.* (2012).

On the other hand, the aforementioned major rethinking in macroeconomics has not only paved new routes for researchers, but it showed some new perspectives of problems that have been studied for decades. Just before the crisis, the empirical macroeconomics was focused on the observed correlation of changes of the world economic activity. The years preceding the crisis have seen new studies focused on construction of appropriate measures of synchronization of the business cycles rather, than examining well established properties of the cycle in the most of economies (see Stock & Watson, 2005; Doyle & Faust, 2005; Imbs, 2004; Kose *et al.,* 2003; Kose *et al.,* 2008).

The economic growth in the 1980s and 1990s has been remarkably more stable than the eight or nine decades that preceded it. Consequently, many researchers indicated that the properties of the business cycles changed distinctly, making fluctuations of economic activity relatively weaker at the beginning of the XXI century (see Taylor 1998; Romer 1999; Stock & Watson, 2003). In the mid-1980s, recessions in advanced economies rarely occurred and have become less pronounced, while expansion phases have become longer-lasting (see Kannan *et al.*, 2012). The literature explains this phenomenon by the globalization processes, the organizational and technical development observed in financial markets, changes in the structure of aggregate output, with growing importance of the service sector and still important but declining contribution of manufacturing to the growth, and – more importantly – better macroeconomic policies (see Blanchard & Simon, 2001; Romer, 1999).

However the impact of the global financial crisis on the economy was definitely very strong. Hence the properties of the cyclical fluctuations in the real sector may have changed substantially. Also, there is no doubt that all the explanations mentioned above for the hypothetical existence of the new era of stable economic growth that would have been initiated in 1980s, are no longer valid. Therefore the problem of renewed investigation of the empirical properties of the business cycle, especially for small open economies, is of importance nowadays. It is of crucial importance for the design of successful monetary policy. Moreover, Polish economy can be perceived as an interesting case, as it stayed resilient to the impact of the global financial crisis and seems to represent certain degree of balance between internal and external factors influencing business cycle.

The properties of business cycle in the Polish economy were examined by Skrzypczyński (2010), Gradzewicz *et al.* (2010), Adamowicz *et al.* (2008), Skrzypczyńska (2014) and partially in Wośko (2009). Skrzypczyński (2010) used nonparametric band-pass filters and spectral methods; the author concludes that on a basis of Polish GDP data two lengths of business cycle were detected in the 1995–2007 period, namely a shorter business cycle with 3 years length and a longer one, lasting 6-7 years. The same set of tools was considered in Gradzewicz *et al.* (2010), but for a different set of macroeconomic data. The main conclusion formulated in the paper is that the length of the business cycle is approx. 6-8 years based on spectral analysis applied to all cyclical patterns extracted from the macroeconomic series under consideration. Only in the case of monthly industrial production index and monthly export, the business cycles with length of 3-4 years were detected. Wośko (2009) considered a small set of general business indicators, and the main conclusion was that the length of business cycle is approx. 4 years. Adamowicz *et al.* (2008) considered a broad set of macroeconomic indicators, detecting the cycles within 2.5-4 years range. According to Skrzypczyńska (2014), the overall business cycle dynamics of the Polish economy consists of three overlapping cyclical patterns corresponding to cycle lengths of 1.5-2 years, 3-4 years and 8.5 years. In summary, the authors have used different statistical methods, different datasets and obtained somewhat divergent conclusions.

The above overview suggest that the structure of the business cycle fluctuations in Polish economy is not fully transparent. Some of the authors focus on identification of a single most important pattern of cyclical fluctuations, whereas the observed dynamics could have been driven by different interfering components. This suggests that a potentially useful statistical method should allow for joint identification of several frequencies, and that the crucial issue is related to the uncertainty associated with statistical in-

ference. The methods used in the literature vary with the respect to formal advancement; some of the methods do not allow for testing significance or e.g. interval estimation of the cycle length.

The main objective of the paper is to investigate properties of business cycles in the Polish economy before and after the recent crisis, using fully formal methods of statistical inference in order to shed some light on the discrepancies mentioned above. Since the last crisis in Poland was not as deep as in other European economies (Poland was called "the green island" on a red map) we suspect that formal statistical tools might indicate that the length of the business cycle have been relatively stable before and after the crisis.

Research Methodology

We make use of two main groups of statistical methods here. In the first approach, we rely on subsampling inference about discrete spectrum of the Almost Periodically Correlated (APC) stochastic processes (see Lenart, 2013; Lenart & Pipień, 2013). The second approach bases on the Bayesian inference utilized for formal small sample statistical inference of frequencies (or equivalently, period lengths) in a parametric setup. We focus here on analysis of the parameters that are associated with the length of the cycle (or its frequency). Differences arising from amplitude or phase shift parameters are not of primary importance in the paper. Moreover, we compare the results with outcome of the method presented in Li and Song (2002).

We examine monthly series of industrial production index (covering period from beginning of 1995 till the end of 2014). We consider the series in levels and in growth rates (relating current month to analogous month of the previous year). The former is equivalent to analyzing a cycle of deviations, whereas the latter is equivalent to consideration of a growth cycle. The cycles are not perfectly equivalent, although it is possible to compare the resulting estimates for frequency (cycle length) parameters.

As for the first group of methods, the statistical analysis of the length of business cycle is based both on properties of APC time series and subsampling methodology. For observed real valued macroeconomic process $\{P_t: t \in Z\}$ with trend, seasonal and cyclical pattern, we build the concept on the basis on a univariate non parametric representation:

$$E\left(\widetilde{P}_t\right) = f(t, \beta) + \sum_{\psi \in \Psi} m(\psi)e^{-i\psi t}$$

where $\tilde{P}_t = \ln(P_t)$ and $f(t, \beta)$ is a polynomial of order d, while $\sum_{\psi \in \Psi} m(\psi) e^{-i\psi t}$ is an almost periodic function (see: Corduneanu, 1989), with unknown set of frequencies Ψ and corresponding Fourier coefficients $m(\cdot)$. The set of frequencies that corresponds to business cycle length that is greater than one and a half a year, is invariant after non-parametric differencing and $(2 \text{x} T)$MA filters, where T is the number of observations during a year (see Lenart & Pipień, 2013). Since $\psi \in \Psi \Leftrightarrow m(\psi) \neq 0$, the problem of testing significance of frequency ψ (in the sense that $\psi \in \Psi$) is equivalent to testing the significance of a Fourier coefficient $m(\psi)$ (in the sense that $m(\psi) \neq 0$). It is important to emphasize that the methodology is not based on the filtering methods, which is a distinctive feature of the approach. In order to test the significance of Fourier coefficients, the subsampling (see: Politis *et al.,* 1999) is applied since the asymptotic distribution of the test statistics is too complicated to be used in practice. More details is given by Lenart and Pipień (2013).

As for the second group of the methods, for the sake of parametric analysis we assume the following structure of the time series under consideration:

$$R_t = \mu_t + v_t$$

where R_t represents y-o-y growth rates, with v_t corresponding to a stationary Gaussian autoregressive process of order p, and

$$\mu_t = \sum_{f=1}^{F} \left(\alpha_{1,f} \sin(t\phi_f) + \alpha_{2,f} \cos(t\phi_f) \right).$$

Parameters $\phi_f \in (\phi_L, \phi_U) \subseteq (0, \pi)$ represent frequencies of the fluctuations, whereas $\alpha_{1,f}$ and $\alpha_{2,f}$ represent amplitudes and phase shifts. With F being estimated rather than set known *a priori*, the structure of the dynamics can be modeled in a flexible way, allowing for the existence of several significant components in the overall dynamic pattern. Estimates of F can be obtained by conducting a fully formal model comparison.

Bayesian estimation of the above model requires specification of the prior densities for the parameters under consideration. We make use of the proper priors, in particular the frequency parameters (that are crucial in the analysis to follow) are assumed to be *a priori* uniformly distributed on (ϕ_L, ϕ_U). The lower and upper boundary values ϕ_L and ϕ_U are fixed so that cycles shorter than one year and longer than 10 years are *a priori* ruled out. The idea of excluding longer cycles is related to the fact that the time

series available for the Polish economy are not really long, making the inference on very low frequency features very problematic. Moreover, based on posterior results for ϕ_f it is possible to induce the equivalent posterior for cycle length, which takes into account the uncertainty associated with identification of the cycle length. The resulting marginal posterior can be irregular (in particular multimodal), most likely suggesting that $F > 1$.

It must be highlighted that the crucial feature of the methods outlined above is the formal way of dealing with inferential uncertainty. Significant frequencies (or cycle lengths) can be identified using formal tests (for the subsampling-based approach) or e.g. highest posterior density (HPD) intervals (for the Bayesian approach). It is therefore possible to avoid *ad hoc* decisions based on point estimates only.

In order to illustrate properties of the methods used here relative to some other approaches used in the literature, we also consider the results obtained using the procedure proposed by Li and Song (2012). This method is called contraction mapping method (CM in short) and assumes that univariate time series $\{X_t : t \in Z\}$ is given by:

$$X_t = \sum_{k=1}^{r} \beta_k \cos(\omega_k t + \vartheta_k) + \varepsilon_t,$$

where $\{\varepsilon_t : t \in Z\}$ corresponds to stationary time series with zero mean. The objective of the method is to estimate the unknown frequency. Notice that the mean function of the time series $\{X_t : t \in Z\}$ is almost periodic. For details concerning the estimation procedure see Li and Song (2002).

Empirical Results

In order to evaluate potential influence of the recent crisis on business cycle pattern, the empirical analysis to follow is based on the sequence of expanding-window samples, with the shortest sample ending in December 2006, and the longest one ending in December 2014. In order to maintain coherence, for the methods based on levels, the initial observation is January 1995, whereas for the growth rates it is January 1996.

The empirical results presented in the paper are founded on analysis of the time series of the industrial production index. The idea is to choose the crucial dataset and use a whole menu of various statistical methods instead of applying simple methods to a broad set of series, which makes formal pooling of the results difficult. The dataset used here is depicted in Fig. 1.

Figure 1. Dynamics of the industrial production index in Poland (y-o-y percentage growth rates, monthly data) in years 1996–2014
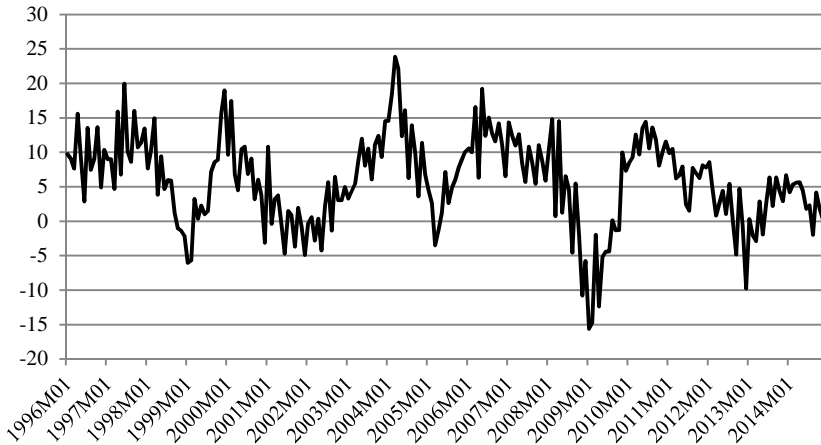
Source: Eurostat.

Recursive analysis based on the subsampling approach applied to the data in log-levels (which amounts to analysis of the deviations cycle) has revealed the results depicted in Fig. 2, which presents the test statistics for significance of $|m(\psi)|$ with subsampling quantiles at nominal levels of 0.08, 0.05 and 0.02. Solid lines in each panel correspond to values of the test statistics, with critical values represented by dotted lines.

Figure 2. Polish industrial production index – significant frequencies of the deviations cycle uncovered by subsampling test
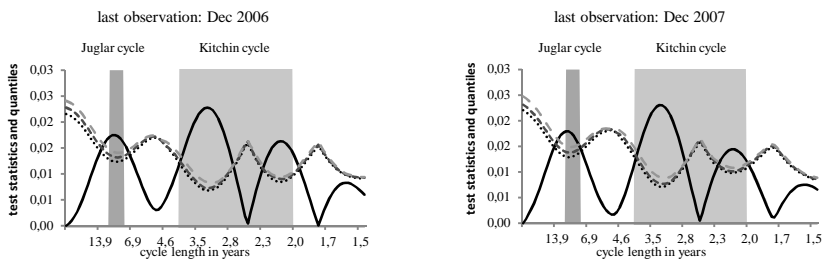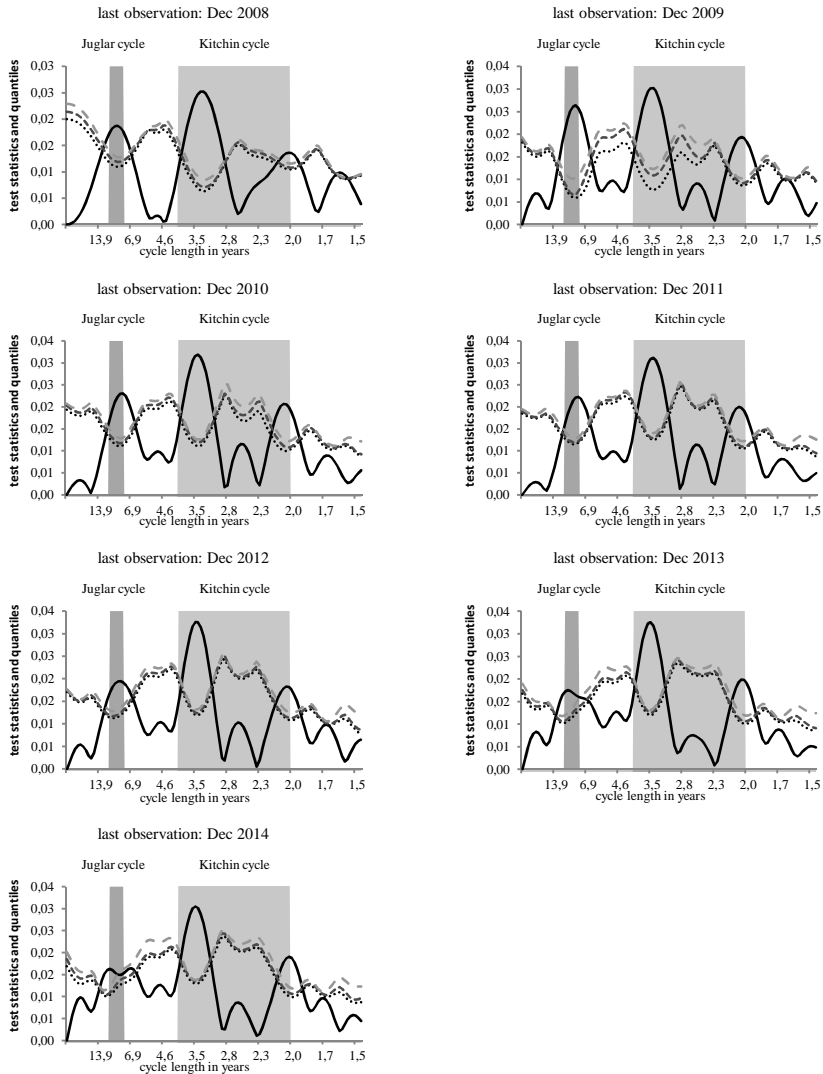
Figure 2 continued

Source: own calculations.

In Fig. 2 the values on the horizontal axes are associated with cycle length in years and significant frequencies (cycle lengths) correspond to the cases in which the test statistics exceeds the critical values. The analysis suggests the existence of three components in the dynamics of Polish industrial production data, and the highest values of the test statistics (relative to

the critical values) characterizes the cycle of approx. 3.5 years. The two remaining significant frequencies correspond to cycle lengths of about 2 years and approximately 8-10 years (with quite considerable uncertainty in the latter case). The results seem to be fairly stable along with recursive expansion of the sample. One can also see that the uncertainty as for the cycle length seems higher for shorter samples, which is quite intuitive.

The results of the Bayesian parametric approach applied to the industrial production index transformed to growth rates are depicted in Fig. 3. The solid line represents probability density function of the marginal posterior distribution for the duration parameter, obtained as one-to-one transformation of the frequency parameter ϕ_f, obtained by assuming $F = 3$. The distribution has three modes, indicating existence of three different cycles. Again, there are cycles with period length of 2 years and about 3.5 years. The two-year cycle seems to be estimated very precisely in terms of length, which is also very stable over time. The second component associated with the cycle of almost 3.5 years shows more uncertainty and some instability. However, it is very moderate and as the uncertainty is taken into account, the instability is by no means significant.

The analysis suggests the existence of the third component corresponding to the cycle of approx. 8 years. However, the probability mass related to the component is dispersed and it is difficult to derive decisive conclusions other than that there is visible instability in its estimates, though it is coupled with quite large dispersion. There is also a difference between the results from the non-parametric approach (Fig.2) and the results from the Bayesian approach (Fig. 3) with respect to the properties of the longest cycle. The changes in its estimated cycle length (arising from recursive expansion of the sample) in the two approaches seem to follow the opposite direction. However, the differences do not seem to be significant.

On the whole, the results of the Bayesian approach within the growth cycle setup seem quite coherent with the results obtained by subsampling methods with respect to the deviations cycle. The Bayesian parametric method applied to growth cycle and non-parametric method used to investigate cycles in deviations from trend lead to very similar inference regarding cycles with period length of 2 and 3.5 years. As the uncertainty is taken into account, the results do not support the claim of significant changes in the business cycle pattern in Polish economy after the crisis.

Figure 3. Polish industrial production index – Bayesian marginal posterior for growth cycle length induced by posterior distribution of the frequency parameter
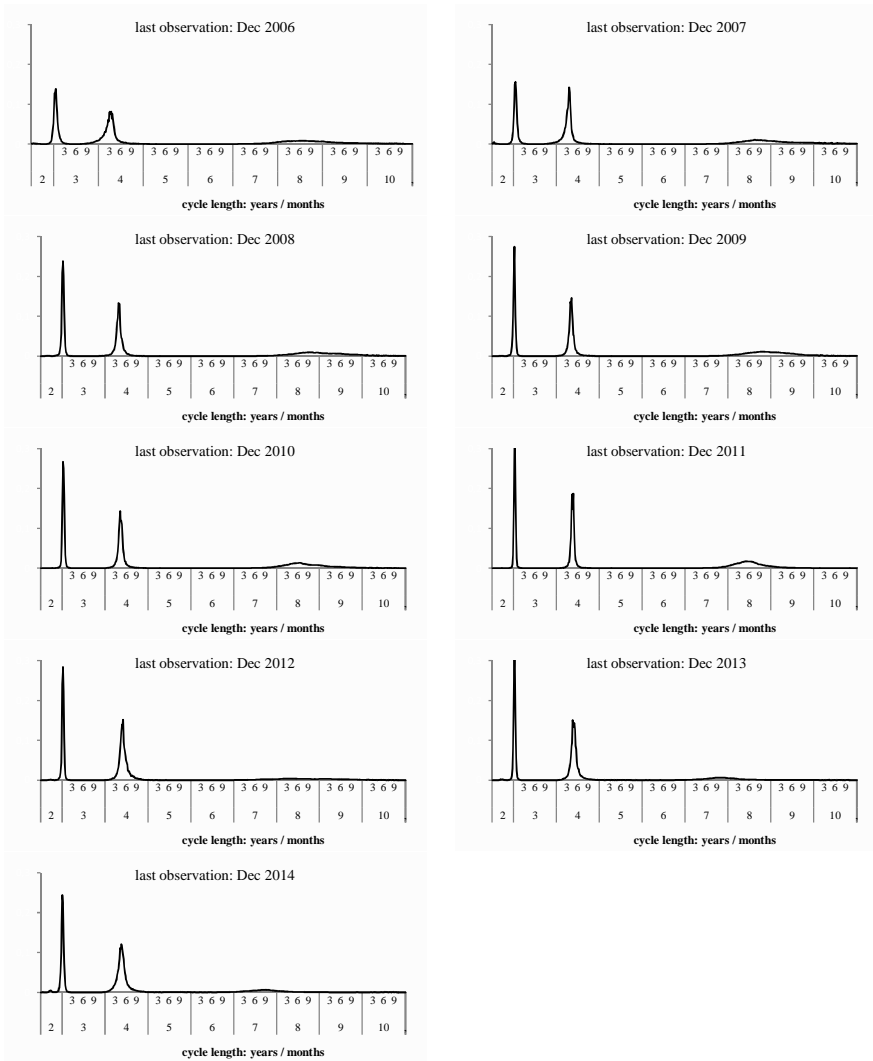
Source: own calculations.

However, in order to provide a comparison to other methods used in the literature, Fig. 4 depicts the outcome obtained using the parametric proce-dure proposed by Li and Song (2002).

Figure 4. Analysis of the Polish industrial production index (y-o-y growth rates) using the approach of Li and Song (2002)
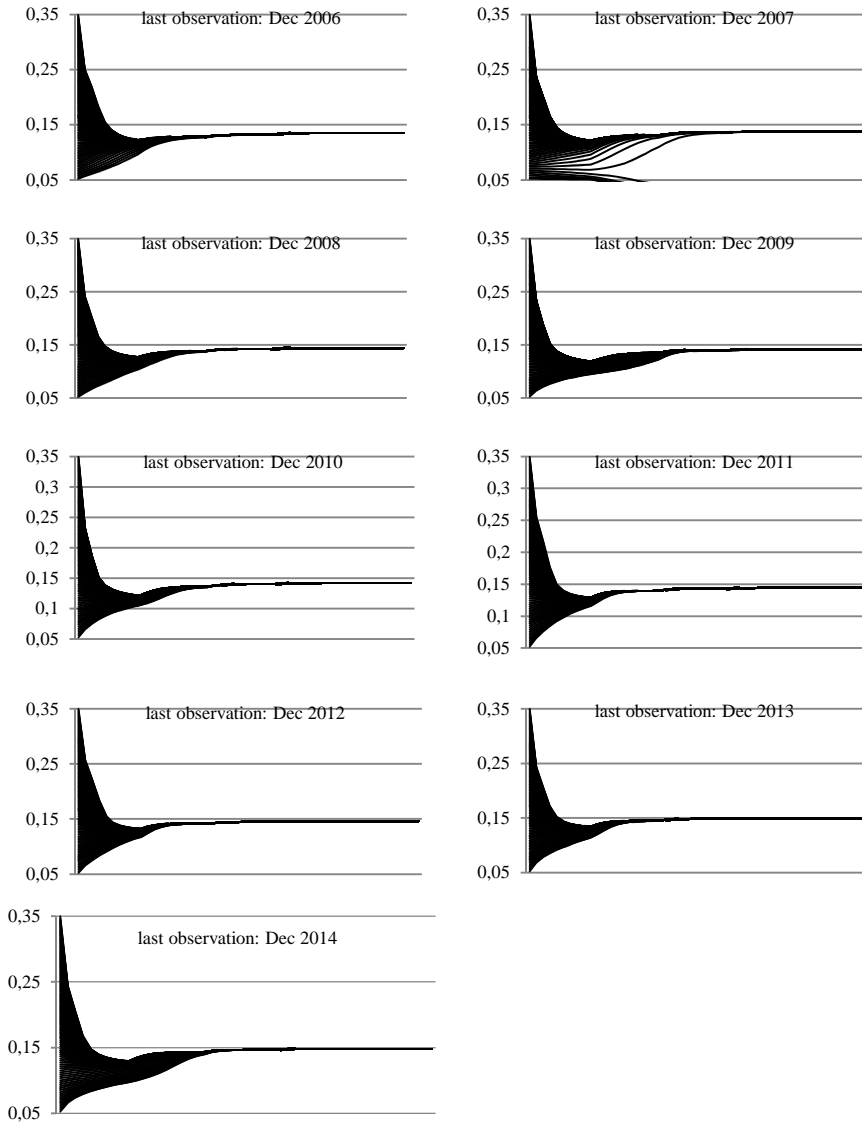
Source: own calculations.

CM frequency estimates ranging from 0.05 to 0.35 are depicted on ver-
tical axes, with increasing number of iterations on horizontal axes. The
number of iterations is equal to 50. The bandwidth parameters are the same
as in Lenart (2013): $\eta_1 = 0.98$ for $m \leq 8$, $\eta_2 = 0.99$ for $9 \leq m \leq 16$, and $\eta_3 = 0.995$ for $m \geq 17$. Each frequency ψ corresponds to the cycle length of $2\pi/\psi$. Therefore, for the monthly data the set of frequencies (0.05;0.35) corre-
sponds to the length of the cycle between one and a half year and ten years.
The results indicate that, contrary to the approaches used in the paper, the
method of Li and Song fails to detect different periodic components that
seem to be present in the Polish industrial production data. The results also
reinforce the importance of the cycle of almost 3.5 years (which is associat-
ed with values of frequency parameter close to 0.15).

Figure 5. Significant cycle lengths – comparison of the results from non-
parametric and parametric Bayesian approach
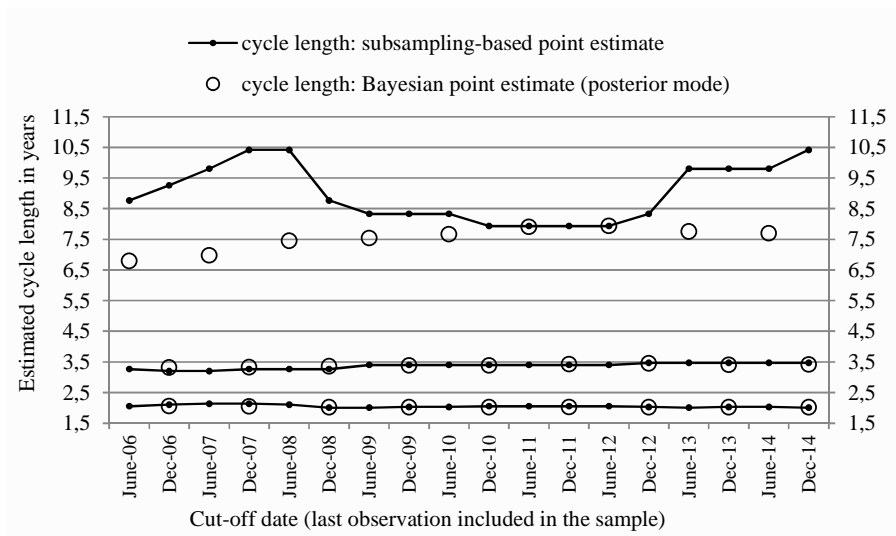
Source: own calculations.

A summary of the point estimates of cycle lengths obtained by the non-
parametric subsampling-based approach and the parametric Bayesian ap-
proach is depicted in Fig. 5. Since the non-parametric method is not com-
putationally time-consuming, the estimates are updated every six months.
As for the two cycles with higher frequencies, the results are rather stable
in time and very similar irrespective of the inference method. For the long-

est cycles the point estimates from the two methods are somewhat divergent, though the difference has to be assessed having the uncertainty of estimation in mind. The estimation errors that are visible in Fig 3. and can be approximately inferred from the results depicted in Fig. 2. suggest that the differences (in time and between the methods) are rather insignificant.

Conclusions

The main objective of the paper is to investigate properties of business cycles in Polish economy before and after the recent crisis. The essential issue addressed here is whether formal methods of statistical inference provide evidence supporting the view that the recent crisis has changed the properties of the business cycle fluctuations. It is of particular interest whether considering the data representing also the after-crisis period leads to differences as for inference on crucial frequencies describing the dynamics of Polish economy.

In order to improve robustness of the results, we do not confine ourselves to any single inference method, but instead use two different groups of statistical tools. As for the first group, these are non-parametric methods that rely on subsampling. The second group includes Bayesian methods employed within the parametric approach. However, all the methods used here use allow for formal quantification of uncertainty and co-existence of cycles with different periods, which is a crucial feature of our analysis. Within the non-parametric approach, a formal test is used to detect significant frequencies. Within the Bayesian approach, the uncertainty is fully described by (multimodal) posterior distribution of frequencies (or equivalently, period lengths), so the inference is fully formal.

We examine monthly the series of the industrial production index (covering period from the beginning of 1995 till the end of 2014), taking into account their levels (for deviations cycle) and growth rates (for growth cycle). Empirical analysis is based on the sequence of expanding-window samples, with the shortest sample ending in 2006. The main finding of the paper is that the two most important frequencies driving business cycle fluctuations in Poland correspond to cycles with periods of 2 and almost 3.5 years, and (perhaps surprisingly) the result holds before and after the crisis. Results regarding the cycles with period length of 7-10 years are less stable, but do not support significant change after the crisis either. Moreover, the estimated cycle lengths are quite close to the results obtained by Skrzypczyńska (2014).

We therefore find no support for the claim that the pattern of cycle lengths that characterize Polish business cycle fluctuations was affected by the crisis. The conclusion is unanimously supported by various statistical methods that are used in the paper (given the cut-off date being the end of 2014). However, we do not consider potential changes in phase shift or amplitude of the fluctuations. It is therefore possible that along with the inflow of new post-crisis observations, some evidence as to the influence of the crisis on the business cycle dynamics would eventually be identified.

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