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Detecting Business Cycles and Concordance of the Demand-based Classified Production of the Visegrad Countries – Regime Switching Approach[1]

*Ľubica ŠTIBLÁROVÁ – Marianna SINIČÁKOVÁ**

Abstract

The aim of this paper is to detect business cycles of the Visegrad countries using Markov-switching approach and to examine their synchronicity with the Euro Area aggregate as one of the inevitable conditions for optimal common monetary policy implementation. Unlike previous studies, we provide a further analysis by the use of disaggregated data in order to achieve a detailed look at the co-movement of the production and find the highest level of the synchronization within the capital and intermediate goods sector. On the contrary, non-durable consumer goods production can be identified as a potential demand-based source of the asymmetric shocks due to the lowest rate of concordance. The results on the aggregated level complemented with the Hodrick-Prescott filtered data suggest a medium-to-high level of synchronization, although its increase in time cannot be confirmed for all Visegrad countries.

Keywords: *Markov-switching models, Visegrad countries, synchronization, EMU, industrial production*

JEL classification: C24, E32, F44, F45

Introduction

Monitoring and measuring symmetry of the economic activity in member countries of the monetary union represents one of the crucial conditions of the successful common monetary policy implementation[2] (Aguiar-Conraria and

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[1] The paper was elaborated within the project VEGA 1/0994/15.

[2] It represents essential, but not sufficient condition for the optimum common monetary policy implementation.

Soares, 2011). If countries forming the monetary union show a divergent trend in their business cycles phases, they may be exposed to asymmetric shocks resulting to the non-optimality of the common monetary policy (also referred in the literature as *"one size does not fit all"* problem – see e.g. De Haan, Inklaar and Jong-A-Pin, 2008). This condition along with the recent problematic issues of the monetary union in Europe might raise doubts about the suitability of the potential future enlargement of the Economic and Monetary Union (EMU).

It may seem that due to the increase of global interdependencies and contagion effect, business cycles in Europe converge – however, it is questionable whether it is the case of the Visegrad and other Central and Eastern European (CEE) countries. These former communist countries characterized by dissimilar initial conditions joined the European Union (EU), some of them the EMU, too, and have differed evidently in many areas from the Western European countries until now. The financial and economic crisis in 2008 caused recession in many European countries,[3] but assuming the existence of the synchronization in general would be inappropriate due to the different type of linkages among the countries (e.g., trade or financial openness) as heterogeneity can be still prevailing (Fidrmuc and Korhonen, 2006). Differences can be observed in terms of the amplitude or the length of the business cycles, which may result in different reactions to the common monetary policy (Horváth and Rátfai, 2004).

The aim of this paper is to detect and evaluate business cycles synchronization of the Visegrad countries with the Euro Area aggregate using regime switching approach. For the purpose of this paper, business cycles are defined in terms of cyclical behaviour of the industrial production due to the use of data-demanding regime switching approach (similar concept used in e.g. Aguiar--Conraria and Soares, 2011, or Artis, Krolzig and Toro, 2004). Policy recommendations will be given in terms of identification of the Visegrad countries for which would be beneficial to enter the third stage of the EMU (represented by irrevocable fixing of conversion rates and introduction of the euro) confronting these results with the fulfillment of the convergence criteria. Unlike the previous studies examining only aggregate level of production, we extend our analysis by the use of disaggregated data and try to find potential demand-based sources of the asymmetric shocks.

The remainder of this paper is organized as follows. Section 1 briefly reviews theoretical background of the business cycles synchronization and previous research. Section 2 provides used methodology and description of the data. Section 3 discusses the results and the final section concludes our comments with policy recommendations.

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[3] Poland was the only EU country with positive economic growth in 2009.

1. Theoretical Background and Previous Research

Theoretical foundations of the business cycles synchronization research in monetary unions are based on the Optimum currency areas (OCA) theory formulated by Robert Mundell (1961);[4] the OCA theory offers a set of inevitable conditions which geographic area should fulfill in order to create an optimum currency area. Whereas this topic almost lost its attention in economic literature in the 1970s and 1980s, the OCA theory has become highly relevant in the context of the EMU in the following decades (Gächter and Riedl, 2014). The Maastricht (nominal convergence) criteria formally determine the requirements which a country needs to meet before entering the third stage of the EMU, however abandoning independent monetary and exchange rate policies is according to the OCA theory beneficial only in the case of synchronous business cycles (Frankel and Rose, 1998). Otherwise, member countries may face potential costs of a currency union in terms of limited ability of demand management and capability of the absorption of the real shocks (Horváth and Rátfai, 2004).

Empirical studies examining business cycles synchronization use two theoretical approaches to measure cyclical activity of an economy – a classical and deviation (or growth) cycles approach. The classical approach defines business cycles in terms of their absolute expansions and recessions (Schumpeter, 1939), whereas deviation cycles represent deviations from the time series' long-term trend (Kydland and Prescott, 1990). The stylized facts of the both – classical and deviation business cycles – in the core European countries[5] are examined by Altavilla (2004). The author concludes that convergent tendencies are observed mainly during periods of recession, although differences concerning a time path and size of the business cycles are still present. According to the results, membership of the EMU countries in the monetary union is likely to increase business cycles symmetry which may support the idea of emerging "an European cycle". Artis, Krolzig and Toro (2004) investigate the existence of this phenomenon and find a common unobserved component driving overall macroeconomic activity in Europe and identify similar dynamics of the business cycles.

Recent empirical research implies some novel methodological approaches to examine the synchronization – e.g. Aguiar-Conraria and Soares (2011) use a wavelet analysis for the EU-12 countries and develop a new metric to measure asynchronicity of the business cycles based on the wavelet spectra, whereas Marsalek, Pomenkova and Kapounek (2014) apply a novel wavelet-based approach

[4] The OCA theory was consequently extended and many authors contributed to its research, see e.g. McKinnon (1963), Kenen (1969), Fleming (1971) or Frankel and Rose (1998).

[5] Germany, France, Italy, Spain, Belgium, and the United Kingdom.

acting as a co-movement selective filter on the Euro Area business cycles. Antonakakis et al. (2016) use a novel complex network approach (the threshold-minimum dominating set) to examine international business cycles synchronization and detect heterogeneous patterns from the historical perspective.

Although studies provide us with the extensive empirical evidence of the Western European business cycles (see Altavilla, 2004; Artis, Krolzig and Toro, 2004; Canova, Ciccarelli and Ortega, 2012 and many others) and finding of the global or "international" business cycle (e.g. Krolzig, 1997; Chauvet and Yu, 2006), systematic research of the CEE countries' business cycles synchronization is still scarce and as a method, business cycle correlations are generally applied. Fidrmuc and Korhonen (2006) apply a meta-analysis of the business cycles correlations between the Euro Area and the CEE countries. They conclude that some countries show a high level of business cycles synchronicity, even though they have not yet adopted the euro (for example, Hungary or Poland). However, the Czech Republic and the Baltic countries seem not to be fully synchronized with the Euro Area aggregate.

Contribution of this paper is twofold; we examine business cycles synchronization of the Visegrad countries by the use of more sophisticated Markov-switching models capturing regime switching nature of macroeconomic time series (filtering technique and correlation analysis will be used as a complementary method). Secondly, unlike the previous studies, as we assume that aggregate level hides industry-specific differences in the production, we try to identify which production sectors may be problematic from the synchronization perspective and become sources of the asymmetric shocks.

2. Data and Methodology

2.1. Data

To detect business cycles, we use seasonally and calendar adjusted monthly data of the industrial production index (IPI) of the Visegrad countries and the Euro Area as a proxy variable for the aggregate output (Table 1). Even though it does not cover the whole economy,[6] the IPI has the advantage of the availability at a monthly frequency and it serves as a good predictor of business cycles turning point.[7] Data were collected from the OECD (2017) database for time period M01/1991 – M12/2016.[8]

[6] Industrial production represents on average 26% of GDP in the European Union, whereas the Visegrad countries exceed the average – 37% of GDP in the Czech Republic, 31% of GDP in Hungary, 33% of GDP in Poland, and 36% in the Slovak Republic (data source: World Bank, time period 1995 – 2015).

Table 1

Descriptive Statistics, Industrial Production Index (IPI)

Country	Obs	Mean	Stdev	Min	Max	Kurt.	Skew.	ADF test (log-diff)	KPSS test (log-diff)
CZ	312	85.141	20.125	55.431	121.674	–1.457	0.133	26.383 (<0.001)	0.274 (0.1)
HU	312	79.660	28.913	32.874	125.576	–1.400	–0.172	–23.729 (<0.001)	0.184 (0.1)
PL	312	72.472	29.976	27.063	127.211	–1.321	0.180	–23.778 (<0.001)	0.086 (0.1)
SK	312	77.005	30.619	39.679	143.038	–1.137	0.532	–17.160 (<0.001)	0.337 (0.1)
EA	312	97.681	7.886	80.707	114.810	–0.657	–0.248	–6.151 (<0.001)	0.070 (0.1)

Note: CZ – the Czech Republic, HU – Hungary, PL – Poland, SK – the Slovak Republic, EA – the Euro Area aggregate. We employed Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root Tests on log-differenced time series intercept included in the test equations. We provide t-statistics and LM-statistics (p-values in parentheses). Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017).

We assume that co-movement in the aggregate production averages industry-specific differences which may present potential demand-based sources of the asymmetric shocks in future. For this purpose, we follow statistical classification of economic activity NACE Rev. 2 and additionally take into account disaggregated data of the IPI. We extend our analysis and examine synchronization in terms of the MIG demand-based classification:[9] (i) capital goods, (ii) consumer goods (total), (iii) durable consumer goods, (iv) non-durable consumer goods, (v) intermediate goods, (vi) energy goods.

2.2. Methodology

In order to identify classical cycles of the Visegrad countries, the Markov-switching autoregressive (MS-AR) models will be used based on the log-differenced IPI data[10] (Δy_t). We choose this type of non-linear model due to its suitability for capturing fluctuations of macroeconomic time series, as we assume their regime-switching nature. Many macroeconomic time series have a tendency to behave differently in economic slowdowns, whereas they show dominant long-term growth patterns (Hamilton, 1989). Considering a stochastic process as a subject to discrete shifts in the mean (Altavilla, 2004), regimes will reflect states of low and high growth – recessions and expansions, respectively. Suitability of the MS-AR models is also supported by the fact that recessions have

[7] For the robustness check, we performed the analysis of the deviation cycles on the GDP data (Q1/1995 – Q4/2016); the results are qualitatively similar and thus omitted for the sake of brevity (available upon request).

[8] Disaggregated data available only for M01/2000 – M12/2016 from Eurostat (2017) database.

[9] Main industrial grouping defined by the Commission regulation No. 656/2007. Descriptive statistics in Appendix.

[10] Stationarity was confirmed by augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests at a 1% significance level (Table 1).

shorter length than expansions (see e.g. Stock and Watson, 1999). A baseline model has a form:

$$\Delta y_t = \upsilon(s_t) + \sum_{i=1}^{p} \phi_i(s_t) \cdot \Delta y_{t-i} + \varepsilon_t, \ \varepsilon_t | s_t \sim NID\left(0, \Sigma(s_t)\right) \qquad (1)$$

where (s_t) denotes that parameters depend on s_t = 1, 2, 3, … m (regime of the model). Let us assume a two-regime model (s_t = 1 or 2). The stochastic process generating non-observable regimes presents the ergodic Markov chain defined by the transition probabilities:

$$p_{ij} = Pr\left(s_t = j | s_{t-1} = i, \ s_{t-2} = k, \ldots, y_{t-1}, y_{t-2}, \ldots\right) = Pr\left(s_t = j | s_{t-1} = i\right)$$
$$\sum_{i=1}^{2} p_{ij} = 1 \quad \forall i, j \in \{1, \ 2\} \qquad (2)$$

Transition probabilities express the probabilities of moving from one state (regime 1 – recession) to another (regime 2 – expansion) and can be written in form of a 2 x 2 transition probabilities matrix where p_{ij} represents the probability of moving from regime i to regime j:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \qquad (3)$$

For each time series, number of lags (p) and decision which parameters will depend on regimes s_t (intercept – υ, autoregressive coefficients – ϕ_i and the variance of the error term – Σ) have been selected via information criteria.[11] Models with two regimes (indicating recession and expansion) were sufficient for the majority of time series, however three-regime models were more suitable in several cases (capturing periods of recession, growth and high growth).

In order to check the robustness of our results, the classical cycles' analysis will be complemented with the deviation cycles investigation. Numerous filtering techniques can be used to retrieve deviation cycles; here we decided to apply Hodrick-Prescott (HP) filter (Hodrick and Prescot, 1997), the most frequently used de-trending method in the business cycles literature, thereby our results might be comparable with other studies. Even though the application of the HP filter has been subject to some criticism (e.g. end-point bias problem), De Haan,

[11] Prior to the estimation of the MS-AR models, lag structure of the linear AR models was identified based on the autocorrelation and partial autocorrelation functions. Suitability of the non-linear MS-AR models compared to their non-switching autoregressive alternatives was tested by LR test – LR statistics available in Table 2. Furthermore, Quandt-Andrews Breakpoint Test was performed; the null hypothesis of no breakpoints cannot be rejected in case of the Czech Republic, Hungary, and the Slovak Republic. The null hypothesis can be rejected in case of Poland (breakpoint M02/1995) and the Euro Area aggregate (breakpoint M05/2009) at a 5% significance level.

Inklaar and Jong-A-Pin (2008) conclude that most studies using different filtering techniques (HP, Baxter-King or Christiano-Fitzgerald filter) find qualitatively similar results. Moreover, it is widely used in the business cycles research of the CEE countries (Fidrmuc and Korhonen, 2006). The HP filter decomposes a time series y_t[12] into trend g_t and cyclical component c_t by minimizing the following equation:

$$\min_{g_t}\left[\sum_{t=1}^{N}(y_t-g_t)^2+\lambda\sum_{t=2}^{N-1}\left[(g_{t+1}-g_t)-(g_t-g_{t-1})\right]^2\right] \qquad (4)$$

Parameter lambda needs to be explicitly defined; we use value 129 600 according to the recommendations concerning monthly frequency of data (Ravn and Uhlig, 2002).

Besides the traditional way of measuring synchronization of the Visegrad countries in form of the correlation analysis, we decided to calculate an index of concordance proposed by Harding and Pagan (2002) measuring the coincidence of the business cycles phases of the Visegrad countries with the Euro Area aggregate.

After detecting turning points of a given macroeconomic series y_t, we define a binary variable $s_{y,t}$ taking value 1 in expansion, otherwise 0 (recession). Suppose $s_{x,t}$ for another macroeconomic series x_t, the index of concordance (IC) measuring percentage of time (average number of periods) when these two time series are in the same phase simultaneously can be expressed as follows:

$$IC_{x,y}=\frac{1}{T}\sum_{t=1}^{T}\left[s_{xt}\,s_{yt}+(1-s_{xt})(1-s_{yt})\right] \qquad (5)$$

where T is a number of observations. The IC takes the value 1 in case of perfect concordance (time series are always in the same phase simultaneously), whereas value 0 indicates absolute discordance of time series. To avoid dating spurious business cycles (which might happen due to the higher volatility in the monthly IPI data), we decided to calculate adjusted values of the concordance index taking into account only recessions lasting at least two consecutive quarters. This step will allow us to carefully detect business cycles' phases (expansions and recessions, respectively) in the MS-AR models, as well as in the HP filtered data.

Parameters of the MS-AR models were estimated via MLE and all computations were carried out using *MSwM*, *forecast* and *tseries* packages in an R environment (R Core Team, 2016).

[12] In this case, we use log-transformed data of industrial production indices. Stationarity, therefore log-differenced transformation of data is not required in deviation cycles estimation.

3. Results and Discussion

3.1. Detecting Classical and Deviation Business Cycles of the Visegrad Countries

Estimation of the Markov switching models defining classical business cycles are given in Table 2. According to the information criteria, first-order autoregressive models were estimated for all the Visegrad countries except for the Slovak Republic and the Euro Area aggregate, for which second-order models were preferable.

T a b l e 2

Estimation of the Markov Switching Models for the Visegrad Countries and the Euro Area Aggregate

	Regime	CZ	HU	PL	SK	EA
υ	1	–0.0026 (0.0023)	–0.0050 (0.0031)	–0.0002 (0.0032)	–0.0072 (0.0047)	–0.0006 (0.0008)
	2	0.0018*** (0.0005)	0.0033*** (0.0006)	0.0027** (0.0009)	0.0039*** (0.0007)	0.0014*** (0.0003)
	3			0.0038*** (0.0008)		
ϕ_1	1	–0.5038*** (0.1313)	–0.3399* (0.1362)	–0.2907*** (0.0493)	–0.4268*** (0.0705)	0.2405 (0.1262)
	2	–0.1765* (0.0714)	–0.3601*** (0.0600)	–0.2907*** (0.0493)	–0.4268*** (0.0705)	–0.5207*** (0.1278)
	3			–0.2907*** (0.0493)		
ϕ_2	1				–0.1446** (0.0485)	0.3996*** (0.1161)
	2				–0.1446** (0.0485)	–0.2683* (0.1228)
Residual SE	1 2 3	0.0175 0.0060	0.0194 0.0082	0.0145 0.0083 0.0037	0.0320 0.0083	0.0046 0.0032
Recession duration		4.54	9.40	8.20	3.34	5.88
Log Lik		1 020.77	985.21	1 040.52	926.68	1 291.27
LR stat		105.40	71.58	45.96	166.56	58.56
AIC		–2 033.54	–1 962.43	–2 073.03	–1 845.36	–2 570.53
BIC		–1 995.65	–1 924.53	–2 035.14	–1 807.49	–2 513.73

Note: Two-regime models: regime 1 – recession, regime 2 – expansion. Three-regime model of Poland: regime 1 – recession, regime 2 – growth, regime 3 – high growth. Standard deviations of estimates in parentheses. Recession duration expressed in months. Sig. levels: *** 0.01 ** 0.05 * 0.1. Time period M01/1991 – M12/2016.

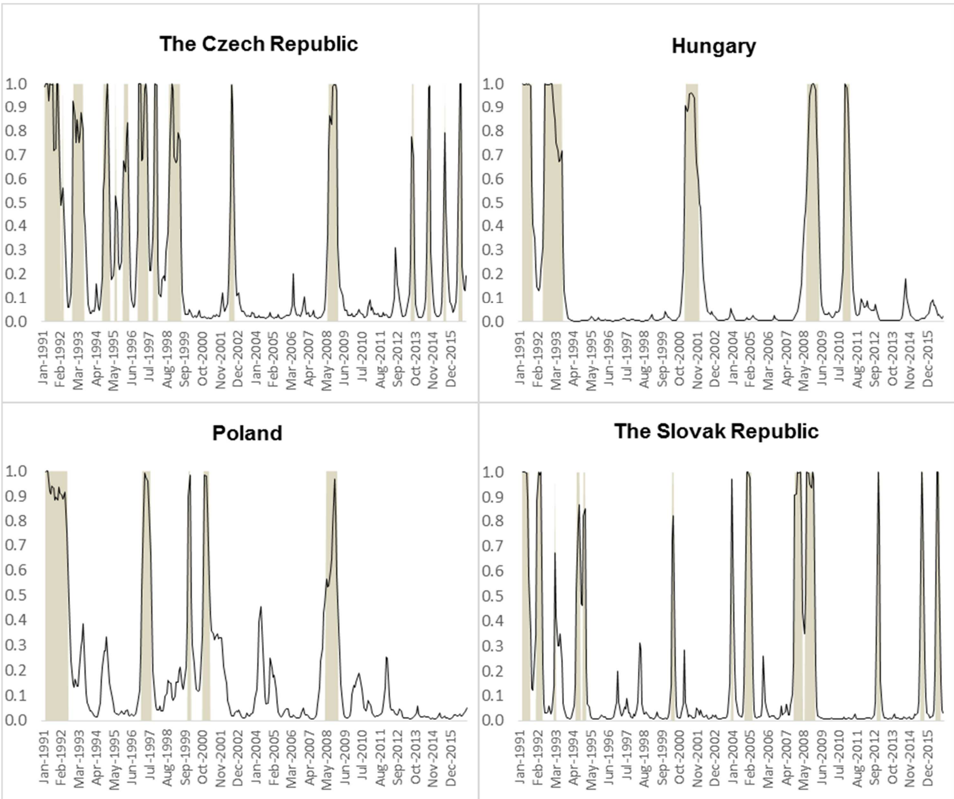
Source: Own calculations based on OECD (2017).

Intercept and variance of the error term are allowed to switch between regimes in all cases as we assume that recessions and expansions are characterized by different volatility. Autoregressive coefficients in model of the Czech Republic, Hungary, and the Euro Area aggregate are also allowed to switch (the selection based on the information criteria). We choose two-regime switching models for the Czech Republic, Hungary, the Slovak Republic and the Euro Area aggregate; regime 1 with negative intercept indicates recession, whereas regime 2 represents expansion (Table 2). A three-regime switching model was selected for Poland on the basis of information criteria capturing recession – regime 1, periods of growth – regime 2 and high growth – regime 3 (see similar notation in e.g. Altavilla, 2004).

To detect classical business cycles' turning points of the Visegrad countries, smooth probabilities of being in recessions (solid line) are depicted in Figure 1.

F i g u r e 1

Smooth Probabilities of Being in Recession – Classical Business Cycles of the Visegrad Countries



Note: Smooth probabilities of being in recession – solid line, grey bands represent captured expected periods of recession. Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017).

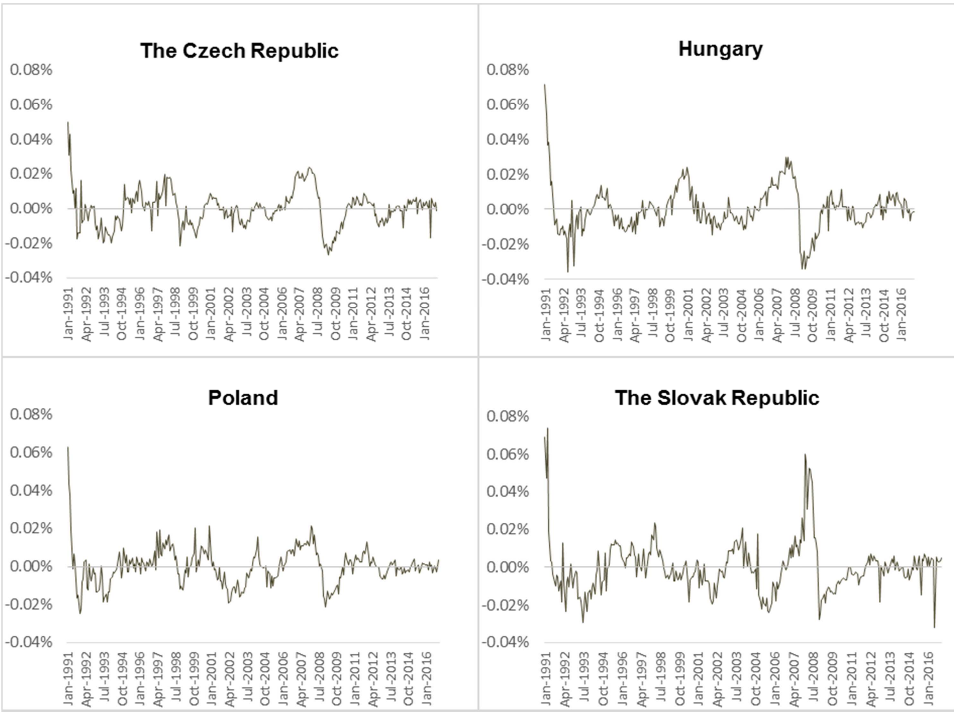
Grey bands present captured expected recession periods. In all cases, models detected the financial and economic crisis in 2008 and decrease of the economic activity in 1999 – 2000 (the Slovak Republic and Poland) or 2001 (the Czech

Republic and Hungary). The estimation of model of the Czech Republic (especially at the beginning of the selected period) might be associated with the currency crisis in 1997. It is evident that business cycles (in terms of recession occurrence) of the Visegrad countries do not seem fully synchronized; a common pattern can be generally found only in the case of the financial and economic crisis in 2008.

A different point of view can be brought by the comparison with the deviation cycles estimates by the Hodrick-Prescott filter (Figure 2). Deviation cycles confirm a decline at the beginning of the selected period in all the Visegrad countries, although the Slovak Republic shows the outstanding overheating of the economy in 2007.

Figure 2

Cyclical Component of the IPI – Deviation Business Cycles of the Visegrad Countries



Note: Cyclical component as % of potential output retrieved by the HP filter. Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017).

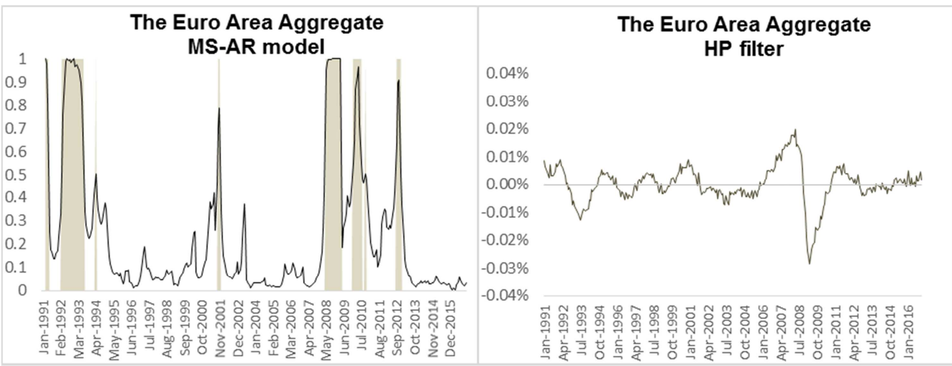
Differences in business cycles may result also from the fiscal policy arrangements; the overall macroeconomic activity of the Slovak Republic was influenced in 1999 by the stabilization arrangements (i.e. increase of the consumption taxes, regulated prices or public finance consolidation). Macroeconomic stabilization arrangements besides economic slow-down caused the rise in the domestic price level and had a positive effect on the trade balance deficit; this should serve as a starting point of the price levels convergence within the EMU countries.

As we are interested in measuring level of synchronicity of the Visegrad countries with the Euro Area member countries, the Euro Area aggregate data are used to compute reference business cycles. Classical Euro Area business cycles in terms of smooth probabilities of being in recession are illustrated in Figure 3 (left). Transition probability matrix (Table 3) indicates that observations tend to stay in regime 1 or 2, respectively (this situation is identical for all models of the Visegrad countries).

Recessions of the Euro Area according to the MS-AR model are detected in 1992, 2001, 2008 – 2009 and at the end of 2012. Comparing those results with deviation business cycles (Figure 3 right), we may conclude that the HP filter detected more recession periods (years 1996 and 1999) as this filtering method tends to detect phases of cycles with the same length (which may not be realistic, see Stock and Watson, 1999) resulting to artificial cycles.

F i g u r e 3

Smooth Probabilities of Being in Recession – Classical Euro Area Business Cycles (left), Cyclical Component of the IPI – Deviation Euro Area Business Cycles (right)



Note: Smooth probabilities of being in recession – solid line, grey bands represent captured periods of recession. Cyclical component as % of potential output (solid line) retrieved by the HP filter. Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017).

To compare and verify our results, we provide the chronology of the Euro Area business cycles identified by the Centre for Economic Policy Research (CEPR) Euro Area Business Cycle Dating Committee.[13] Comparison of the

[13] The objective of the CEPR Euro Area Business Cycle Dating Committee is to establish the chronology of the Euro Area business cycles' turning points (similar to NBER dating the US business cycles).

CEPR (2015) chronology and the MS-AR(2) model of the Euro Area business cycles is presented in Table 3. Generally, our results correspond to the CEPR chronology of the business cycles troughs; as we use industrial production index (unlike the real GDP data), the troughs are in some cases detected several quarters ahead.[14]

T a b l e 3

Transition Probabilities Matrix of the MS-AR Euro Area Model and the Chronology of the EA Business Cycles' Turning Points

			CEPR		**MS-AR model**	
	Transition probabilities		Peak	**Trough**	Peak	**Trough**
	Regime 1	Regime 2	1992Q1	1993Q3	1991Q4	1992Q3
Regime 1	0.9524	0.1381	2008Q1	2009Q2	2003Q4	2009Q1
Regime 2	0.0476	0.8619	2011Q3	2013Q1	2011Q3	2012Q4

Note: Regime 1 – recession, regime 2 – expansion. We do not include recession in 2001Q1 according to the MS-AR model – see explanation below. Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017) and CEPR (2015).

According to CEPR, the latest trough was reached in 2013Q1 indicating the start of the new expansionary period for the Euro Area. However, historic data showed quite a sluggish recovery process compared to the previous cycles (e.g. low GDP growth rate, inflation) which should signal a pause in the recession rather than an expansionary period.

The CEPR Committee does not identify the turning points solely based on the data of the real economic activity, they monitor several indicators (employment, particularly). For this reason, MS-AR(2) recession in 2001Q1 was not identified by the CEPR. Although the industrial production index showed the recession between 2001 and 2003 (decline in real GDP was also present), CEPR did not identify recession as other indicators did not show a decline. Despite this fact we can conclude that our model performs plausible results.

3.2. Synchronization of the Visegrad Countries with the Euro Area Aggregate

After detecting turning points of the Visegrad countries, we are interested in measuring their level of synchronicity with the Euro Area aggregate. We want to identify the Visegrad countries already synchronized with the Euro Area and the countries for which the entrance to the monetary union would not be beneficial in terms of common monetary policy implementation. For these purposes, results of the correlation analysis (lower triangle) and the calculations of the adjusted

[14] It may not be considered as a disadvantage – we are primarily interested in measuring level of synchronicity, results will not be biased as business cycles of all countries will be detected from this leading position (which may be also suitable for forecasting).

concordance index[15] (upper triangle) based on the smooth probabilities of being in recession from the Markov switching models[16] (classical cycles) are provided in Table 4 (findings are complemented with the HP filter (deviation cycles) results).

Table 4

Synchronization of the Visegrad Countries with the Euro Area Aggregate

	Adj. Concordance Index											
	MS-AR models (classical cycles)						**HP filter (deviation cycles)**					
Correlation		EA	CZ	HU	PL	SK		EA	CZ	HU	PL	SK
	EA		0.8000	0.8742	0.8484	0.8290	EA		0.7596	0.8045	0.7724	0.6314
	CZ	0.2115		0.8161	0.8548	0.8097	CZ	0.7411		0.6667	0.7628	0.6603
	HU	0.6514	0.3015		0.8323	0.8000	HU	0.7748	0.6976		0.7179	0.5513
	PL	0.3862	0.4187	0.4715		0.8710	PL	0.6422	0.7504	0.7122		0.7051
	SK	0.2854	0.3378	0.2389	0.4053		SK	0.5450	0.6595	0.5497	0.5862	

Note: Upper triangle – adjusted concordance index which takes into account only recessions lasting at least two consecutive quarters, lower triangle – Pearson correlation coefficient. All correlation estimates are statistically significant ($p < 0.001$). Time period M01/1991 – M12/2016.

Source: Own calculations based on OECD (2017).

Overall, correlation coefficients do not indicate a strong statistical relationship (lower than 0.8) between the Visegrad countries, nor with the Euro Area aggregate. A more precise look at the business cycles synchronization can be done by the calculation of the concordance indices (upper triangle) measuring percentage of time when two time series are in the same phase simultaneously. Although correlation coefficients are low (MS-AR models), concordance indices reach quite high values – at least 80% of time countries‘ business cycles are in the same phases (MS-AR models), which may be considered as a medium-to--high level of synchronization. Our results are in line with Fidrmuc and Korhonen (2006), as the Czech Republic seems to be the least synchronized Visegrad country (MS-AR models).

Moreover, the single monetary policy implemented by the Czech National Bank achieved plausible results (supporting Czech exports i.a.) as it started intervening in 2013 by the use of the exchange rate as an additional instrument for easing the monetary conditions. For this reason it might be questionable, whether the common monetary policy implemented by the ECB would bring such results. The Slovak Republic as the only Euro Area Visegrad member country is the second least synchronized Visegrad country according to MS-AR models and the least synchronized according to the HP filtered cycles. Our results are in

[15] Although the ranking of the countries concerning synchronization remains stable using the original concordance index, we use the adjusted version to carefully identify the business cycles in the whole analysis.

[16] In case of a three-regime model of Poland, calculation of the adjusted concordance index is based on the smooth probabilities of being in regime 1.

accordance with other studies examining Slovak business cycles synchronization (e.g. Artis, Fidrmuc and Scharler, 2008; Benčík, 2011) confirming an overall lower level of synchronization among the Visegrad countries, although we cannot precisely specify the level of concordance sufficient for the entrance to the monetary union. Despite non-adopting common currency, Hungary seems to be the most synchronized country within the Visegrad group with the Euro Area aggregate, even though it has not met the nominal convergence criteria yet (it does not fulfill the fiscal criterion of acceptable level of debt-to-GDP ratio yet).

Table 5

Synchronization of the Visegrad Countries with the Euro Area Aggregate in Time

	After 2004											
	MS-AR models (classical cycles)						**HP filter (deviation cycles)**					
Before 2004		EA	CZ	HU	PL	SK		EA	CZ	HU	PL	SK
	EA		0.8974	0.8782	0.9103	0.8205	EA		0.8141	0.8269	0.8269	0.6987
	CZ	0.7013		0.9423	0.9872	0.8974	CZ	0.7051		0.8077	0.8462	0.6282
	HU	0.8701	0.6883		0.9295	0.8397	HU	0.7821	0.5256		0.7308	0.5641
	PL	0.7857	0.7208	0.7338		0.8205	PL	0.7179	0.6795	0.7051		0.6282
	SK	0.8312	0.7208	0.7597	0.8377		SK	0.5641	0.6923	0.5385	0.7821	

Note: Upper triangle – adjusted concordance index calculated for time period M01/2004 – M12/2016, lower triangle – adjusted concordance index for the time period M01/1991 – M12/2003.

Source: Own calculations based on OECD (2017).

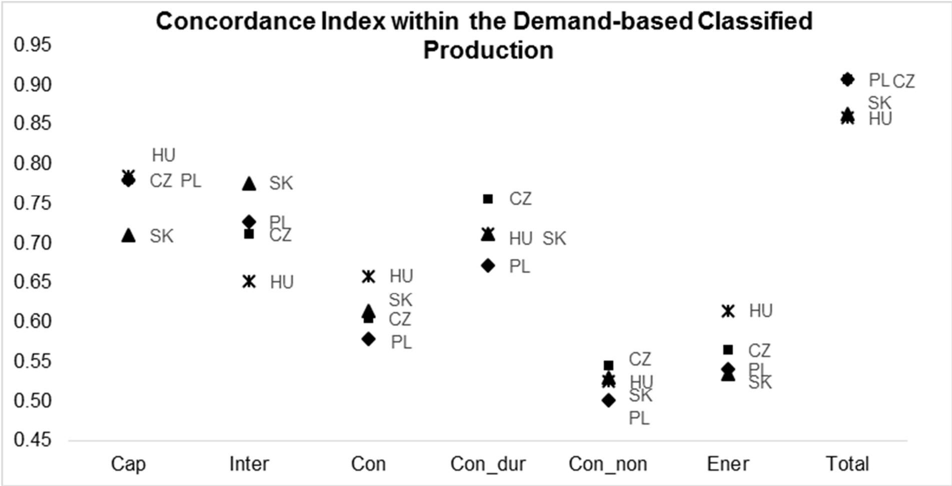
Results based on the MS-AR models confirm the increasing level of synchronization in time (Table 5) for the Czech Republic and Poland after their EU entrance. The Hungarian level of synchronization seems to be relatively high and stable, although Slovak business cycles show slightly decreasing concordance with the Euro Area business cycles. The HP filtered deviation cycles support the idea of increasing synchronization in time for all countries, although after 2004, the Slovak Republic shows a lower of synchronization with the Visegrad countries.

3.3. Synchronization of the Visegrad Countries within the Demand-based Classified Production

In accordance with the previous studies, our results confirm a progressing convergence process and an increasing level of synchronization in time at the aggregate level of industrial production (except for the Slovak Republic, although the overall level of synchronization is relatively high). But as we assume that industry-specific differences can be diminished at the aggregate level, we try to find potential demand-based sources of the asymmetric shocks by disaggregating data. We estimated, in addition, 30 univariate Markov-switching models for the Visegrad countries and the Euro Area in order to obtain a detailed look at their co-movement (Figure 4 summarizes our results[17]).

F i g u r e 4

Synchronization of the Visegrad Countries with the Euro Area Aggregate within the Demand-based Classified Production (MS-AR Models)



Note: Cap – capital goods, Inter – intermediate goods, Con – consumer goods, Con_dur – durable consumer goods, Con_non – non-durable consumer goods, Ener – energy goods, Total – total industrial production index. Time period M01/2000 – M12/2016.

Source: Own calculations based on Eurostat (2017).

The analysis within the demand-based classified production appeared to be reasonable as remarkable differences can be seen at the disaggregated level. These results (based on the MS-AR models) for all the Visegrad countries can be summarized as follows: (i) the highest level of the synchronization is observed within the capital or intermediate goods sector; (ii) the consumer goods production is characterized by the low rate of concordance; (iii) a low level of synchronization within the consumer goods sector is the problem mainly of the non-durable consumer goods production.

A comparison of the classical (MS-AR models) and deviation (the HP filter) cycles' synchronization based on the concordance indices is available in Table 6. Results generally agree on the concordance of the disaggregated industrial sectors' production of the Slovak Republic – the position is quite unexpected as the concordance indices are the lowest within the Visegrad group for multiple sectors (the HP filter). The MS-AR models imply that the Slovak Republic is not the most synchronized within the capital goods production, which includes the manufacture of motor vehicles, machineries and equipment, although it is well-known for the highest production of motor vehicles within the Visegrad group. The highest level of concordance (0.7761) is observed within the intermediate

[17] Due to the limited length of the paper we do not provide detailed estimation results for all 30 models (available upon request).

goods production (e.g., the manufacture of the electronic components or metal products). Hungary among other Visegrad countries reaches the highest value of concordance index (0.7850 for capital goods sector).

Table 6

Comparison of the Classical and Deviation Cycles' Synchronization of the Demand--based Classified Production of the Visegrad Countries with the Euro Area Aggregate

	Classical cycles				Deviation cycles			
	CZ	HU	PL	SK	CZ	HU	PL	SK
Capital goods	0.7800	0.7850	0.7800	0.7100	0.8039	0.8382	0.7255	0.7206
Intermediate goods	0.7114	0.6517	0.7264	0.7761	0.8578	0.8480	0.8039	0.7892
Consumer goods	0.6040	0.6584	0.5792	0.6139	0.7108	0.7941	0.6225	0.7157
Durable consumer goods	0.7562	0.7114	0.6716	0.7114	0.7500	0.7304	0.5980	0.7255
Non-durable consumer goods	0.5446	0.5248	0.5000	0.5297	0.7304	0.7157	0.5735	0.5490
Energy	0.5644	0.6139	0.5396	0.5347	0.6569	0.6520	0.7206	0.6471
Total production	**0.9069**	**0.8578**	**0.9069**	**0.8627**	**0.7745**	**0.8382**	**0.8333**	**0.6324**

Note: Synchronization is measured by the adjusted concordance index, the lowest row value is depicted in grey. Time period M01/2000 – M12/2016.

Source: Own calculations based on Eurostat (2017).

Consumer goods production – especially non-durable goods production – can be identified as a problematic area from the synchronization point. Differences in the consumer patterns may become potential demand-based sources of the asymmetric shocks caused by e.g. different tax systems in countries or national arrangements about wages. We assume that further integration (e.g., the unification of the fiscal policies) may contribute to the more intense synchronization in future. After the entrance to the EU, increased concentration and competitiveness caused notable changes in the industrial production and its structure. Another reason to explain this situation is the economic and financial crisis in 2008; prices of the consumer goods decreased and a massive slow-down of the consumer demand in connection to the uncertainty about future development of the unemployment rate and economic growth may also contribute to the differences in the consumer goods production patterns. Besides the fact that the industrial production of the Visegrad countries seems to be highly synchronized with the Euro Area aggregate, discordance at the disaggregated level is still prevailing.

Conclusions

One of the inevitable conditions for an optimal monetary policy implementation in the monetary unions represents the business cycles synchronization of its member countries. The Visegrad countries examined in this study exhibit a medium-to-high level of synchronization, although several differences can be observed concerning the amplitude/evolution in time. For example, Hungary seems to be more synchronized Visegrad country with the Euro Area (even though it has not met the nominal convergence criteria yet) compared to the Slovak Republic, which is among other Visegrad countries the only EMU member country using common currency. However, the overall level of synchronization is relatively high and we cannot confirm asynchronous business cycles. After the initial contagion effect, the financial and economic crisis followed by the debt crisis may led to the creation of the disentangled patterns concerning business cycles of the "core" EMU countries (such as Greece, Portugal) compared to the e.g. Germany or other founding EMU countries, hence the synchronization of these Visegrad countries among others within the EMU presents very complex topic requiring careful examination.

Unlike the previous studies, we extend our analysis of the synchronization as we assume that an aggregate level compensates differences at the lower level. In order to have a more precise look at the co-movement, we use disaggregate data of the industrial production and find the highest level of synchronization (computed as a concordance index) for the capital and intermediate goods productions. Consumer (especially non-durable) goods sector may present potential risks as it reaches the lowest value of concordance index. This holds especially for the Slovak Republic after the adoption of the common currency – the consumer goods sector suffered from the aggravated bargaining position in the worldwide scale and decreasing employment in the food industry is nowadays caused by the decline in export of the food products, especially with the higher value added. It remains questionable whether the Visegrad countries will follow converging or diverging patterns in terms of their business cycles evolution concerning their changing position in the global supply chain. For this purpose, further analysis concerning production classified according to technologies (e.g. low--technology, high-technology production) would be advisable.

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Appendix

Descriptive Statistics – Industrial Production Index (MIG classification)

Country		Obs	Mean	Stdev	Min	Max	Kurt.	Skew.	ADF test (log-diff)	KPSS test (log-diff)
Capital goods	CZ	204	92.254	30.066	37.500	165.600	–1.046	–0.030	–14.669 (<0.001)	0.277 (0.1)
	HU	204	98.189	31.594	46.900	156.900	–1.083	0.018	–20.482 (<0.001)	0.083 (0.1)
	PL	204	87.844	32.548	36.700	146.900	–1.174	–0.128	–21.383 (<0.001)	0.132 (0.1)
	SK	204	90.807	48.684	26.200	195.400	–1.256	0.276	–14.826 (<0.001)	0.042 (0.1)
	EA	204	105.369	7.575	89.100	122.600	–0.783	0.091	–5.734 (<0.001)	0.060 (0.1)
Intermediate goods	CZ	204	97.876	13.910	66.000	119.100	–0.950	–0.381	–14.503 (<0.001)	0.181 (0.1)
	HU	204	103.083	11.254	74.400	130.700	–0.441	0.115	–18.387 (<0.001)	0.126 (0.1)
	PL	204	90.741	25.290	52.900	138.200	–1.290	0.033	–14.994 (<0.001)	0.047 (0.1)
	SK	204	105.713	26.830	61.800	170.300	0.090	0.875	–18.329 (<0.001)	0.045 (0.1)
	EA	204	104.040	6.439	86.000	119.900	0.708	0.349	–7.058 (<0.001)	0.067 (0.1)
Consumer goods	CZ	204	103.554	6.611	90.000	123.500	0.416	0.904	–13.548 (<0.001)	0.148 (0.1)
	HU	204	92.321	11.347	64.100	109.500	–0.696	–0.625	–19.637 (<0.001)	0.171 (0.1)
	PL	204	84.357	25.278	45.600	129.000	–1.385	–0.056	–21.506 (<0.001)	0.144 (0.1)
	SK	204	84.357	28.516	39.700	146.200	–0.903	0.092	–18.408 (<0.001)	0.214 (0.1)
	EA	204	100.838	2.310	95.600	106.500	–0.397	0.385	–14.838 (<0.001)	0.062 (0.1)
Durable consumer g.	CZ	204	98.682	18.769	66.600	150.300	–0.316	0.295	–19.926 (<0.001)	0.139 (0.1)
	HU	204	65.991	26.190	15.300	110.400	–0.958	–0.473	–17.555 (<0.001)	0.378 (0.1)
	PL	204	71.711	33.984	20.900	127.300	–1.457	–0.122	–18.951 (<0.001)	0.311 (0.1)
	SK	204	68.931	39.894	13.900	130.300	–1.610	–0.220	–13.845 (<0.001)	0.206 (0.1)
	EA	204	109.988	13.852	90.100	137.000	–1.550	0.093	–5.490 (<0.001)	0.108 (0.1)
Non-durable consumer g.	CZ	204	104.888	6.076	93.900	121.600	–0.505	0.254	–15.017 (<0.001)	0.122 (0.1)
	HU	204	111.792	6.139	95.600	123.400	0.005	–0.869	–15.763 (<0.001)	0.095 (0.1)
	PL	204	90.127	21.125	57.300	130.000	–1.308	0.016	–23.500 (<0.001)	0.042 (0.1)
	SK	204	101.432	24.176	71.400	229.000	7.662	2.630	–12.195 (<0.001)	0.069 (0.1)
	EA	204	99.515	2.853	92.700	108.100	–0.213	0.610	–15.316 (<0.001)	0.051 (0.1)
Energy goods	CZ	204	102.756	15.041	66.200	124.200	–0.786	–0.673	–9.851 (<0.001)	0.059 (0.1)
	HU	204	96.616	9.632	77.600	122.300	–0.622	0.353	–13.713 (<0.001)	0.076 (0.1)
	PL	204	103.812	9.858	79.100	135.300	0.425	0.588	–15.135 (<0.001)	0.039 (0.1)
	SK	204	96.425	17.091	55.200	149.800	0.645	–1.000	–13.597 (<0.001)	0.061 (0.1)
	EA	204	99.565	9.470	70.500	115.000	0.218	–0.825	–14.539 (<0.001)	0.043 (0.1)

Note: We employed Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root Tests on log-differenced time series intercept included in the test equations. We provide t-statistics and LM-statistics (p-values in parentheses). Time period M01/2000 – M12/2016.

Source: Own calculations based on Eurostat (2017).