Four Years After Expansion: Are Czech Republic, Hungary and Poland Closer to Core or Periphery of EMU?

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1. Introduction

Both waves of EU enlargement were perceived as political and economic success. Most economies of Central and East European Countries (CEECs) benefited from capital inflow and free foreign trade and experienced during last years sound economic growth. However enlargement agreement, signed by all CEECs, obliges them to second part of integration, namely, joining European Monetary Union (EMU). Two sets of criteria are used in this case to assess readiness of future members: nominal and real (respectively Maastricht Treaty and Optimum Currency Area [OCA] criteria). Many researchers are concerned whether catching-up economies like Czech Republic, Hungary and Poland should "bound" their economies to strict conditions allowing them to introduce common currency in next few years. This question is even more substantial when confronted with several publications proving that there are significant heterogeneities among present euro-area members (Artis and Zhang [1997]).

One of the most important criteria among real ones is similarity (synchronization) of business cycles (OCA theory Mundell [1961]). Popular way of measuring this similarity is to use cross-correlations of particular time series of reference countries, mainly industrial production or GDP. This measures are however biased (especially industrial production), as they capture only part of the real economic activity occurring in economies.

In our paper we are trying to analyze readiness of chosen CEECs countries (Czech Republic, Hungary and Poland) to join euro-area checking their convergence towards real criteria. As a workhorses of our exercise we employ:

- Stock and Watson unobserved component model to extract particular country's business cycle measure.
- Coherence based on spectral analysis of extracted unobserved components as business cycle similarity indicator.
- Cluster analysis to check position of particular country in relation to present European Monetary Union members taking into account business cycle synchronization and other OCA criteria.

The rest of this paper can be viewed as constituting six parts: 1) presentation of up-to-date literature on EMU membership readiness 2) description of

OCA criteria characteristics, 3) presentation of statistical and econometric methodologies used to perform survey, 4) description of used economic data and its treatment 5) presentation of gained results and 6) conclusions.

2. Overview of the literature on country's EMU membership readiness analysis based on clustering technique

Last eight years provided bunch of EMU membership readiness surveys based on clustering technique. Pioneering work of Artis and Zhang was published in 2001 [Artis and Zhang, 2001] and contained detailed hard hierarchical cluster analysis of six economic domains based on Optimum Currency Area (OCA) criteria. One of the most important criteria considered was business cycle correlation. Business cycle series was extracted with help of Hodrick-Prescott (HP) filter, relations among exact country's business cycles were checked using cross-correlation analysis. In 2002 Boreiko's working paper [Boreiko, 2002] was issued. It supplemented OCA real convergence analysis with Maastricht Treaty nominal convergence criteria and embraced set of central and east European countries (CEECs). Due to short and unreliable[1] time series instead of hard version fuzzy clustering was used. Business cycle was isolated with HP filter and compared with help of cross-correlation analysis. Two newest articles [Kozluk, 2005; Ozer, Ozkan and Aktan, 2007] were based on fuzzy clustering technique as well. However they included more time series as West/North/South European countries were analysed in detail. Moreover Ozer, Ozkan and Akan used additionally Baxter-King (BK) method for business cycle extraction.

Detailed information about described articles and working papers was gathered in the table 1.

3. Traditional theory of Optimum Currency Area and its enhancements

The main architect of Optimum Currency Area theory was Mundell. In his seminal paper [Mundell, 1961] he described two two-country models in which he analysed influence of negative demand shock affecting one country (country A) and positive demand shock in the second one (country B). Both models were built on four principal assumptions. At the beginning of the analysis Mundell assumed that that in the country A and B there is:

- Balance of payment equilibrium.
- Unemployment on natural rate level.
- Applied anti-inflation policy of country's monetary authorities.
- Prices and wages levels which cannot be diminished in the short term without accelerating unemployment rate.

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[1] In the second half of 1990s CEECs' statistical offices often changed methodology of time series compilation. Moreover there were very serious revisions of the data.

Table 1.

Overview of literature on country's EMU membership readiness analysis based on clustering techniques

Authors, year of publication	Title	Surveyed countries and regions	Data categories used	Methods of business cycle extraction	Time series similarity checking methods	Pattern recognition method
Artis and Zhang [2001]	Core and Periphery in EMU: A Cluster Analysis	Austria, Canada, Belgium, Denmark, Finland, France, Greece, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Romania, Spain, Sweden, United Kingdom, United States	Business cycle correlation, Real exchange rate volatility, Real interest rate, Labour market flexibility, Trade integration, Inflation rate	Hodrick-Prescott	Cross-correlation	Hard clustering
Boreiko [2002]	EMU and Accession Countries: Fuzzy Cluster Analysis of Membership	Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, Slovenia, EU 12	Business cycle correlation, Exchange rate volatility, Interest rate, Trade integration, Inflation rate, budget deficit, public debt	Hodrick-Prescott	Cross-correlation	Fuzzy clustering
Kozluk [2005]	CEEC Accession Countries and the EMU: An Assessment of Relative Suitability and Readiness for Euro-Area Membership	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden	Business cycle correlation, Exchange rate volatility, Labour market flexibility, Trade integration, Inflation rate, budget deficit, public debt	Hodrick-Prescott	Cross-correlation	Fuzzy clustering
Ozer, Ozkan and Aktan [2007]	Optimum Currency Areas Theory: An Empirical Application to Turkey	Austria, Canada, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Turkey, United Kingdom	Business cycle correlation, Real exchange rate volatility, Real interest rate, Trade integration, Inflation rate	Hodrick-Prescott filter, Baxter-King filter	Cross-correlation	Fuzzy clustering

Source: own analysis.

Then demand shocks occur in both countries. Within the first model these countries use their own currencies with fixed regime exchange rates. In this situation country A will be affected by higher than usual unemployment and country B with higher than usual inflation. Higher prices in country B will negatively change its term of trade. Country A can take the advantage of this fact and produce more goods to export them to country B. However, to avoid further inflation monetary authority of country B will start to tighten its monetary policy. In case of lack of labour force mobility it will cause additional recession in the country A.

In the second model countries A and B are within common currency area. Beside this, there is centralized monetary authority common for the whole area which tries to eliminate unemployment higher than natural. Country B will be touched with higher inflation pressure and balance of payments deficit and A with higher unemployment and current account surplus. Trying to prevent described tendency in country A common monetary authority will increase amount of money in this country. In the case of free capital movement and common currency this movement will however increase amount of money in the country B as well, which will cause additional inflation pressure in this country.

One solution of described problem will be to use exchange rate as instrument of policy. However it cannot be used when A and B belong to one currency area. But there exists another solution of this problem as well. If we assume that labour and capital can be freely moved between country A and B shifts of labour force and capital can restore equilibrium. It could occur in the following way: after negative demand shock in country A amount of employed workers and used capital in this country will be reduced. Simultaneously there will be an increase in demand for labour force in country B. Lack of limitation of production factors movement will cause unemployed workers from country A to emigrate to find employment in country B. In the same direction capital will be shifted. In the country B additional labour and capital usage will generate income which could be spend on goods imported from country A. At the same time lower income in country A will limit demand for goods imported to this country from country B. Hence amount of labour force will be extended in country B and unemployment will be diminished in country A. In the next stage there will be further development of import of goods from country A to B and further reduction of export from country B to A. Described process will occur as long as the equilibrium will be reached.

Having in mind statistical data of developed countries after Second World War, Mundell assumed (in new-Keynesian way) inflexibility of labour force prices (wages). In his book de Grauwe [2003] noticed that flexibility of wages can be alternative method of adjustment to migration of workers. Negative demand shock affecting country A and positive shock in country B causes decrease of production and increase of unemployment in the first country and opposite effects in the second one. These changes generate surplus in the current account of country A and current account deficit in country B. Next, the unbalance in current account will result in real wages decrease in country A and, symmetrically, real wages increase in country B. This causes positive shift in aggregated supply curve in the first country and negative shift of analogous curve in the second economy. Price of goods will rise in economy A and fall in country B what makes export of these goods less competitive in the first case and more competitive in the second. This way the equilibrium in both countries will be restored.

Role of production factors mobility in restoring equilibrium between countries building common currency area is questioned in the work of Dennis and Presley [1976]. They noticed that:

- Workers in the country affected by unemployment can be unready for change of their place of living when they expect better situation in the local labour market in the future. Moreover labour force in different countries can have different skills or can be characterized with lack of skills.
- Shift of labour force to country with positive demand shock (economy B) can generate additional benefits of scale what will result in unit costs decrease and deflation in this country. Simultaneously reduction of production scale in country B will force higher inflation and increase of unit costs in this economy.
- Countries may have different aggregated production curves what may cause problems with absorbing by country B unemployed labour force originating country A.

Another contribution to Optimum Currency Area theory was given by McKinnon [1963]. He turned his attention to effective policy-mix (fiscal and monetary policy configuration) in particular countries of the area, which could sustain stability of internal prices, balance of payments equilibrium and unemployment rate on its natural level. Beside that he suggested that Optimum Currency Area should consist of economies opened to trade with other area members (he recommended proportion of tradable goods to non-tradable goods as a measure of country level of openness). In case of these countries transactional cost and exchange rate risk will be eliminated, what can generate additional profits for importers and exporters.

In the next step theory of Optimum Currency Area was enhanced by work of Kennen [1970]. He noticed that frequent changes of terms of trade and exchange rates in particular country can be avoided when the economy production is highly diversified what is connected with higher diversification of export structure. In this case in would be far easier to introduce fixed relation of currencies within common currency area. Moreover greater diversification immunizes economy to sectoral shocks which can in effect generate macroeconomic disturbances affecting whole country. Kennen emphasised role of free mobility of labour and capital and necessity of establishing in common currency area one centralized authority, which would be responsible for conducting monetary and fiscal policy. He understands labour mobility in three different fields: between geographical regions, between different categories of jobs and between particular sectors of considered economy. His vision of monetary and fiscal policy authority embraces central budget of this institution, on base of which in case of asymmetric economic troubles interregional/international transfers can be made.

Particular contributions to Optimum Currency Area idea established consistent theory, which is popular among modern macroeconomists. However OCA found its critiques. As argue Frankel and Rose [1996], several mechanisms of OCA, above all immunity to asymmetric shock, may be endogenous. It means that country could get more resistant to external shocks after it enters common currency area. Beside that modern international financial markets allow to share costs of negative shock in one country among other members of currency area. Alleged endogenity of some OCA mechanisms complicates this theory, however it is not crucial for analysis conducted in this paper, because we would like to identify similarities of countries in particular point of time and don't consider our analysis as continuous process.

Traditional OCA allows to enumerate several conditions under which creation of this single currency area can be optimal for individual participants. They are:

1. Relative small asymmetry of shocks affecting common currency area countries.
   Accessing common currency area particular country gets rid of independent monetary policy. If its economy is affected with demand or supply shock, which is not influencing other countries, it does not have monetary instruments to help economy get back to equilibrium and it cannot expect particular help from the side of other countries or central monetary authority. From statistical point of view this condition is checked by studying relations between business cycle components of different countries' outputs using cross-correlation (in time domain) or coherence (in frequency domain). In our survey cyclical components were extracted from monthly industrial production of particular country with use of Stock and Watson unobserved component model then compared in frequency domain with cyclical part of aggregated EMU industrial production (extracted with Stock and Watson method as well).
2. Flexibility of labour markets embodied with interregional/international labour force mobility and lack of wages rigidity.
   It was shown at the beginning of the present section that flexibility of full labour market is essential background of natural adjustment mechanism which should be triggered in the economy after it is hit by asymmetric shock. In reality it is almost impossible to achieve full flexibility of labour market. However we can determine level of labour market openness. For operational purposes statistics of employment process legislation (EPL) gathered by OECD is used as a measure of labour market flexibility.

3. High integration of country's financial markets.
   Father of Optimum Currency Area theory, Mundell, assumed that apart from labour force mobility free movements of capital between all area member countries should be ensured. In our paper synchronization of financial markets is measured using correlation of one of the most important financial indicators, real interest rate (difference between a short term nominal interest rate and rate of CPI). Analogously to the first studied condition we observe cyclical components (extracted with Hodrick--Prescott filter) of real interest rate of current and perspective EMU members with except to Germany and compare it with cyclical component of real interest rate time series of the last mentioned country (we choose Germany as a benchmark as it can be considered EMU central country)
4. Openness to external trade.
   Reduction of transactional costs and currency exchange risks extends profits of open economies from accession to common currency area. The level of the country external trade openness can be determined by statistical data on bilateral trade intensity, measured as relation of sum of export and import to EMU to sum of total (worldwide) export and import.
5. Synchronization of the actual inflation levels in common currency area countries.
   Monetary policy of common currency area central institution can be regarded as effective when it is applied to countries with similar rate of inflation. In other case it would be able to support anti-inflation efforts of only part of currency area members group. Inflation rate convergence is assessed with help of difference between inflation rate in particular country and dominative country of EMU, which in case of our survey is Germany.
6. Low volatility of real exchange rates.
   Entrance to common currency area is connected with loss of independent real exchange rate of local currency. Cost of this loss is relatively small if little volatility of real exchange rate was observed before currency area accession by the country. In case of actual EMU members volatility is measured as standard deviation of the log-difference of real bilateral DM exchange rates with producer prices as deflator. In case of perspective EMU members (Czech Republic, Hungary and Poland) standard deviation of the log difference of real bilateral Euro exchange rate is used.

4. Statistical and econometric methods used in the survey

4.1. Hierarchical cluster analysis

Cluster analysis is family of algorithms, which allows to classify set of investigated objects into particular groups. These algorithms try to maximize similarity of objects grouped together and to minimize similarities between objects classified to different groups. Generally there are two main types of cluster algorithm:

- Hierarchical, which forms iteratively tree-like structure of nested groups (at the end there is one root of the tree—one group of objects).
- Non-hierarchical, which needs final number of clusters given explicit before start of the analysis (at the end set of cases is broken down into chosen number of disjoint clusters).

In further part of this section we will describe in detail first kind of clustering algorithm. This presentation is based on *OECD Handbook on Constructing Composite Indicators* [2003] and description found in Rószkiewicz [2002].

Process of hierarchical clustering can be divided into several stages. First we choose appropriate distance measure. Among others most popular are (all measures are taken between cases i and j, each characterized with set of p parameters):

- Euclidean distance:

$$d_{ij} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk} \right)^2} \tag{4.1.1}$$

- Minkowski distance (generalization of the Euclidean distance):

$$d_{ij} = \sqrt[m]{\sum_{k=1}^{p} \left| x_{ik} - x_{jk} \right|^m} \tag{4.1.2}$$

- City-block (Manhattan) distance:

$$d_{ij} = \frac{\sum_{k=1}^{p} \left| x_{ik} - x_{jk} \right|}{p} \tag{4.1.3}$$

- Chebychev distance:

$$d_{ij} = \max_{k=1 \ldots p} \left| x_{ik} - x_{jk} \right| \tag{4.1.4}$$

Using one of them we compute similarity between cases. Taken into account that there is *N* objects we form *N* by *N* diagonal symmetric matrix. So we form *N* initial clusters which one object per one cluster.

In the next step we chose two clusters with minimal distance and group them together. After this operation we need to update similarity matrix—we decrease its dimensions by one end compute new similarity values for created subcluster. Last two steps we repeat until we reduce number of clusters to one.

After that our clustering algorithm is almost completed. One thing we need to determine additionally is method of computing similarity distance between new "cases" generated by clustering and other objects or subclusters described in similarity matrix. We can distinguish here seven basic options:

- Single linkage—similarity of two subclusters, C_i and Cj, (or subcluster and object) is perceived as distance of two elements (or subcluster and object) which are closest to each other:

$$d_{\min}\left(C_i, C_j\right) = \min_{o \in C_i,\, o' \in C_j} \|o - o'\| \tag{4.1.5}$$

where o denotes any object in the cluster i, o' denotes any object from the subcluster j and $\|o - o'\|$ describes one of the distance measures (4.1.1)–(4.1.4).

- Complete linkage—similarity of two subclusters (or subcluster and object) is measured by two elements from two subclusters (or subcluster and object) which are furthest from each other:

$$d_{\max}\left(C_i, C_j\right) = \max_{o \in C_i,\, o' \in C_j} \|o - o'\| \tag{4.1.6}$$

- Unweighted pair-group average—similarity of two subclusters is based on average distance between all pairs of elements of two clusters (or cluster and object):

$$d_{ave}\left(C_i, C_j\right) = \frac{1}{N_i N_j} \sum_{o \in C_i} \sum_{o' \in C_j} \|o - o'\| \tag{4.1.7}$$

where N_i, N_j stands for number of elements in cluster C_i and C_j respectively.

- Unweighted centroid—this method allows to compute distance between average values of parameters (centroids) of all elements gathered in each of compared subclusters (or average value of one subcluster elements' parameters and parameters of an object):

$$d_{centr}\left(C_i, C_j\right) = \|m - m'\| \tag{4.1.8}$$

where m denotes centroid (average point in space) of subcluster i and m' centroid of subcluster j.

- Weighted pair-group average—method analogous to unweighted version with one exception—number of elements in compared subclusters is taken into consideration to weight mean distances of elements (or subcluster and object).
- Weighted centroid—number of cases in clusters is used to weight distance of centroids.
- Ward's method—elements of two subclusters are gathered into one cluster based on variance of elements expressed with the sum of the squared deviations from the mean of the subcluster. Two subclusters (or cluster

and object) are merged if after this operation smallest possible increase in the variance is gained.

Finally, when all the steps of computations described above finish successfully, hierarchy of the clusters is presented in form of a dendrogram. This kind of chart shows sequence of merging objects and then subclusters into other clusters as a function of changing linkage distance among subsequent built structures. The less clusters are taken into consideration the more "dissimilar" are their elements from each other.

4.2. Spectral analysis

Spectral analysis allows econometricians to analyse time series behaviour in frequency domain rather than in standard time domain. In our paper we will present only sketch of this subject, more exhaustive description can be found in Hamilton (1994).

Taking into account time dimension every covariance-stationary process Y at time t with mean μ can be modelled as infinite sum of innovations:

$$Y_t = \mu + \sum_{j=0}^{\infty} \psi_j \varepsilon_{t-j} \tag{4.2.1}$$

According to spectral representation theorem (counterpart of Wold's theorem) this process can be simultaneously described in frequency domain in the form of weighted sum of periodic functions (ω denotes certain frequency):

$$Y_t = \mu + \int_0^{\pi} \alpha(\omega)\sin(\omega t)d\omega + \int_0^{\pi} \delta(\omega)\cos(\omega t)d\omega \tag{4.2.2}$$

Let us assume that j-th autocovariance for Y_t can be expressed with formula:

$$\gamma_j = E(Y_t - \mu)(Y_{t-j} - \mu) \tag{4.2.3}$$

If these autocovariances are absolutely summable, autocovariance generating function for (4.2.1) can be given in the form of (z denotes complex scalar):

$$g_Y(z) = \sum_{j=-\infty}^{\infty} \gamma_j z^j \qquad (4.2.4$$

Its counterpart in frequency domain, called population spectrum, may be written as:

$$s_Y(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_j e^{-i\omega j} \tag{4.2.5}$$

where $i = \sqrt{-1}$

Using de Moivre's theorem population spectrum can be expressed in terms of sinus and cosine functions:

$$s_Y(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_j [\cos(\omega j) - i \sin(\omega j)] \tag{4.2.6}$$

Considering fact that autocovariance of covariance-stationary process is symmetric ($\gamma_j = \gamma_{-j}$) and taking into account some simple trigonometry identities equation (4.2.5) may be equivalently written in the form of:

$$s_Y(\omega) = \frac{1}{2\pi} \left[\gamma_0 + 2\sum_{j=1}^{\infty} \gamma_j \cos(\omega j) \right] \tag{4.2.7}$$

Hence, population spectrum is continuous, real-valued function of frequency ω. Moreover, if we have in mind periodicity of cosine function $\{\cos[(\omega j + 2\pi k)j] = \cos(\omega j)$ for any integer k and $j\}$ we can deduce value of (4.2.7) for any value bounding ourselves to the range $\langle 0, \pi \rangle$.

Dependency between population spectrum and autocovariances of the stochastic process is bilateral. k-th autocovariance can be expressed with the following expression:

$$\gamma_k = \int_{-\pi}^{\pi} s_Y(\omega) e^{i\omega k} d\omega \tag{4.2.8}$$

If we put $k = 0$ into 4.2.8 we can notice that area under population spectrum function in the range $\langle -\pi, \pi \rangle$ yields variance of Y_t:

$$\gamma_0 = \int_{-\pi}^{\pi} s_Y(\omega) d\omega \tag{4.2.9}$$

Having in mind symmetric nature of population spectrum we can restrict our computations to the range $\langle 0, \pi \rangle$:

$$\gamma_0 = 2\int_{0}^{\pi} s_Y(\omega) d\omega \tag{4.2.10}$$

For observed finite sample of T observations ($y_1, \ldots, y_T$) equivalent of spectral representation theorem (4.2.2) is:

$$y_t = \hat{\mu} + \sum_{j=1}^{M} \hat{\alpha}_j \cos[\omega_j (t-1)] + \sum_{j=1}^{M} \hat{\delta}_j \sin[\omega_j (t-1)] \tag{4.2.11}$$

where M is the number of considered discrete frequencies $\omega_j = \frac{2\pi j}{T}$, $j = 0, 1, \ldots, T/2$ for even and $j = 0, 1, \ldots, (T-1)/2$ for odd T.

Furthermore the analog of population spectrum (4.2.5), sample periodogram, can be defined as:

$$\hat{s}_Y(\omega) = \frac{1}{2\pi} \sum_{j=-T+1}^{T-1} \hat{\gamma}_j e^{-i\omega j} = \frac{1}{2\pi} \left[\hat{\gamma}_0 + 2\sum_{j=1}^{T-1} \hat{\gamma}_j \cos(\omega j) \right] \tag{4.2.12}$$

where $\hat{\gamma}_j$ is sample covariance computed with help of formula:

$$\hat{\gamma}_j = \begin{cases} T^{-1} \sum_{t=j+1}^{T} \left(y_t - \overline{y}\right)\left(y_{t-1} - \overline{y}\right) & \text{for } j = 0, 1, \ldots, T-1 \\ \hat{\gamma}_{-j} & \text{for } j = 0, 1, \ldots, -T+1 \end{cases} \tag{4.2.13}$$

and $\overline{y}_j = T^{-1} \sum_{t=1}^{T} y_t$ is sample mean

Finally sample variance may be written in the form:

$$\hat{\gamma}_0 = \int_{-\pi}^{\pi} \hat{s}_Y(\omega) d\omega = 2\int_{0}^{\pi} \hat{s}_Y(\omega) d\omega \tag{4.2.14}$$

Sample periodogram is unbiased estimator of population spectrum but unfortunately it is inconsistent as well. Lets make an assumption that we have simplification of the process expressed with the equation (4.2.1):

$$Y_t = \sum_{j=0}^{\infty} \psi_j \varepsilon_{t-j} \tag{4.2.15}$$

As cited in the mentioned book of Hamilton, Fuller [1976] proved that for appropriate sample size T twice ratio of the sample periodogram to the population spectrum of this process can be approximated with χ^2 distribution with 2 degrees of freedom:

$$\frac{2\hat{s}_Y(\omega)}{s_Y(\omega)} = \chi^2(2) \tag{4.2.16}$$

Afterwards expected value of left side of (4.2.16) can be written as:

$$E\left[\frac{2\hat{s}_Y(\omega)}{s_Y(\omega)}\right] = 2 \tag{4.2.17}$$

what gives us opportunity to show lack of the bias of sample periodogram:

$$E\left[\hat{s}_Y(\omega)\right] = s_Y(\omega) \tag{4.2.18}$$

However is not going to be more accurate while size of the sample increases.

Assumption that $s_Y(\omega)$ is close to $s_Y(\lambda)$ when ω is close to λ lies as a basis of kernel estimation. Taking this assumption as granted $s_Y(\omega)$ can be estimated as weighted average of $s_Y(\lambda)$ if values of λ lie in the direct neighborhood of ω. Hence estimator of population spectrum can be expressed as:

$$\hat{s}_Y\left(\omega_j\right) = \sum_{m=-h}^{h} k_m s_Y\left(\omega_{j+m}\right) \tag{4.2.19}$$

where m is bandwith parameter (which determines how many frequencies are used in the neighborhood of ω_j) and kernel function k_m expresses how much power is given for frequency with appropriate subscript (weights k_m are symmetric /$k_m = k_{-m}$/ and summable to 1/ $\sum_{m=-h}^{h} k_m = 1$/.

One of the most popular kernel functions is modified Bartlett kernel:

$$k_m = \begin{cases} \dfrac{h+1-|m|}{(h+1)^2} & \text{for } |m| \le h \\ 0 & \text{for } |m| > h \end{cases} \qquad (4.2.20)$$

When we would like to analyse dependencies between variables in the frequency domain we should use cross-spectrum of these series. For two covariance stationary processes $\{x_t\}_{t=-\infty}^{\infty}$ and $\{y_t\}_{t=-\infty}^{\infty}$, defined as independent and dependent variables respectively, the population cross-spectrum can be expressed with the formula:

$$s_{YX}(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{YX}^{k} e^{-i\omega k} = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{YX}^{k} \{\cos(\omega k) + i \sin(\omega k)\} \qquad (4.2.21)$$

where γ_{YX}^{k} is the cross-covariance of y and x of k-th order:

$$\gamma_{YX}^{k} = (y_t - \mu_y)(x_t - \mu_x) \qquad (4.2.22)$$

Population cross-spectrum may be perceived as sum of two components cospectrum:

$$c_{YX}(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{YX}^{k} \cos(\omega k) \qquad (4.2.23)$$

and quadrature spectrum of y and x:

$$q_{YX}(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{YX}^{k} \sin(\omega k) \qquad (4.2.24)$$

Since cross-covariance of y and x is not symmetric $\gamma_{YX}^{-k} \neq \gamma_{YX}^{k}$ (4.2.21) is usually complex number.

Knowing cospectrum and quadrature spectrum we can define three statistics, which allow us to evaluate in detail shape of the relationship between processes y and x in the frequency domain. They are (in all statistics below ω is bounded to the range [0, π]):

- Coherence:

$$h_{YX}(\omega) = \frac{[c_{YX}(\omega)]^2 + [q_{YX}(\omega)]^2}{s_X(\omega) s_Y(\omega)} \qquad (4.2.25)$$

- Phase shift:

$$p_{YX}(\omega) = \tan^{-1}\left(\frac{-c_{YX}(\omega)}{q_{YX}(\omega)}\right) \qquad (4.2.26)$$

- Gain:

$$g_{YX}(\omega)=\left(\frac{\left[c_{YX}(\omega)\right]^2+\left[q_{YX}(\omega)\right]^2}{s_X(\omega)}\right)^{\frac{1}{2}} \tag{4.2.27}$$

First of above statistics measures force with which cycle with frequency w on jointly influences processes y and x. It keeps its values in the range [0, 1]. Phase shift informs econometrician about leading (positive value) or lagging (negative value) of process $\{y_t\}$ by process $\{x_t\}$. Gain determines relation of the amplitudes between processes $\{y_t\}$ and $\{x_t\}$for particular frequency ω.

When we would like to deal with cross-spectrum of time series realizations of the processes $\{y_t\}$ and $\{x_t\}$ we need to replace theoretical cross-covariance (4.2.22) with empirical. Computation of coherence, phase shift and gain requires computation of smoothed versions of cospectrum and quadrature spectrum. Analogically to sample spectrum they can be achieved with application of modified Bartlett window.

4.3. Unobserved component ARIMA model

Unobserved component models (UCM) can be used for analysis of single time series and whole groups of data. Version of unobserved component model for single time series was described by Watson [1986], group series analysis was depictured in two works of Stock and Watson [1989, 1991]. Taking into account quantity of series which should be analyzed during our survey (series for 17 countries and EMU) we decided to use single time series approach. This models allows for each time series to isolate two components: trend and cycle. Both of the components are modeled with help of ARIMA framework, so the full name of de model is UCARIMA.

Structure of the model is as follows (m_t denotes trend component, w_t cyclical component) and is presented in a way similar to Skrzypczynski paper [2008]:

$$\begin{aligned} y_t &= \mu_t + \psi_t \\ \mu_t &= \delta + \mu_{t-1} + \varepsilon_t \\ \psi_t &= \phi_1\psi_{t-1} + \phi_2\psi_{t-2} - \xi_t \end{aligned} \tag{4.3.1}$$

Stochastic elements in second and third equation are uncorrelated Gaussians with mean 0 and variance σ_ε and σ_ξ respectively. As we can see from above set of equations trend is modeled as random walk process with drift while cyclical factor is given as AR(2) process

Estimation of (4.3.1) parameters is made with help of maximum likehood method with application of Kalman filter.

Thus, described set of equations should be written in state-space form, which consists of measurement block:

$$y_t = \begin{bmatrix}1 & 1 & 0\end{bmatrix}\begin{bmatrix}\mu_t \\ \psi_t \\ \psi_{t-1}\end{bmatrix} \tag{4.3.2}$$

and state block:

$$\begin{bmatrix}\mu_t \\ \psi_t \\ \psi_{t-1}\end{bmatrix} = \begin{bmatrix}\delta \\ 0 \\ 0\end{bmatrix} + \begin{bmatrix}1 & 0 & 0 \\ 0 & \phi_1 & \phi_2 \\ 0 & 1 & 0\end{bmatrix}\begin{bmatrix}\mu_{t-1} \\ \psi_{t-1} \\ \psi_{t-2}\end{bmatrix} + \begin{bmatrix}1 & 0 \\ 0 & 1 \\ 1 & 0\end{bmatrix}\begin{bmatrix}\varepsilon_t \\ \xi_t\end{bmatrix} \tag{4.3.3}$$

5. Statistical data and its treatment

In the third section of our paper we presented the most important criteria for Optimum Currency Area creation and assigned statistical data. In this section we would like to give more detailed description of the data used in the survey.

Before our survey was performed we had to decide on time framework used in the analysis. There were two issues that determined our decision: endogenity of OCA criteria and changes in the statistical system which affected CEECs in the first half of 1990s. So we have chosen to compare countries' statistic data in the certain time range before EMU accession. For current EMU members (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain) and Denmark, Sweden and UK we took five years range from 1992. For aspiring countries (Czech Republic, Hungary and Poland) we assumed that their accession to EMU will materialize in 2012. For them we chose 5 years period of time as well, beginning in 2003 (last observation of the data span is fife years before assumed accession time).

First we dealt with non time series data. Flexibility of labour market was proxied with employment protection legislation (EPL) measure found in OECD Economic Outlook [OECD, 2004]. In case of current EMU members Denmark, United Kingdom, and Sweden as a base year we took 1998, for aspiring EMU countries we considered 2003. External trade openness was described with proportion of sum of export and import to EMU to sum of total (worldwide) export and import/(export from EMU cif + export to EMU fob)/(export worldwide cif + export worldwide fob)/ and computed for year 1996 in the case of old and for year 2007 in the case of new EU countries.

After that we started to perform statistical transformations of time series data. For industrial production (IP), assigned according to Artis and Zhang [2001] paper to business cycle synchronization criterion, we decided to eliminate seasonal and working days effects with help of TRAMO/SEATS procedures implemented in the Demetra package. Next transformation of IP, extraction of cycle component, was performed in Eviews statistical package with help of unobserved component model (equation blocks (4.3.2) and (4.3.3)). As a reference series for European Business Cycle we considered unobserved component estimated from aggregated industrial production of EMU (unobserved components graphs of countries' and EMU industrial production were depictured in the Annex in the Figure set A).

In the next step we computed real exchange rate to check its volatility. To evaluate nominal local exchange rate against deutsche mark we used for EMU members nominal exchange rate of local currency against US dollar and nominal exchange rate of US dollar against deutsche mark (our computations were based on triangular arbitrage assumption). For CEECs we used local exchange rate against US dollar and US dollar exchange rate against euro. Real exchange rates were derived from nominal after multiplying them by proportion of local production price index/wholesale price index to PPI observed in Germany.

In the case of financial markets integration criterion based on real interest rate synchronization we applied difference of local nominal short term interest rate and local chained consumer price index. Then we used described H-P detrending procedure with parameter $\lambda = 1440$.

Last we derived time series for convergence of inflation condition. We used difference between local inflation rate and inflation rate in Germany.

Two sets of derived variables, cyclical component of industrial production and of real interest rate, were prepared to be treated with cross-correlation, spectral and cross-spectral analysis, Thus we had to check whether these series are stationary within the sample. We used augmented version of Dickey-Fuller (ADF) test implemented in Eviews. Results of the analysis we presented in Tables B and C in the Annex. According to ADF test all variables, except industrial production of the Eurozone and Greece, can be considered as stationary with 5% confidence interval (ADF test p-value for Eurozone and Greece industrial production only slightly exceeded 5% threshold).

Before applying cluster methods, information contained in particular time series had to be summarized with one parameter. In case of business cycle synchronization criterion for each country we estimated unobserved cyclical component using state space framework ((4.3.2) and (4.3.3)) and Kalman filter. Next we used spectral and cross-spectral analysis. We computed univariate periodogram (4.2.12) for reference time series, EMU IP, and then multivariate population cross-spectrum for reference series as an independent variable and industrial production of each country as dependant indicator. On this basis we evaluated square of the coherence (4.2.25) and computed its average for two frequencies which were connected with highest values of reference series periodogram. Results were placed in the second column of the Table 2.

Computation of real exchange rate volatility was far easier, we just used standard deviation of country's real exchange rates (third column in Table 2.). Finally we determined dependencies between real interest rate of the reference country (Germany) and other EU members with help of cross-correlation analysis (fourth column in Table 2.).

Table 2.

Criteria by OCA theory

	Business cycle synchronization	Real exchange rate volatility	Real interest rate synchronization	Openness of the economy	Inflation convergence	Labour market flexibility
Austria	0,9	0,84	–0,03	0,79	–0,26	2,21
Belgium	0,89	0,71	–0,1	0,75	–0,67	2,93
Czech Republic	0,42	1,63	0,15	0,81	1,04	1,9
Denmark	0,85	0,83	0,65	0,72	–0,79	1,92
Finland	0,73	2,41	0,05	0,7	–0,97	2,16
France	0,9	0,74	0,42	0,67	–0,92	2,98
Germany	0,97	0	1	0,65	0	2,99
Greece	0,83	2,06	0,37	0,66	5,43	3,54
Hungary	0,57	2,38	0,1	0,7	5,29	1,27
Ireland	0,61	1,9	0,31	0,65	–0,53	0,93
Italy	0,93	2,35	0,05	0,64	1,39	3,44
Netherlands	0,6	0,5	0,48	0,7	–0,31	2,73
Poland	0,46	2,86	–0,26	0,74	2,32	1,49
Portugal	0,3	1,66	–0,22	0,81	2,77	3,82
Spain	0,89	1,89	0,36	0,71	1,36	3,38
Sweden	0,86	2,41	0,03	0,66	–0,02	2,76
UK	0,5	2,3	0,13	0,57	0,31	0,6

Source: own computations.

6. Survey results

6.1. Results of cluster analysis

Cluster analysis was performed on data gathered in Table 2. We decided to use hard clustering technique because we perceive CEECs statistical time series from 2003 to 2007 stable and reliable. As the main variant of linkage distance computation we chose weighted pair-group average (Figure 1) but we show that changing agglomeration criteria doesn't change contents of the clusters (Figure 2) After examining both clustering procedures we recognized four clusters. Process of forming particular groups for weighted pair-group average case is presented in Table 3. Smallest dissimilarity coefficient (0.56) was discovered in the case of Spain and Italy. Similar close distance (0.59) was found between Belgium and France. In the next step these two countries were joined by Netherlands (with coefficient 0.78). Then Austria, Denmark (coefficient 1.02) and Germany (coefficient 1.37) were included into growing group and the first, most homogenous cluster was formed (cluster homogeneity can be measured by average distance of linkage of its objects). Meanwhile in the fifth step of the agglomeration procedure another cluster started to grow. It was originated when UK and Ireland were grouped together (coefficient 1.01) and was made complete after including Finland and Sweden (coefficient 1,92). The group of the most similar countries, Spain and Italy, was first joined by Czech Republic (coefficient 1,72), then by Poland (coefficient 2.12) and Portugal (coefficient 2.42). This way third cluster was established. Last cluster (called by us "outlier cluster") was created from two remaining countries: Greece and Hungary (with dissimilarity coefficient 2.32).

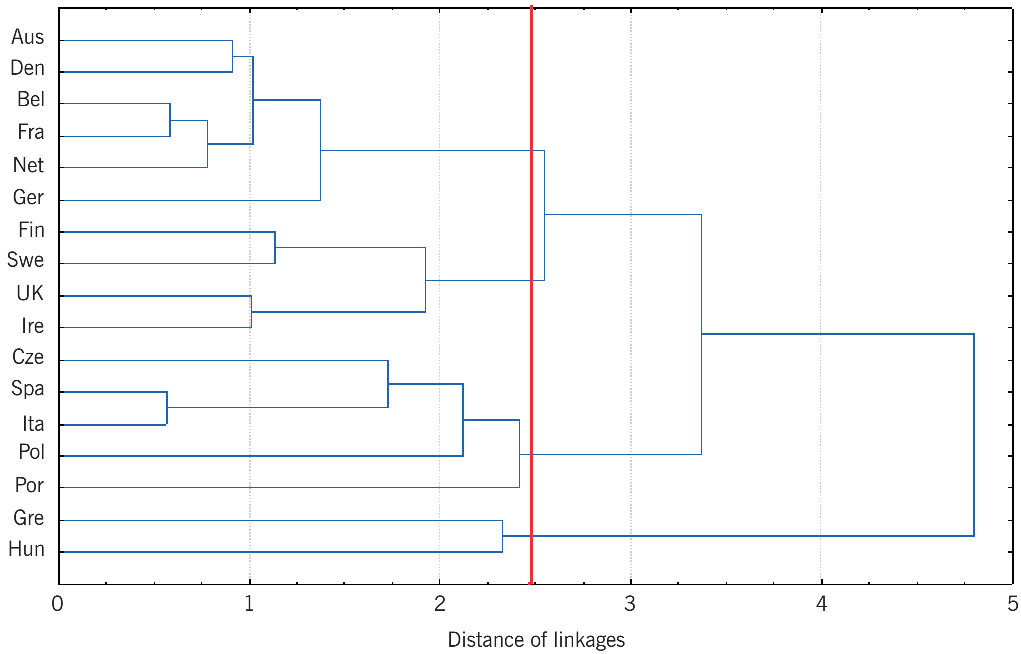

Figure 1.

Dendrogram of weighted pair-group average clustering with Euclidean distance
Source: own computations.

What economic characteristics of the countries determined described division into clusters? Answer to this question can be found in the Table 4. Countries belonging to the first cluster can be characterized with high business cycle correlation, low real exchange rate volatility, high convergence of inflation and medium protection of labour market. The second cluster is described with medium business cycle synchronization, high variance of real exchange rate, medium interest rate synchronization, low or medium integration of external trade, high inflation convergence and high or medium labour market flexibility. Countries from the third cluster are characterized with mixed business cycle synchronization tendency, high or medium real exchange rate volatility, medium or low real interest rate synchronization, high fraction of external trade with EMU countries, medium convergence of inflation and medium or low labour market flexibility. Last cluster, pair of Hungary and Greece, has high/medium synchronization of business cycle, high real exchange volatility, medium real interest rate synchronization, and medium/low openness of the economy. Moreover countries from this cluster are characterized with low convergence of inflation and mixed tendency in labour market flexibility.

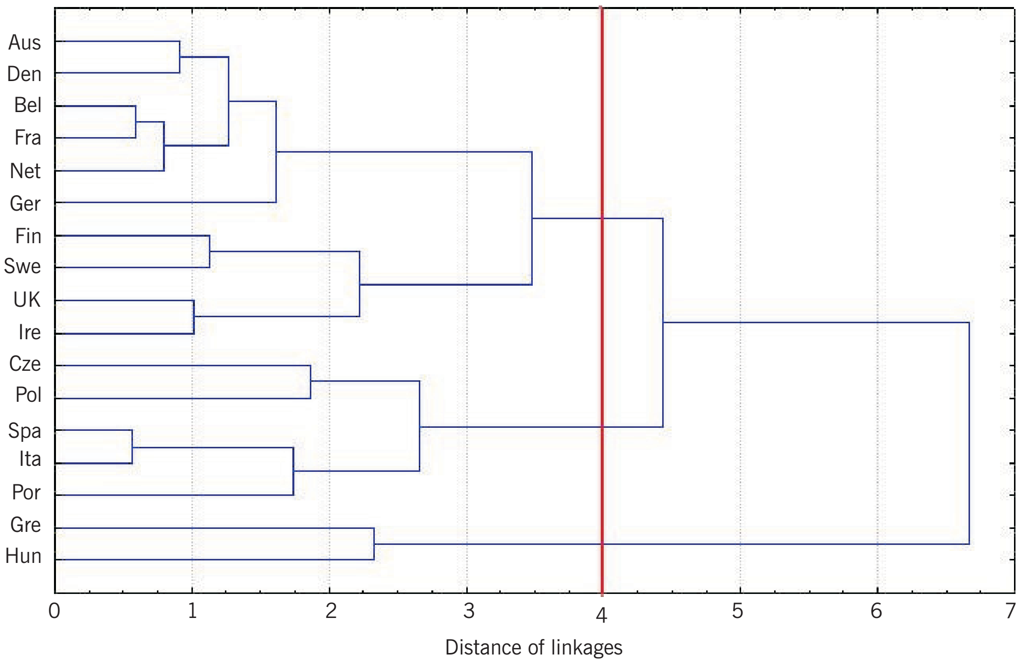

Figure 2.

Dendrogram of complete linkage clustering with Euclidean distance

Source: own computations.

Trying to summarize our results we suggest that three analyzed CEECs have to be treated as peripheral economies. They are located much further from core group {Austria, Belgium, France, Germany, Netherlands} than EU northern economies (Finland, Sweden, UK, Ireland). Two of surveyed economies, Czech Republic and Poland, may be considered as similar to EMU southern countries: Italy, Portugal and Spain. Third CEECs country, Hungary is even more distant from core of EMU and is paired with outlier economy, Greece. When we compare these three CEE countries with substantial

Table 3.
Process of particular clusters formation

Dissimilarity coefficient																	
0.56	Spain	Italy															
0.59	Belgium	France															
0.78	Belgium	France	Nether.														
0.91	Austria	Denmark															
1.01	UK	Ireland															
1.02	Austria	Denmark	Belgium	France	Nether.												
1.13	Finland	Sweden															
1.37	Austria	Denmark	Belgium	France	Nether.	Germany											
1.72	Czech Rep.	Spain	Italy														
1.92	Finland	Sweden	UK	Ireland													
2.12	Czech Rep.	Spain	Italy	Poland													
2.32	Greece	Hungary															
2.42	Czech Rep.	Spain	Italy	Poland	Portugal												
2.54	Austria	Denmark	Belgium	France	Nether.	Germany	Finland	Sweden	UK	Ireland							
3.37	Austria	Denmark	Belgium	France	Nether.	Germany	Finland	Sweden	UK	Ireland	Czech Rep.	Spain	Italy	Poland	Portugal		
4.80	Austria	Denmark	Belgium	France	Nether.	Germany	Finland	Sweden	UK	Ireland	Czech Rep.	Spain	Italy	Poland	Portugal	Greece	Hungary
Object number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Source: own computations.

economies of the monetary union we notice that his situation is mainly consequence of relative low business cycle synchronization, high volatility of exchange rate and lack of real interest rate synchronization and inflation convergence.

Table 4.

Countries classification based on one criteria

Characteristics	Groups of the countries
Business cycle synchronization	
High	Germany, Italy, France, Austria, Spain, Belgium, Sweden, Denmark Greece
Medium	Finland, Ireland, Netherlands, Hungary, UK
Low	Poland, Czech Republic, Portugal
Real exchange rate volatility	
High	Poland, Sweden, Finland, Hungary, Greece, UK
Medium	Ireland, Spain, Portugal, Czech Republic
Low	Austria, Denmark, France, Belgium, Netherlands, Germany
Real interest rate synchronization	
High	Germany, Denmark, Netherlands, France
Medium	Greece, Spain, Ireland, Czech Republic, UK, Hungary, Finland, Italy, Sweden
Low	Austria, Belgium, Portugal, Poland
Openness of the economy	
High	Czech Republic, Portugal, Austria, Belgium, Poland, Denmark, Spain
Medium	Netherlands, Hungary, Finland
Low	France, Greece, Sweden, Germany, Ireland, Italy, UK
Inflation convergence	
High	UK, Germany, Sweden, Austria, Netherlands, Ireland, Belgium, Denmark, France, Finland
Medium	Portugal, Poland, Italy, Spain, Czech Republic
Low	Greece, Hungary
Labour market flexibility	
High	UK, Ireland, Hungary, Poland
Medium	Czech Republic, Denmark, Finland, Austria, Netherlands, Sweden, Belgium, France, Germany
Low	Spain, Italy, Greece, Portugal

Source: own analysis.

6.2. Comparisons with other surveys

Results achieved in our survey can be easily compared with results published in the works described in the second section of this paper. Our division of "old" EU countries into clusters is similar to these presented by Artis and Zhang (2001). They distinguish one core group of EMU members consisting of Austria, Belgium, Germany, Netherlands and France and two periphery groups: northern periphery to which belong Denmark, Ireland, Finland, Sweden and UK, and southern periphery made up Greece, Italy, Spain and Portugal.

Clustering of Czech Republic, Hungary and Poland was depictured in the papers of Boreiko, Kozluk and Ozer, Ozkan and Aktan. Results are rather mixed. First author suggests that according to OCA criteria and different periods of time (1993–2001, 1995–2001, 1997–2001 and 1999–2001) Czech Republic, Hungary and Poland can be classified to group of countries relatively close to core of EMU, whereas in our survey Hungary is separated from two remaining countries due to lower openness of the economy and lower inflation convergence. Beside that all three countries are quite distinct from EMU core.

Kozluk uses two reference periods for his analysis, 11 and 5 years before potential EMU expansion. In the first case he claims that Czech Republic is similar to group of core common currency countries (which analogously to work of Artis and Zhang consists of Austria, Belgium, Germany, Netherlands and France). For Hungary and Poland he reserves different special group. He calls it "transition periphery" group. In the case of 5 years before expansion reference period he proposes different configuration of clusters. Core group is formed only with West European economies. Hungary belongs with Spain and Portugal to "southern periphery" and "northern periphery" is based on similarity of Finland and Ireland. Analogously to our survey Greece is treated like outlier country, being only weakly correlated with EMU economies.

Last group of authors, Ozer, Ozkan and Aktan, suggests in part of their survey based on cluster analysis that it is Poland and then Hungary which are the most similar to putative central country of EMU, Germany.

In our opinion these diversification of the results is caused by different time periods for which CEECs countries are surveyed. We have to remember that Czech Republic, Hungary and Poland are still transition countries with evolving structure of internal economic processes.

7. Conclusions and suggestions of future work

In our survey we performed analysis of three CEE countries (Czech Republic, Hungary and Poland) readiness to join European Monetary Union. This survey was based on Optimum Currency Area theory which highlights six particular real criteria for successful single currency area members. One of the most important OCA criteria is business cycle synchronization between countries trying to introduce common currency. This criteria requires quite sophisticated economic data analysis as, first of all, for every surveyed country business cycle component should be extracted and in the next phase power of the relationships between country's cycle components should be checked. For the first part we used unobserved component model proposed by Stock and Watson and for the second part spectral and cross-spectral analysis with coherence as the main measure. Trying to avoid obstacles connected with statistical data unavailability for CEECs we used statistical data in the four years span five years before (potential) EMU joining. So for Czech Republic, Hungary and Poland we've chosen 2012 as a deadline and introduced economic data that depictures situation in these countries up to four years after first wave of recent EU expansion. All gathered and transformed statistical data was used as an input for substantial part of our survey, cluster analysis. Result of the clustering process showed that similarly to other surveys [Artis and Zhang, 2001; Kozluk, 2005] EMU member countries can be divided into consistent groups. First of all we can notice that several economies (Austria, Belgium, Denmark, France and Netherlands) group together around Germany -putative central EMU country. Taking Artis and Zhang nomenclature they can be perceived as core of common currency area. Beside that two other homogenous groups can be identified: northern group to which belong Finland, Ireland, UK and Sweden and southern periphery consisting of Italy, Portugal and Spain. Two surveyed CEE countries, Czech Republic and Poland can be classified jointly with last mentioned group. Third CEE country, Hungary, is bound to Greece, EMU outlier country.

Described results may have substantial implications for policy makers in "new" EU countries. They should however remember that we show only static snapshot of EMU and CEE economies (what we mentioned in the third part of our paper). Taking decisions about introduction of common currency requires knowledge of dynamics of the EMU readiness status. So we plan to conduct similar surveys on moving span of data. To do that we however need additional observations of time series, hence we have to wait until these new observations will be gathered by local statistical institutes and Eurostat.

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Appendix

Table A.
Statistical data and its characteristics

Country	Industrial production	Exchange rate	Short term interest rate	PPI/WPI	Consumer price index	Ext. trade statistics	Employment prot. legislation (EPL)
	a	b	Monthly	Monthly	Monthly	Non time series data	Non time series data
Austria	1992:01–1996:12	1992:01–1996:12	3-month VIBOR; 1992:01–1996:12	WPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Belgium	1992:01–1996:12	1992:01–1996:12	3-month treasury certificates; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Czech Republic	2003:01–2007:12	2003:01–2007:12	3-month PRIBOR; 2003:01–2007:12	PPI;2003:01–2007:12	2003:01–2007:12	2007	2003
Denmark	1992:01–1996:12	1992:01–1996:12	DNK 3-month uncollateralized interbank rate; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Eurozone	1992:01–1996:12	–	–	–	–		
Finland	1992:01–1996:12	1992:01–1996:12	3-month HELIBOR; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
France	1992:01–1996:12	1992:01–1996:12	3-month PIBOR; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Germany	1992:01–1996:12	1992:01–1996:12	3-month FIBOR; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Greece	1992:01–1996:12	1992:01–1996:12	Yield 12-month treasury bills; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	2000	1998
Hungary	2003:01–2007:12	2003:01–2007:12	3-month interbank rate;2003:01–2007:12	PPI;2003:01–2007:12	2003:01–2007:12	2007	2003
Ireland	1992:01–1996:12	1992:01–1996:12	3-month Dublin interbank rate; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Italy	1992:01–1996:12	1992:01–1996:12	3-month interbank rate on deposits; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Netherlands	1992:01–1996:12	1992:01–1996:12	3-month AIBOR; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Poland	2003:01–2007:12	2003:01–2007:12	3-month WIBOR; 2003:01–2007:12	PPI;2003:01–2007:12	2003:01–2007:12	2007	2003
Portugal	1992:01–1996:12	1992:01–1996:12	Rate 86 to 96-day interbank;1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Spain	1992:01–1996:12	1992:01–1996:12	Rate 3-month interbank loans; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
Sweden	1992:01–1996:12	1992:01–1996:12	Yield 90-day treasury bills;1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998
UK	1992:01–1996:12	1992:01–1996:12	3-month mean LIBID/LIBOR; 1992:01–1996:12	PPI;1992:01–1996:12	1992:01–1996:12	1996	1998

a: Monthly seasonally and working days adjusted; b: Monthly, local exchange rate/euro for Czech Republic, Hungary and Poland, local exchange rate/DM for others
Data for industrial production, exchange rates, interest rates and PPI/WPI were retrieved from OECD database. Ext. trade stat. comes from Eurostat database Source: own analysis.

Table B.

Results for ADF test of cyclical component of industrial production (quantity of lags determined with help of Schwartz information criterion)

Country	Lags	ADF statistics	p-value
Austria	8	–2.103260	0.0344
Belgium	11	–2.684351	0.0074
Czech Republic	11	–2.832714	0.0048
Denmark	9	–3.727492	0.0002
Eurozone	10	–1.927627	0.0517
Finland	11	–2.761830	0.0059
France	9	–3.155882	0.0018
Germany	13	–2.372696	0.0175
Greece	8	–1.935160	0.0509
Hungary	10	–2.375948	0.0174
Ireland	11	–1.984669	0.0455
Italy	7	–5.399795	0.0000
Netherlands	11	–1.970406	0.0470
Poland	8	–3.331128	0.0010
Portugal	11	–2.749055	0.0062
Spain	11	–2.061954	0.0380
Sweden	8	–2.894820	0.0040
UK	13	–3.579150	0.0004

Source: own computations

Table C.

Results for ADF test of real interest rate detrended with HP filter (quantity of lags determined with help of Schwartz information criterion)

Country	Lags	ADF statistics	p-value
Austria	9	–3.317943	0.0011
Belgium	9	–5.983351	0.0000
Czech Republic	9	–4.687759	0.0000
Denmark	9	–5.664842	0.0000
Finland	5	–3.559919	0.0005
France	5	–3.322167	0.0011
Germany	10	–2.959050	0.0035
Greece	10	–2.738399	0.0063
Hungary	3	–3.925956	0.0001
Ireland	3	–4.570633	0.0000
Italy	7	–4.134883	0.0001
Netherlands	10	–3.967049	0.0001
Poland	1	–5.805854	0.0000
Portugal	7	–4.751148	0.0000
Spain	9	–5.198601	0.0000
Sweden	0	–4.214427	0.0000
UK	9	–3.421279	0.0008

Source: own computation.

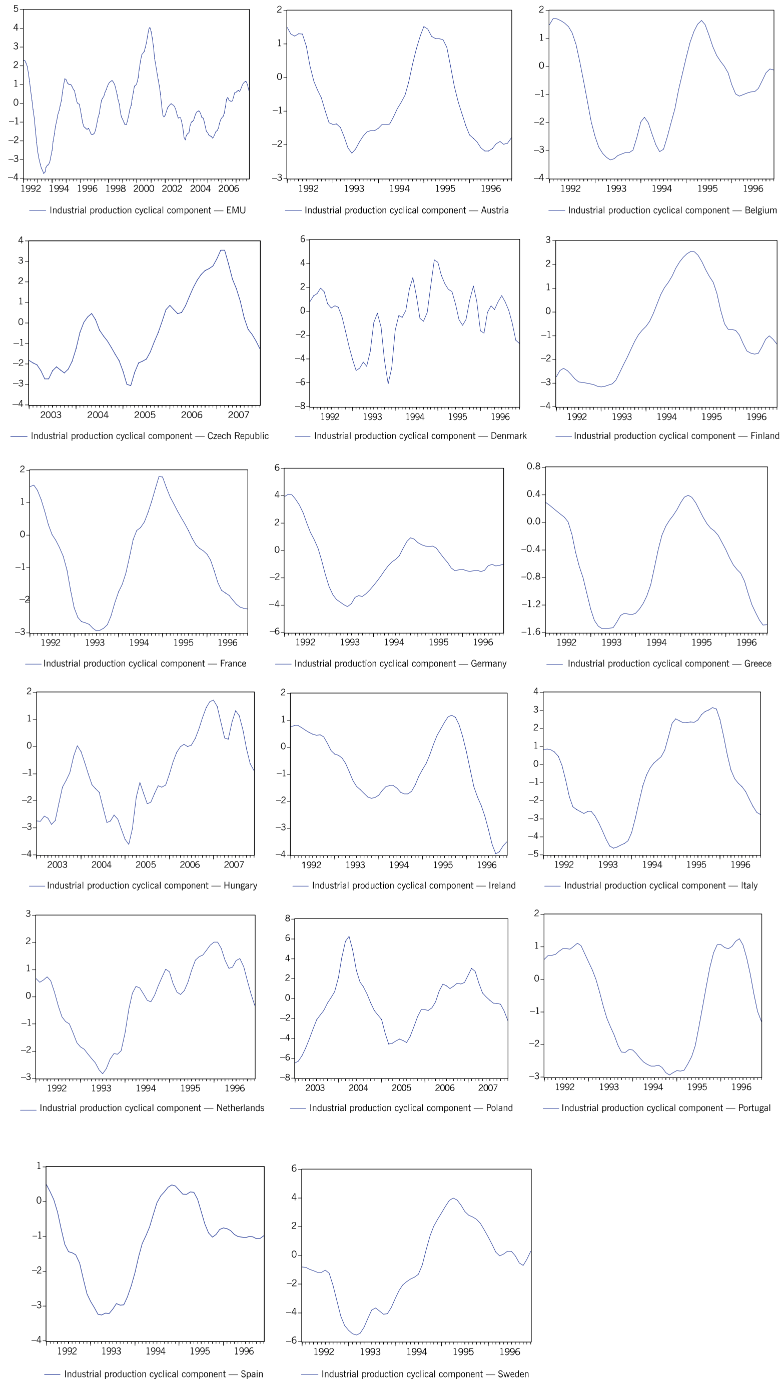

Figure set A.

Business cycle components extracted with UCARIMA model

Source: own computations.

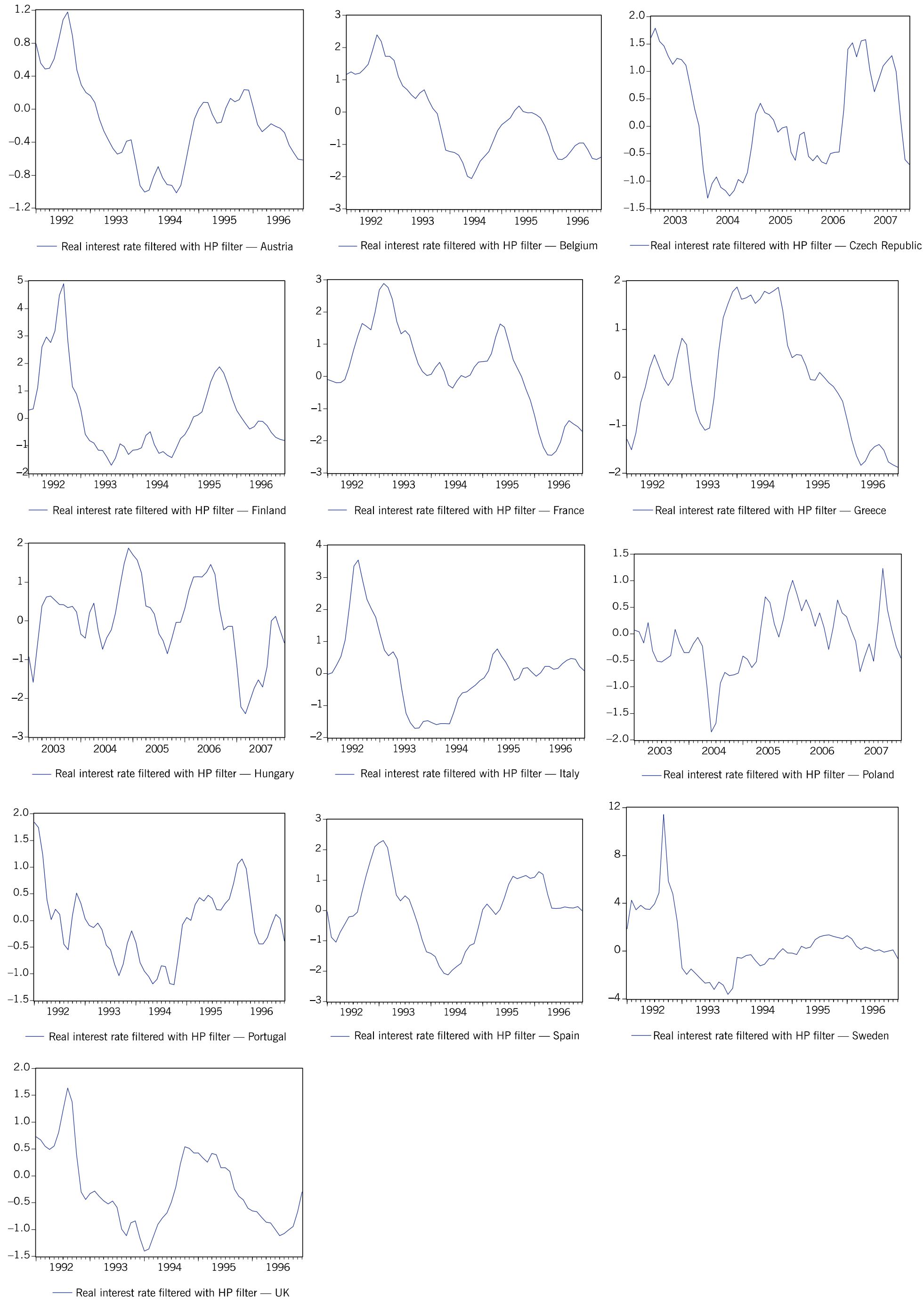

Figure set B.

Real interest rates filtered with Hodrick-Prescott filter

Source: own computations.

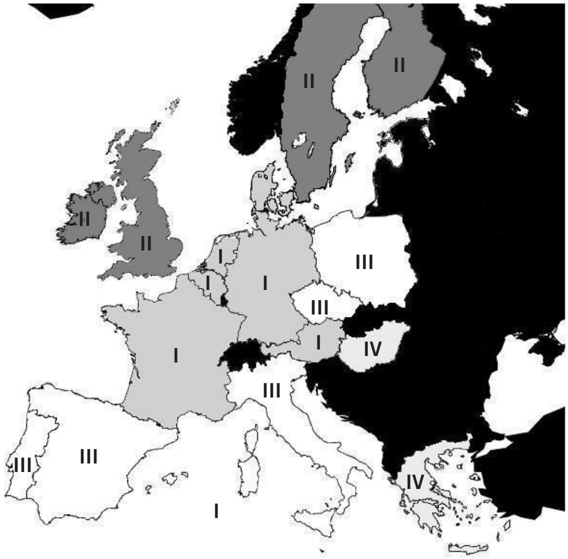

Figure A.

Identified groups of countries on the map of Europe
Source: own analysis.

A b s t r a c t **Four Years After Expansion: Are Czech Republic, Hungary and Poland Closer to Core or Periphery of EMU?**

In this paper we try to check readiness of three Central and Eastern Europe countries, Czech Republic, Hungary and Poland, to introduce European single currency, euro. As a background in the macroeconomic field we use Optimal Currency Area Theory and in the mathematical field three procedures and models: Stock and Watson unobserved component model, spectral and cross-spectral analysis and cluster analysis. Achieved results allow us to state that four years after EU expansion three new countries are rather similar to EMU periphery countries like Italy, Portugal, Spain and Greece than to EMU core economies like Austria, Belgium, Denmark, Germany France and Netherlands.