E C O N O M I C S B U L L E T I N

Optimum filtering for optimum currency areas criteria

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Abstract

This study aims to analyze Turkey and the Economic and Monetary Union (EMU) countries in the light of criteria suggested by the optimum currency areas (OCA) theory and to compare the criteria obtained by an application of Hodrick-Prescott (H-P) and Baxter-King (B-K) filters. To this end, we follow a novel technique, fuzzy c-means (FCM) clustering with upper and lower levels of fuzziness. The results show that the application of the H-P filtering technique with appropriate smoothing parameter values produces sensible clusters.

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1. Introduction

Optimum currency areas (OCA) theory aims to define the optimal geographic domain of a single currency. It has been developed by the seminal contributions of Mundell (1961), McKinnon (1963) and Kenen (1969) in the pioneering phase of the early 1960s and 1970s. From the 1980's until today, OCA theory has been reassessed and the theoretical developments have been tested with empirical studies[1].

Some empirical studies have been carried out by the techniques of pattern recognition and these studies have employed fuzzy clustering techniques[2]. For example, Artis and Zhang (2001) looked for inhomogeneities in the actual and prospective membership of the Economic and Monetary Union (EMU) by applying techniques of fuzzy clustering analysis to a set of variables suggested by the OCA theory. Boreiko (2002) estimated the readiness of the Accession Countries of Central and Eastern Europe for the EMU by fuzzy clustering analysis by using both the Maastricht criteria (nominal convergence) and the OCA criteria (real convergence). Similarly, by applying fuzzy clustering technique, Kozluk (2005) used the OCA criteria to judge the suitability of the accession countries for the EMU, relative to current members, while Kozluk (2005) used the Maastricht criteria to give an idea about readiness, and the effort it will take to fulfill the entry requirements. OCA studies carried out by the techniques of pattern recognition generally assumed that Germany is the center country.

Synchronization in business cycles, volatility in the real exchange rates, synchronization in the real interest rates, the degree of trade integration and convergence of inflation are the criteria widely used in these studies (Artis and Zhang, 2001; Boreiko, 2002 and Kozluk, 2005). We have included the same OCA criteria in our analysis.

The analysis in this study is different than these studies in two respects. Firstly, in the OCA theory literature, industrial production series and the real interest rates have been detrended with an application of the Hodrick-Prescott filter in which the smoothing parameter has been set at 50,000. The application of different filtering techniques produces different results for the same data. Therefore, in the calculation of synchronization in business cycles and synchronization in the real interest rates, we have applied both the Hodrick-Prescott and the Baxter-King filters to industrial production series and the real interest rates. In the application of the Hodrick-Prescott filter, we have followed a different approach than the OCA theory literature and we have set the smoothing parameters value at 50,000 for the industrial production series following Artis and Zhang (2001), Boreiko (2002) and Kozluk (2005), whereas we have used the estimated smoothing parameters for the real interest rates.

Secondly, we have employed fuzzy c-means (FCM) clustering to the criteria suggested by the optimum currency areas (OCA) theory in order to uncover the similarities of economic structures of the European countries and Turkey, which started the European Union (EU) accession negotiations in October 2005. We aim to determine the relative positions of the European countries and Turkey with respect to the OCA criteria. FCM clustering is a novel approach in this area and we believe it is more suitable for such an analysis since we are interested in the position of the patterns which FCM captures. Besides, FCM is an objective function based clustering technique and has the advantage of its tolerance to imprecise data. The number of clusters and the level of fuzziness are the parameters that need to be determined for

[1] For an overall assessment of the OCA theory, see Mongelli (2002).

[2] Pattern recognition is the act of taking raw data (which is based on *a priori* information or statistical information formed from patterns) and taking an action based on the "category" of the pattern (Duda, Hart and Stork, 2000, p.15).

FCM clustering. We have used the levels of fuzziness of 1.4 and 2.6 as lower and upper levels of fuzziness determined by Ozkan and Turksen (2007).

The remaining of the paper is as follows. In section 2, data and methodology are briefly discussed. In section 3, the results are provided. Finally, in section 4 conclusions of the study are presented.

2. Data and Methology

2.1 OCA Variables

The criteria suggested by the OCA theory[3] have been computed as follows for the countries in the sample[4]:

1) Synchronization in business cycles has been represented by the cross-correlation of the cyclical components of industrial production series. The cross-correlations have been measured for all the countries in the sample, with reference to Germany. Since correlation results in values between –1 and +1 inclusive, correlation values have been subtracted from one, so the new values are between zero and two. Zero represents perfect positive correlation (perfect synchronization), and two represents perfect negative correlation.

2) Volatility in the real exchange rates has been represented by the standard deviation of the log-difference of real bilateral DM exchange rates before 1999. After 1999, the Euro has been used instead of DM exchange rates. Real exchange rates have been obtained by deflating nominal rates by relative wholesale/producer price indices[5].

3) Synchronization in the real interest rates has been represented by the cross-correlation of the cyclical components of the real interest rate series of a country with that in Germany. Real interest rates have been obtained by deflating short-term nominal rates by consumer price indices. Cross-correlations have been measured for all the countries in the sample with reference to Germany, and again the values have been set between zero and two.

4) The degree of trade integration has been measured by $(x_i^{EU-25} + m_i^{EU-25})/(x_i + m_i)$, where x_i and m_i are exports and imports (of goods) of country *i*, respectively, and superscript *EU-25* represents European Union countries as of May 2004.

5) Convergence of inflation has been measured by e_i-e_g, where e_i and e_g are the rates of inflation in country *i* and Germany, respectively.

In OCA theory literature, in the calculations of synchronization in business cycles and synchronization in the real interest rates, monthly industrial production series and monthly real interest rates have been detrended with an application of the Hodrick-Prescott (H-P) filter (Hodrick and Prescott, 1997) with the smoothing parameter set at 50,000 (Artis and Zhang, 2001, Artis and Zhang, 2002 and Boreiko, 2003). In some atheoretic studies of business cycles (Murray, 2003; Takaya, 2005), the Baxter-King (B-K) filter has been used to obtain the cyclical components of industrial production series (Baxter and King, 1999). Therefore, both the H-P and the B-K filtering techniques have been employed in this study.

In the analysis with the H-P filter, the smoothing parameter has been set at 50,000 for industrial production series and for the real interest rates the optimum smoothing parameters have been calculated, based on the nature of the time series data (Dermoune, Djehiche and

[3] Frequency, data sources and the time interval of the data used in our analysis are given in Appendix A.

[4] Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, Turkey, and the UK are the countries in the sample, whereas Canada and Japan are the control group countries.

[5] For Portugal, consumer price index has been used because of the lack of data.

Rahmania, 2006, pp. 2-4) following Schlicht (2005). In the analysis with the B-K filter, the Baxter-King (B-K) filter has been employed to both industrial production series and the real interest rates with lower period of 13, and upper period of 86 following the study of Burns and Mitchell (1946)[6].

2.2 Fuzzy C-Means Clustering

Fuzzy c-means (FCM) clustering partitions data into clusters in which each country is assigned a membership value between zero and one to each cluster. The membership values indicate the degree of belongingness of each country to each of the clusters. As the membership value gets higher, the degree of belongingness increases. Bezdek (1973) showed that in the minimization of the objective function;

$$J_m(U,V:X) = \sum_{k=1}^{nd}\sum_{c=1}^{nc} \mu_{c,k}^{m} \left\| x_k - v_c \right\|_A^2 \qquad (1)$$

where, $\mu_{c,k}$: membership value of k[th] vector in c[th] cluster such that $\mu_{c,k} \in [0,1]$, *nd* is the number of vectors, *nc* is the number of clusters, $\left\| . \right\|_A$ is norm[7] and *m* is the level of fuzziness, the membership function is calculated as:

$$\mu_{i,k} = \left[\sum_{c=1}^{nc} \left(\frac{\left\| x_k - v_i \right\|_A}{\left\| x_k - v_c \right\|_A} \right)^{\frac{2}{m-1}} \right]^{-1} \qquad (2)$$

where, $\sum_{c=1}^{nc} \mu_{k,c} = 1$ for some given $m>1$.

In FCM clustering analysis, the number of clusters and the level of fuzziness need to be identified before clustering. In the literature, several cluster validity indices have been introduced to identify the number of clusters (Bezdek, 1974, 1975; Fukuyama and Sugeno, 1989); and fairly limited studies have been made for the level of fuzziness (Ozkan and Turksen, 2004, 2007). We have included Canada and Japan as the control group countries, which are expected to be distinguished from the European countries with respect to the OCA criteria. Therefore, the FCM clustering algorithm must partition data in such a way that when there is optimal number of clusters, European countries should have low membership values to the cluster(s) that Canada and Japan belong. If the data set does not demonstrate a clear-cut clustering structure, the level of fuzziness should not be high, but at the same time the number of clusters should be in accordance with the observation that Canada and Japan are distinguished as a different group. To this end, we have made experiments in order to find the optimal number of clusters and an appropriate value for the level of fuzziness. In these experiments, we have created a search list for the number of clusters between two and seven and the level of fuzziness between 1.4 and 2.6 (as

[6] The calculated values of the OCA variables for the analyses with the H-P filter and the B-K filter are given in Tables B-1 and B-2 in Appendix B. They present the OCA variables to which the FCM clustering technique has been applied.

[7] This is the similarity measure. After standardizing the OCA variables following Artis and Zhang (2001), Boreiko (2002), and Kozluk (2005), we have employed Euclidian distance as a similarity measure. The Euclidian distance between country *i* and country *j* is given as:

$$Dist_{Euclidian}(\boldsymbol{y_i}, \boldsymbol{y_j}) = \sqrt{(y_i - y_j)^T (y_i - y_j)}$$

suggested in Ozkan and Turksen, 2007). We have identified that the optimal number of clusters are four and five and we have made the comparison for the levels of fuzziness of 1.4 and 2.6.

3. Results

Table 4 presents the membership values assigned to Canada and Japan for four and five clusters for the levels of fuzziness of 1.4 and 2.6.

Table 4 Canada's and Japan's Membership Values to their Cluster(s)

		Analysis with the H-P Filter	**Analysis with the B-K Filter**
***m*=1.4**	Canada	**0.99829**[a]	0.51983[b]
***c*=4**	Japan	**0.99827**[a]	0.45431[b]
***m*=1.4**	Canada	**0.99760**[a]	**0.98268**[a]
***c*=5**	Japan	**0.99768**[a]	**0.98346**[a]
***m*=2.6**	Canada	**0.2527438**[a]	0.2592561[b]
***c*=4**	Japan	**0.2573606**[a]	0.2550412[b]
***m*=2.6**	Canada	0.202572[b]	0.2134590[b]
***c*=5**	Japan	0.204990[b]	0.2071428[b]

m: level of fuzziness
c: number of clusters
[a] Canada and Japan are in the same cluster.
[b] Canada and Japan are in different clusters.

When the level of fuzziness is 1.4, Canada and Japan exhibit high membership values to their cluster for four and five clusters in the analysis with the H-P filter. In these cases, European countries have low membership values to the cluster, to which Canada and Japan belong[8]. In the analysis with the B-K filter, Canada and Japan exhibit high membership values to their cluster for five clusters[9]. When the level of fuzziness is 2.6, since the clusters get overlapped, Canada and Japan have low membership values to their clusters[10]. In order to separate the clusters, a threshold called *α-cut* is used. In this study, the value of *α-cut* has been set to 1/*nc*, where *nc* is the number of clusters.

Tables 5 and 6 show the clusters' members for levels of fuzziness of 1.4 and 2.6, respectively.

[8] See Table B-3 in Appendix B.
[9] See Table B-4 in Appendix B.
[10] See Tables B-5 and B-6 in Appendix B. The membership values for five clusters, the classification of five clusters in the analysis with the H-P filter, the membership values for four clusters, the classification of four clusters in the analysis with the B-K filter, and cluster centers for four and five clusters are available from the authors upon request.

Table 5 Classification of Clusters for the Level of Fuzziness of 1.4

***m*=1.4**	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**
Analysis with the H-P Filter, *c*=4 *α-cut*=0.25	France Denmark Netherlands Italy Spain Sweden Belgium Luxembourg Finland Austria Poland Germany Ireland Cyprus Slovenia[1] Norway Portugal[2]	Slovak Republic Czech Republic Croatia Hungary Greece United Kingdom Portugal Slovenia	Canada Japan	Turkey Romania	-
***m*=1.4**	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**
Analysis with the B-K Filter, *c*=5 *α-cut*=0.20	Denmark Italy Spain Sweden Poland Germany Czech Republic	Belgium Slovenia Hungary Austria Slovak Republic Finland Greece United Kingdom Croatia[3]	Netherlands Luxembourg Portugal France Ireland Cyprus Norway Croatia[3]	Japan Canada	Turkey Romania

m=level of fuzziness
c=number of clusters
α-cut=1/*nc*, where *nc* is the number of clusters.
[1, 2] Slovenia is a member of clusters I and II. Portugal is a member of clusters I and II. For the membership values, see Table B-3 in Appendix B.
[3] Croatia is a member of clusters II and III. For the membership values, see Table B-4 in Appendix B.

As Table 5 illustrates in the analysis with the H-P filter, Cluster I is identified as one containing France, Denmark, the Netherlands, Italy, Spain, Sweden, Belgium, Luxembourg, Finland, Austria, Poland, Germany, Ireland, Cyprus, Slovenia, Norway and Portugal. Cluster I contains seventeen countries, twelve of which are EMU members. Cluster II consists of the Slovak Republic, the Czech Republic, Croatia, Hungary, Greece, the United Kingdom, Portugal and Slovenia. Greece, Portugal and Slovenia are the EMU member countries in Cluster II. Canada and Japan form a separate cluster labeled as Cluster III. Similarly, Turkey and Romania are grouped in a separate cluster. In the analysis with the B-K filter, Cluster I comprises Denmark, Italy, Spain, Sweden, Poland, Germany and the Czech Republic. Three of these countries are EMU members. Cluster II contains Belgium, Slovenia, Hungary, Austria, the Slovak Republic, Finland, Greece, the United Kingdom and Croatia. Five of these countries are the members of the EMU. Cluster III is composed of the Netherlands, Luxembourg, Portugal, France, Ireland, Cyprus, Norway and Croatia. Five of these countries are the EMU members. Cluster IV comprises Japan and Canada, whereas Cluster V contains Turkey and Romania.

When the level of fuzziness is 1.4, the control group countries, Canada and Japan remain in a separate group than the European countries for four clusters in the analysis with the H-P filter, whereas they form a separate group for five clusters in the analysis with the B-K filter. However, in the analysis with the H-P filter, Cluster I comprises central European countries and twelve of the thirteen EMU members. Therefore, the analysis with the H-P filter produces better results for the level of fuzziness of 1.4. Clusters' members for the level of fuzziness of 2.6 are given in Table 6.

Table 6 Classification of Clusters for the Level of Fuzziness of 2.6

***m*=2.6**	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**
Analysis with the H-P Filter, ***c*=4** ***α-cut*=0.25**	France Italy Netherlands Denmark Spain Sweden Belgium Finland Luxembourg Austria Germany Ireland Poland Slovenia Cyprus Portugal	France Italy Netherlands Denmark Spain Sweden Belgium Finland Luxembourg Austria Germany Ireland Poland Slovenia Cyprus Portugal	Croatia Slovak Republic United Kingdom Czech Republic Greece Hungary Romania Turkey Japan Canada Norway	Croatia Slovak Republic United Kingdom Czech Republic Greece Hungary Romania Turkey Japan Canada Norway	-
Analysis with the B-K Filter, ***c*=5** ***α-cut*=0.20**	Italy Denmark Spain Sweden Germany Poland Czech Republic Cyprus Canada	United Kingdom Ireland Croatia Belgium Slovenia Greece France Netherlands Slovak Republic Hungary Luxembourg Portugal Finland Norway Romania Austria Japan Turkey	United Kingdom Ireland Croatia Belgium Slovenia Greece France Netherlands Slovak Republic Hungary Luxembourg Portugal Finland Norway Romania Austria Japan Turkey	United Kingdom Ireland Croatia Belgium Slovenia Greece France Netherlands Slovak Republic Hungary Luxembourg Portugal Finland Norway Romania Austria Japan Turkey	United Kingdom Ireland Croatia Belgium Slovenia Greece France Netherlands Slovak Republic Hungary Luxembourg Portugal Finland Norway Romania Austria Japan Turkey

m=level of fuzziness
c=number of clusters
α-cut=1/*nc*, where *nc* is the number of clusters.

It can be observed in Table 6 that, in the analysis with the H-P filter, Cluster I and Cluster II, and Cluster III and Cluster IV contain the same members. Clusters I and II are composed of France, Italy, the Netherlands, Denmark, Spain, Sweden, Belgium, Finland, Luxembourg,

Austria, Germany, Ireland, Poland, Slovenia, Cyprus and Portugal. Clusters I and II contain sixteen countries, twelve of which are EMU members. Clusters III and IV consist of Croatia, the Slovak Republic, the United Kingdom, the Czech Republic, Greece, Hungary, Romania, Turkey, Japan, Canada and Norway. Greece is the only EMU member country in Clusters III and IV.

In the analysis with the B-K filter, Cluster I comprises Italy, Denmark, Spain, Sweden, Germany, Poland, the Czech Republic, Cyprus and Canada. Three of these countries are EMU members. Clusters II, III, IV and V contain the same members and they comprise the United Kingdom, Ireland, Croatia, Belgium, Slovenia, Greece, France, the Netherlands, the Slovak Republic, Hungary, Luxembourg, Portugal, Finland, Norway, Romania, Austria, Japan and Turkey. Ten of these countries are the members of the EMU. It should be emphasized that Clusters II, III, IV and V do not include all the central European countries. For example, Italy, Denmark, Spain, Sweden and Germany are grouped together with Canada in Cluster I. When the level of fuzziness is 2.6, neither Canada and Japan are distinguished from the European countries, nor do Turkey and Romania form a separate group than the European countries. We would like to note that analysis with the H-P filter produces consistent results in the sense that FCM clustering partitions the central European countries for the levels of fuzziness of 1.4 and 2.6.

4. Conclusion

This study involves FCM clustering technique and compares the results of the application of the H-P and the B-K filters to the same data set. To this end, we have applied FCM clustering technique to the OCA criteria in order to uncover homogeneous groups of European countries and to assess the relative position of Turkey as a candidate country. In the OCA theory literature, the Hodrick-Prescott (H-P) filter has been employed with the smoothing parameter set at 50,000 (Artis and Zhang, 2001, Artis and Zhang, 2002 and Boreiko, 2003). In this study, we have followed a different approach in the application of filtering techniques. We have employed the H-P filter with the smooting parameter set at 50,000 for the industrial productions series and we have estimated the optimum smoothing parameters for the real interest rates. We have also applied the B-K filter to both the industrial production series and the real interest rates. The analyses show that the results are highly sensitive to the filtering techniques employed. To our knowledge, this is the first analysis in this area that uses the H-P and the B-K filtering techniques as used in our analysis, and employs FCM clustering.

In FCM clustering, the clusters are identified based on an *a priori* number of clusters, and level of fuzziness. In this study, we have made experiments in order to find the optimal value of the number of clusters. As a result of the experiments made, the optimal number of clusters has been found as four and five depending on the filtering technique employed. For the level of fuzziness, we have made the comparison for the values 1.4 and 2.6. For the level of fuzziness of 1.4, control group countries are grouped in a separate cluster when the number of clusters is four in the analysis with the H-P filter and when the number of clusters is five in the analysis with the B-K filter. When the value of the level of fuzziness is increased to 2.6, control group countries are not distinguished from the central European countries and the central European countries are not grouped in the same cluster in the analysis with the B-K filter.

The analysis with the H-P filter produces better results both for the levels of fuzziness of 1.4 and 2.6. When the level of fuzziness is 1.4 (close to crisp clustering), Cluster I contains seventeen countries, twelve of which are EMU members, whereas Greece, Portugal and Slovenia are the EMU member countries in Cluster II. Canada and Japan, and Turkey and Romania form separate clusters labeled as Cluster III and Cluster IV respectively. When the level of fuzziness is

2.6, Clusters I and II contain twelve EMU members, whereas Clusters III and IV contain one EMU member. In this case, countries are partitioned in such a way that the central European countries remain in the same cluster (except for the United Kingdom and Greece). Control group countries, Canada and Japan; accession countries, Croatia and Turkey; new entrants, the Slovak Republic, the Czech Republic, Hungary and Romania; non-EU member, Norway are grouped together with the United Kingdom and Greece. It should be emphasized that the United Kingdom and Greece are the EU countries. However, the United Kingdom is not a member of the EMU and Greece became an EMU member in 2001. Therefore, it is expected that these countries are clustered in a different group than the central European Union countries and the members of the EMU with respect to the OCA criteria if appropriate data analysis technique is employed. In this sense, analysis with the H-P filter produces very successful results.

FCM clustering analysis provides an important framework for such an analysis. Besides, an application of lower and upper levels of fuzziness of 1.4 and 2.6 sheds light to the appropriate choice of filtering techniques. Therefore, it can be concluded that the OCA theory provides quite sensible results when FCM clustering technique is applied to the OCA criteria obtained by the appropriate H-P filter.

5. Appendices
5. 1 Appendix A
OCA Variables

Table A-1 Frequency, Data Sources and the Time Interval of the OCA Variables

	Frequency	**Data Sources**	**Time Interval**
Industrial production series	monthly	IFS	1996:1-2005:6
Real exchange rates	monthly	IFS, TURKSTAT	1991:1-2006:12
Real interest rates	monthly	IFS, EUROSTAT, Central Bank of Luxembourg	1997:2-2006:10 (H-P filtered series) 1996:2-2006:10 (B-K filtered series)
Trade data	annual	UNCTAD; Handbook of Statistics Online	2004
Inflation data	annual	WDI	2005

The interest rates in Table A-2 have been used for the countries in the sample.

Table A-2 Interest Rates

Austria	: Government Bond Yield	Netherlands	: Government Bond Yield
Belgium	: Government Bond Yield	Norway	: Government Bond Yield
Croatia	: Money Market Rate	Poland	: Money Market Rate
Cyprus	: Deposit Rate	Portugal	: Government Bond Yield
Czech Republic	: Money Market Rate	Romania	: NBR Structural Credit Rate
Denmark	: Call Money Rate	Slovak Republic	: Average Lending Rate
Finland	: Government Bond Yield	Slovenia	: Money Market Rate
France	: Government Bond Yield	Spain	: Call Money Rate
Germany	: Call Money Rate	Sweden	: Call Money Rate
Greece	: Government Bond Yield	**Turkey**	**: Interbank Money Market Rate**
Hungary	: Treasury Bill Rate	United Kingdom	: Government Bond Yield
Ireland	: Government Bond yield	*Canada*	: Bank Rate
Italy	: Money Market Rate	*Japan*	: Govenment Bond Yield
Luxembourg	: Government Bond Yield		

5.2 Appendix B
Calculated Values of the OCA Variables and the Membership Values

Table B-1 OCA Variables[a], Analysis with the H-P Filter

	Synchronization in Business Cycles[b]	**Volatility in the Real Exchange Rates[c]**	**Synchronization in the Real Interest Rates[b]**	**The Degree of Trade Integration[d]**	**Convergence of Inflation[e]**
Austria	0.0965	0.0046	0.3633	76.38	0.3436
Belgium	0.2821	0.0121	0.5183	75.52	0.8296
Croatia	0.9736	0.0253	1.6042	67.49	1.3846
Cyprus	0.8874	0.0047	0.4384	63.82	0.6046
Czech Republic	0.9351	0.0129	1.2068	80.03	-0.1080
Denmark	0.4276	0.0046	0.0497	70.49	-0.1454
Finland	0.2459	0.0044	0.5648	62.00	-1.0923
France	0.4427	0.0028	0.5049	66.83	-0.2098
Greece	0.3882	0.0047	1.1608	57.33	1.6073
Hungary	0.1536	0.0206	1.4870	75.27	1.5975
Ireland	0.6647	0.0046	0.6415	62.75	0.4617
Italy	0.4642	0.0031	0.5366	59.61	0.0313
Luxembourg	0.5957	0.0111	0.2620	81.54	0.5360
Netherlands	0.6107	0.0042	0.4927	66.98	-0.2906
Norway	0.7397	0.0342	0.2538	75.46	-0.4319
Poland	0.3994	0.0261	0.3448	76.36	0.1528
Portugal	1.1110	0.0053	0.5307	78.20	0.3397
Romania	0.9328	0.0338	0.5271	71.61	7.0354
Slovak Republic	0.6833	0.0145	1.3264	83.13	0.7549
Slovenia	0.3025	0.0067	0.8753	74.16	0.5250
Spain	0.5056	0.0033	0.2794	69.25	1.4138
Sweden	0.4373	0.0123	0.3722	67.49	-1.5007
Turkey	**0.5966**	**0.0672**	**0.4547**	**49.81**	**6.2252**
United Kingdom	0.3170	0.0161	1.0504	53.38	0.8768
Canada	0.3371	0.0241	0.4975	8.38	0.2802
Japan	0.3931	0.0252	1.0198	14.43	-2.2271

[a] OCA criteria values for Germany are not given in Table 1 since Germany is the center country. For Germany, the only variable that is different from zero is the degree of trade integration and it is equal to 62.96.
[b] Values are between zero and two, where zero represents perfect synchronization.
[c] Volatility in the real exchange rates has been calculated for the values after January 1999.
[d] The degrees of trade integration are calculated from 2004 data.
[e] Convergence of inflation values are calculated from 2005 data.

Table B-2: OCA Variables, Analysis with the B-K Filter

	Synchronization in Business Cycles	**Volatility in the Real Exchange Rates**	**Synchronization in the Real Interest Rates**	**The Degree of Trade Integration**	**Convergence of Inflation**
Austria	0.1666	0.0046	0.8889	76.38	0.3436
Belgium	0.2679	0.0121	1.1420	75.52	0.8296
Croatia	0.6137	0.0253	1.5185	67.49	1.3846
Cyprus	0.9908	0.0047	0.3985	63.82	0.6046
Czech Republic	0.5229	0.0129	0.5238	80.03	-0.1080
Denmark	0.3813	0.0046	0.0784	70.49	-0.1454
Finland	0.2638	0.0044	1.0970	62.00	-1.0923
France	0.6445	0.0028	1.1125	66.83	-0.2098
Greece	0.3918	0.0047	0.9497	57.33	1.6073
Hungary	0.2356	0.0206	0.9508	75.27	1.5975
Ireland	0.6387	0.0046	1.1186	62.75	0.4617
Italy	0.5228	0.0031	0.1182	59.61	0.0313
Luxembourg	0.7352	0.0111	0.8319	81.54	0.5360
Netherlands	0.6992	0.0042	1.1388	66.98	-0.2906
Norway	0.8497	0.0342	0.7174	75.46	-0.4319
Poland	0.3982	0.0261	0.3252	76.36	0.1528
Portugal	0.9859	0.0053	1.2249	78.20	0.3397
Romania	0.9158	0.0338	1.0528	71.61	7.0354
Slovak Republic	0.2643	0.0145	1.4626	83.13	0.7549
Slovenia	0.3463	0.0067	0.9651	74.16	0.5250
Spain	0.5619	0.0033	0.0207	69.25	1.4138
Sweden	0.5813	0.0123	0.3213	67.49	-1.5007
Turkey	**0.4498**	**0.0672**	**0.6090**	**49.81**	**6.2252**
United Kingdom	0.4456	0.0161	1.1981	53.38	0.8768
Canada	0.3641	0.0241	0.2441	8.38	0.2802
Japan	0.4027	0.0252	1.3631	14.43	-2.2271

Table B-3 Membership Values for the Level of Fuzziness of 1.4, Analysis with the H-P Filter

	Membership Values			
m=1.4, c=4	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**
Austria	0.97371	0.02151	0.00358	0.00120
Belgium	0.98711	0.01200	0.00058	0.00030
Croatia	0.02128	0.96117	0.00755	0.01000
Cyprus	0.81878	0.16529	0.01056	0.00537
Czech Republic	0.02962	0.96703	0.00189	0.00146
Denmark	0.99665	0.00252	0.00063	0.00020
Finland	0.97525	0.01892	0.00544	0.00039
France	0.99932	0.00062	0.00005	0.00001
Germany	0.93278	0.03431	0.02794	0.00496
Greece	0.13442	0.85025	0.01271	0.00261
Hungary	0.08976	0.88505	0.01541	0.00978
Ireland	0.90327	0.09368	0.00243	0.00063
Italy	0.99435	0.00496	0.00061	0.00007
Luxembourg	0.98705	0.01182	0.00057	0.00056
Netherlands	0.99446	0.00519	0.00028	0.00006
Norway	0.73263	0.20300	0.02955	0.03482
Poland	0.94592	0.04605	0.00464	0.00338
Portugal	0.52387	0.44157	0.01645	0.01810
Romania	0.00390	0.00645	0.00098	0.98867
Slovak Republic	0.00235	0.99741	0.00012	0.00012
Slovenia	0.74537	0.25072	0.00296	0.00094
Spain	0.99407	0.00518	0.00046	0.00028
Sweden	0.99280	0.00580	0.00124	0.00016
Turkey	0.00156	0.00205	0.00155	**0.99484**
United Kingdom	0.24368	0.70267	0.04921	0.00444
Canada	0.00098	0.00052	**0.99829**	0.00021
Japan	0.00081	0.00082	**0.99827**	0.00010

m=level of fuzziness
c=number of clusters

Table B-4 Membership Values for the Level of Fuzziness of 1.4, Analysis with the B-K Filter

	Membership Values				
m=1.4, c=5	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**
Austria	0.02391	0.96799	0.00733	0.00057	0.00020
Belgium	0.00015	0.99961	0.00022	0.00001	0.00000
Croatia	0.02751	0.41818	0.52662	0.01138	0.01631
Cyprus	0.16609	0.03299	0.78895	0.00751	0.00447
Czech Republic	0.80852	0.07887	0.11132	0.00082	0.00046
Denmark	0.99929	0.00043	0.00025	0.00003	0.00001
Finland	0.03595	0.92389	0.03484	0.00492	0.00040
France	0.00609	0.03314	0.96025	0.00042	0.00011
Germany	0.81126	0.13643	0.02894	0.01998	0.00339
Greece	0.04226	0.89565	0.05765	0.00353	0.00090
Hungary	0.01464	0.97374	0.00995	0.00080	0.00086
Ireland	0.00666	0.05002	0.94251	0.00062	0.00017
Italy	0.99257	0.00290	0.00401	0.00045	0.00008
Luxembourg	0.00803	0.00912	0.98256	0.00014	0.00015
Netherlands	0.00185	0.00771	0.99024	0.00016	0.00004
Norway	0.12832	0.08842	0.75188	0.01414	0.01724
Poland	0.85161	0.09842	0.04358	0.00378	0.00261
Portugal	0.00635	0.01147	0.98068	0.00077	0.00074
Romania	0.00530	0.00856	0.01437	0.00204	0.96973
Slovak Republic	0.00811	0.96532	0.02462	0.00107	0.00088
Slovenia	0.00160	0.99653	0.00183	0.00003	0.00001
Spain	0.97462	0.00952	0.01449	0.00084	0.00053
Sweden	0.93754	0.01656	0.04377	0.00183	0.00029
Turkey	0.00294	0.00378	0.00284	0.00324	**0.98720**
United Kingdom	0.02344	0.84392	0.11848	0.01226	0.00190
Canada	0.00801	0.00454	0.00333	**0.98268**	0.00145
Japan	0.00340	0.00716	0.00519	**0.98346**	0.00078

m=level of fuzziness
c=number of clusters

Table B-5 Membership Values for the Level of Fuzziness of 2.6, Analysis with the H-P Filter

	Membership Values			
***m*=2.6, c=4**	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**
Austria	0.3093146	0.3092243	0.1907307	0.1907304
Belgium	0.3222555	0.3222134	0.1777657	0.1777654
Croatia	0.2041404	0.2041755	0.2958419	0.2958423
Cyprus	0.2658621	0.2658873	0.2341253	0.2341253
Czech Republic	0.2192924	0.2193268	0.2806903	0.2806906
Denmark	0.3314462	0.3313151	0.1686194	0.1686192
Finland	0.3199946	0.3198505	0.1800776	0.1800773
France	0.3696808	0.3693313	0.1304941	0.1304938
Germany	0.2991185	0.2990424	0.2009197	0.2009195
Greece	0.2219429	0.2219637	0.2780468	0.2780467
Hungary	0.2230462	0.2230689	0.2769425	0.2769425
Ireland	0.2889274	0.2889604	0.2110562	0.2110560
Italy	0.3559563	0.3557076	0.1441683	0.1441680
Luxembourg	0.3098362	0.3098365	0.1901637	0.1901636
Netherlands	0.3424282	0.3423113	0.1576304	0.1576302
Norway	0.2497994	0.2498422	0.2501792	0.2501792
Poland	0.2818509	0.2818932	0.2181281	0.2181279
Portugal	0.2502397	0.2502624	0.2497489	0.2497490
Romania	0.2285092	0.2285401	0.2714753	0.2714754
Slovak Republic	0.2092127	0.2092503	0.2907683	0.2907687
Slovenia	0.2802603	0.2802435	0.2197483	0.2197480
Spain	0.3298139	0.3297430	0.1702217	0.1702215
Sweden	0.3295703	0.3294534	0.1704883	0.1704880
Turkey	0.2310060	0.2310319	**0.2689810**	0.2689811
United Kingdom	0.2101063	0.2101389	0.2898776	0.2898772
Canada	0.2472542	0.2472583	0.2527438	0.2527437
Japan	0.2426374	0.2426416	0.2573606	0.2573605

m=level of fuzziness
c=number of clusters

Table B-6 Membership Values for the Level of Fuzziness of 2.6, Analysis with the B-K Filter

	Membership Values				
***m*=2.6, c=5**	**Cluster I**	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**
Austria	0.1712064	0.2071984	0.2071984	0.2071984	0.2071984
Belgium	0.1115720	0.2221070	0.2221070	0.2221070	0.2221070
Croatia	0.1009029	0.2247743	0.2247743	0.2247743	0.2247743
Cyprus	0.2249871	0.1937532	0.1937532	0.1937532	0.1937532
Czech Republic	0.2310803	0.1922299	0.1922299	0.1922299	0.1922299
Denmark	0.4654552	0.1336362	0.1336362	0.1336362	0.1336362
Finland	0.1519394	0.2120151	0.2120151	0.2120151	0.2120151
France	0.1201536	0.2199616	0.2199616	0.2199616	0.2199616
Germany	0.2824160	0.1793960	0.1793960	0.1793960	0.1793960
Greece	0.1196665	0.2200834	0.2200834	0.2200834	0.2200834
Hungary	0.1238426	0.2190393	0.2190393	0.2190393	0.2190393
Ireland	0.1006839	0.2248290	0.2248290	0.2248290	0.2248290
Italy	0.5178269	0.1205433	0.1205433	0.1205433	0.1205433
Luxembourg	0.1435067	0.2141233	0.2141233	0.2141233	0.2141233
Netherlands	0.1218120	0.2195470	0.2195470	0.2195470	0.2195470
Norway	0.1628116	0.2092971	0.2092971	0.2092971	0.2092971
Poland	0.2347416	0.1913146	0.1913146	0.1913146	0.1913146
Portugal	0.1514449	0.2121388	0.2121388	0.2121388	0.2121388
Romania	0.1677708	0.2080573	0.2080573	0.2080573	0.2080573
Slovak Republic	0.1233658	0.2191586	0.2191586	0.2191586	0.2191586
Slovenia	0.1186022	0.2203495	0.2203495	0.2203495	0.2203495
Spain	0.3994023	0.1501494	0.1501494	0.1501494	0.1501494
Sweden	0.3221262	0.1694685	0.1694685	0.1694685	0.1694685
Turkey	0.1802129	0.2049468	0.2049468	**0.2049468**	0.2049468
United Kingdom	0.0819796	0.2295051	0.2295051	0.2295051	0.2295051
Canada	0.2134590	0.1966353	0.1966353	0.1966353	0.1966353
Japan	0.1714287	0.2071428	0.2071428	0.2071428	0.2071428

m=level of fuzziness

c=number of clusters

References

Artis, M. J. and W. Zhang (2001) "Core and Periphery in EMU: A Cluster Analysis" *Economic Issues* **6(**2), 39-60.

Artis, M. J. and W. Zhang (2002) "Membership of EMU: A Fuzzy Clustering Analysis of Alternative Criteria" *Journal of Economic Integration* **17**(1), 54-79.

Bayoumi, T. and B. Eichengreen (1997) "Optimum Currency Areas and Exchange Rate Volatility: Theory and Evidence Compared" in *International Trade and Finance: New Frontiers for Research: Essays in Honour of Peter Kenen* by B.Cohen, Ed., Cambridge.

Baxter, M. and King, R. G. (1999) "Measuring business cycles: Approximate band-pass filters" *The Review of Economics and Statistics*, **81**(4), 575-93.

Bezdek, J. C. (1973) "Fuzzy Mathematics in Pattern Recognition" Ph.D. Thesis, *Applied Mathematics Center*, Cornell University: Ithaca.

Bezdek, J. C. (1974) "Cluster validity with fuzzy sets" *Journal of Cybernetics* **3(**3), 58-72.

Bezdek, J. C. (1975) "Mathematical models for systematics and taxonomy" *Proceedings on 8th International Conference on Numerical Taxonomy* by G. Estabrook, Ed., Freeman: San Francisco, CA.

Boreiko, D. (2002) "EMU and Accession Countries: Fuzzy Cluster Analysis of Membership" *Oesterreichische Nationalbank Working Paper No. 71*.

Burns, A. F. and Mitchell, W. C. (1946) *Measuring Business Cycles*, New York: NBER.

Dermoune, A., B. Djehiche and N. Rahmania (2006) "Consistent estimators of the smoothing parameter in the Hodrick-Prescott filter". *Preprint*.

Duda, R. O., P. E. Hart and D. G. Stork (2000) *Pattern Classification,* John Wiley & Sons: United States.

Frankel, J. A. and A. K. Rose (1996) "The Endogeneity of the Optimum Currency Area Criteria" *NBER Working Paper No. 5700*.

Fukuyama, Y. and M. Sugeno (1989) "A new method of choosing the number of clusters for the fuzzy c-means method" *Proc. of Fifth Fuzzy Systems Symposium*, 247-50.

Hodrick, R. J. and E. C. Prescott (1997) "Postwar U.S. business cycles: An empirical investigation" *Journal of Money, Credit, and Banking* **29**(1), 1-16.

Kenen, P. B. (1969) "The Theory of Optimal Currency Areas: An Eclectic View" *Monetary Problems of the International Economy* by R. A. Mundell and A. K. Swoboda, Eds., University of Chicago Press: Chicago, 41-60.

Kozluk, T. (2005) "CEEC Accession Countries and the EMU: An Assessment of Relative Suitability and Readiness for Euro-Area Membership" *Journal of Economic Integration* **20**(3), 439-74.

McKinnon, R. I. (1963) "Optimum Currency Areas" *American Economic Review* **53(**4), 717-24.

Mongelli, F. P. (2002) " "New" Views on the Optimum Currency Area Theory: What is EMU Telling Us?" *ECB Working Paper No. 138*.

Mundell, R. A. (1961) "A Theory of Optimal Currency Areas" *American Economic Review* **51(**4), 657-65.

Murray, C. J. (2003) "Cyclical Properties of Baxter-King Filtered Time Series" *The Review of Economics and Statistics*, **85**(2), 472-76.

Ozkan, I. and I. B. Turksen (2004) "Entropy Assessment of Type-2 Fuzziness" *Fuzz-IEEE 2004, Special Session on Type-2 Applications*, **2**, 1111- 1115.

Ozkan, I. and I. B. Turksen (2007) “Upper and Lower Values for the Level of Fuzziness in FCM” *Fuzzy Logic, A Spectrum of Theoretical and Practical Issues Series: Studies in Fuzziness and Soft Computing* by P. P.Wang, D. Ruan, and E. E. Kerre, Eds., Springer, **215**(16), 99-112.

Schlicht, E. (2005) “Estimating the Smoothing Parameter in the So-called Hodrick-Prescott Filter” *Journal of the Japan Statistical Society*, **35**(1), 99-119.

Takaya, S. (2005) “Do EMU Countries Have the Same Business Cycles? —A Lesson for Regional Monetary Integration in East Asia” *EUSA-AP-Japan*.