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EUROPEAN UNIVERSITY INSTITUTE, FLORENCE

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Abstract

The paper looks for inhomogeneities in the actual and prospective membership of the EMU by applying techniques of hard partitioning (cluster analysis) to a set of variables suggested by the theory of Optimal Currency Areas. The analysis reveals that the member countries may be divided into those belonging to the core (Germany, France, Austria, Belgium and the Netherlands) or to one of two peripheries, Northern or Southern (respectively, the Scandinavian countries, the UK and Ireland; and Greece, Spain, Italy and Portugal). These groups appear to be relatively well-defined; if the criteria of OCA theory are taken seriously this correspondingly implies a potential threat to the sustainability of the Union.

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June 1998

Introduction

It has been decided now that the European single currency (the euro) will be launched in January 1999 with 11 countries joining in the first wave of Economic and Monetary Union (EMU): Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. While Denmark, Sweden and the UK decided not to join in the first wave, Greece for the moment fails by a wide margin to satisfy the criteria for participation set out in the European Union's Maastricht Treaty. Whilst the Maastricht criteria pertain solely to convergence in inflation performance and "stability orientation", the criteria offered by the traditional economic theory of optimal currency areas (OCAs) cover additional dimensions.

The principal motivation for this paper is to ask the question, whether, in the light of traditional OCA criteria, the prospective EMU appears to be a homogenous group of countries - or whether, on the contrary, a "core group" can be distinguished from other "periphery" groups. This is an important question since the sustainability of EMU depends on the existence of reasonable degree of homogeneity and is threatened by evidence of the contrary; in addition, the analysis may throw light on the rationality of the decision by three of the countries which could qualify under the Maastricht Treaty to "hang back" from joining the first wave[1]. A further motivation for the paper is to explore how far, among the set of OCA criteria, a concentration on just two - bilateral trade and symmetry in output shocks - is representative of the rest. Finally, the results in the paper depend on the use of cluster analysis; whilst this is a well-known technique in the science of pattern recognition, and commonly applied in other disciplines, its use in applied economic analysis is comparatively rare. A subsidiary motivation of the paper is thus to lay out an example by which the usefulness of the method may be judged.

The remainder of the paper contains four sections. The first section outlines the OCA criteria and the particular interpretation given to them in this paper. In

1. The countries in question are the UK, Sweden, and Denmark. None of the three appears exceptional in relation to the Maastricht Treaty, except - in the case of the UK and Sweden - in relation to the Treaty's requirement that a qualifying country should have participated in the "normal bands" of the Exchange Rate Mechanism (ERM) for at least two years without promoting a devaluation of its currency and without excessive strain. Neither of the two countries was a member of the ERM at the time of the decision on membership. The UK government has queried the applicability of this criterion in light of the change in the ERM brought about in the wake of the 1993 speculative crisis.

section II the methodology of cluster analysis is introduced; in section III we report and discuss the main results. Section IV provides a summary of the principal results and conclusions extending the use of pattern recognition techniques by giving a "faces" representation of our main findings.

I. Optimal Currency Area Criteria

The foundations of the traditional theory of optimal currency areas (OCAs) were laid by Mundell (1961) and McKinnon (1963), with important elaborations by, among others, Kenen (1969) and Krugman (1990). These foundations were laid before the concern for inflation control came to dominate policy discussion; more recent contributions to the theory of optimal currency areas have privileged that concern and are indeed amply reflected in the criteria introduced in the Maastricht Treaty. Tavlas (1993) provides a useful perspective.

Whilst the importance of a common adherence to standards of inflation control and "stability orientation" in economic policies among the members of a currency union cannot be gainsaid, the criteria of traditional OCA theory are not made irrelevant by recognition of this fact. Applying these criteria to the prospective members of the EMU is useful to the extent that they remain valid. Only one serious challenge has been mounted to their validity (as opposed to their incompleteness, if they omit reference to the need for agreement on the counter-inflationary qualities of the common monetary policy). This challenge (see Frankel and Rose, 1996) is embodied in the suggestion that the criteria may be "endogenous" in the important sense that the existence of a currency union formed of countries initially not positively indicated to participate in such a union will in itself foster conditions in which the criteria are subsequently positively satisfied. The title of a paper by Frankel and Rose (1997) - "Is EMU more justifiable ex-post than ex-ante?" - in which they speculatively apply this idea to EMU is eloquent. At the present time, however, empirical support for the "endogeneity" view remains suggestive rather than conclusive. It does not render an analysis such as the current one uninteresting.

It is useful to give a concentrated version of the OCA argument. The benefit of a common currency will be the larger the greater the scope for economizing on exchange costs by adopting it (i.e. the greater the volume of trade), whilst the costs of adopting the common currency are essentially the negative of the benefits of having an independent monetary policy and exchange rate. These are the larger the more idiosyncratic the shocks hitting the economy, and the more effective an independent monetary policy is in counteracting them (especially, the greater the effectiveness of changes in the nominal exchange rate); where

policy is ineffective or unreliable, then the disbenefits can be offset if there exists some form of federal fiscal arrangement binding the countries in the union, or if labour mobility between the countries is high.

In the absence of labour mobility across boundaries, more modern arguments would suggest that a greater degree of internal labour market flexibility will help mitigate the damaging effects of idiosyncratic output shocks.

In this paper we propose statistical correlates to capture the basic arguments of OCA theory. As the cluster analysis technique we use essentially runs off similarities in data, our procedure will be to nominate Germany *a priori* as the centre country and then to measure our chosen variables relative to Germany. The groups we subsequently identify will then be similar in respect of their characteristics vis-à-vis Germany. We now turn to consider each of the variables proposed.

Synchronisation in business cycle phase

In terms of measurement it has become popular to implement the OCA criterion related to symmetry of output shocks by studying the cross-correlation of the cyclical components of output (e.g. Artis and Zhang 1996, 1997); an alternative is to identify shocks by applying an SVAR technique as in Bayoumi and Eichengreen (1993). Proponents of the latter approach argue that this facilitates the separate identification of initial shock and policy (and other) response, which are confounded in the business cycle approach. However, there is a cost to the SVAR approach also, since the identification does not come for free but involves the assumption of a particular model. We prefer the more "atheoretical" business cycle approach and adopt here the method of Baxter and Stockman (1989), identifying symmetry in output shocks with the cross-correlations of the cyclical components of monthly industrial production series, detrended by applying the Hodrick-Prescott filter. The cross-correlations are measured for all the countries in our sample, with reference to Germany. Thus the study assumes that Germany is the putative centre country of the currency union[2].

2 The Hodrick-Prescott filter is applied here with a relatively high value for the dampening parameter (λ) of 50,000. The figure was chosen in light of the fact that our industrial production data are monthly and are relatively noisy; additionally, in earlier work (Artis and Zhang, 1996) we found that setting such a value for the dampening parameter reproduces the series of cyclical components implied by the OECD's PAT (Phase Average Trend) detrending method (see Nilsson (1987) for an explanation of the OECD's methodology).

Volatility in the real exchange rate

As explained above, the traditional OCA approach identifies the cost of currency union membership with the loss of an independent monetary policy, more specifically the loss of a separate exchange rate. Of course, it is the *real* exchange rate that is at issue here, even though monetary policy can only directly influence the nominal rate. Thus it is implied that, with an independent monetary policy and floating exchange rate, the real exchange rate would be able to move "in the right way", responding to the appropriate prompting[3]. A "revealed performance" argument thus suggests that a variable measuring variation in the real exchange rate, in the present case against the DM, the currency of the putative "centre" country, would be appropriate. If there has been little cause for variation in the real exchange rate, then little will be revealed and the cost of moving to a single currency can be assumed to be small. We represent volatility in the real DM exchange rate by the standard deviation of the log-difference of real bilateral DM exchange rates, where deflation is accomplished using relative wholesale (producer) prices.

Synchronisation in the real interest rate cycle

A third variable is also indicated by a "revealed preference" argument. In this exercise Germany is taken as the centre country of the currency union. If in fact the monetary policy of a candidate country historically has differed little from that in Germany the cost of relinquishing independence is accordingly low. Thus we assume that synchronisation in real interest rates may be interpreted as an indicator of coordination in monetary policy with Germany. Specifically, we measure monetary policy synchronization by reference to the cross-correlation of the cyclical components of the real interest rate cycle of a country with that in Germany. The de-trending was accomplished by applying the H-P filter to monthly series of real interest rates, defined as the difference between a short-tem nominal rate (assumed to be "set" by the Central Bank) and the rate of consumer price inflation. Whilst our argument for including this measure among our statistical criteria appeals to the framework provided by traditional OCA criteria, a willingness to commit to partner country policies of high counter-inflationary credibility is an essential component of the 'new' optimal currency area criteria (e.g. Tavlas 1993).

3 It must be admitted that Canzoneri *et al.* (1996) do not find much evidence for this.

Openness to trade

Optimal currency area theory suggests that countries which trade a great deal with each other are good candidates for monetary union (since the benefits of monetary union, in terms of transactions costs saving, will be enhanced). Our measure of this criterion is provided by data on bilateral trade intensity, i.e. for any country i as $(x_{ig}+m_{ig})/(x_i+m_i)$ where x_i and m_i are exports and imports (of goods) and subscript g indicates as destination or source Germany, the centre country in this exercise. Viewing this as a measure of benefit it might seem preferable to scale this variable by output; little changes in the results if this is done, except that the extreme value of bilateral output-weighted trade intensity for Austria condemns this country to become an outlier "special case" cluster of its own.

Convergence of inflation

Whilst the traditional OCA literature offers principally real variables as criteria, we supplement these here with a measure of inflation convergence. In fact, the traditional OCA literature was generated during the era of "fix-price" economics, so introducing inflation convergence as a criterion here could just be regarded as an appropriate normalisation. Convergence in inflation performance, both actual and political, is of course the central theme of the Maastricht Treaty criteria.

Labour market flexibility

It is often argued that a currency area will only work well when labour markets are flexible across countries in the sense that there is substantial geographic mobility within the area. Mundell (1961) seems to have had this definition in mind. The consensus on this issue is that labour is much more mobile within the US than it is between the European countries and that on these grounds the EMU is less likely than the US to be an optimal currency area (see, for example, Taylor (1995)). However, it is also argued by Gros and Thygesen (1998) that the key consideration for the OCA criteria is the difference between *interregional* labour mobility *within* countries and *labour mobility across* countries. The data available now suggest that whilst international labour mobility is quite low in the European countries, it is not much lower than interregional labour mobility within member countries, which is also low. Meanwhile, it is generally agreed that in the face of shocks that cannot be easily buffered - labour market flexibility *tout court* is desirable; relatively fast adjustment of employment and of wages reduces the persistence in unemployment that will otherwise be induced. This type of argument has

dominated much of the discussion of the policy adjustment appropriate for Europe in the 1980s and 1990s. One measure of the rigidity of labour markets that has been used (e.g. OECD, 1994) is a ranking measure of the severity of employment protection legislation (EPL); it is such a variable that is used here as an indicator of labour market flexibility[4].

The data

Table 1 displays the data series corresponding to this discussion; data are shown for eighteen countries: for all the EU countries except Luxembourg (and Germany, which is the reference country of the analysis); for the two West European non-EU countries, Norway and Switzerland; and for the USA, Canada and Japan, which are introduced as controls. The measurement period generally is from April 1979 to September 1995 or later (precise definition and sources are shown in Appendix A). It is easiest to comment on these data in the light of Table 2, and we defer this discussion to section III below. Meantime, we turn to a short exposition of the clustering methods used in this paper.

4. Buti *et al.* (1998) provide a recent discussion of the possible significance of this variable in labour market adjustment.

Table 1. Criteria by optimal currency area theory

	Correlation in business cycle	Volatility[1] in exchange rate	Correlation in interest rate cycle	Trade (% of total trade)	Inflation differential (%)	Labour market flexibility[3]
France	.683	1.118	.334	16.853	2.365	12
Italy	.459	1.732	.207	18.467	5.744	18
Netherlands	.730	.582	.587	26.181	-.204	7
Belgium	.634	.864	.529	21.353	.835	15
Denmark	.343	1.039	-.015	20.303	2.037	3
Austria	.745	.907	.216	38.525	.432	14
Ireland	.193	1.244	.136	9.650	3.634	10
Spain	.444	1.617	-.141	12.623	5.177	17
Portugal	.474	1.629	.031	14.156	10.398	16
Switzerland	.164	1.297	.420	26.256	.148	4
Sweden	.289	1.835	-.031	15.515	3.322	11
Norway	.253	1.277	.088	14.643	2.731	9
Finland	-.075	1.769	.095	13.284	2.279	8
Greece	.235	1.710	n.a.[2]	19.132	13.848	n.a.[2]
UK	.217	2.174	.017	13.137	3.305	5
US	.106	2.838	.066	4.984	1.871	1
Canada	.123	2.787	.161	1.848	1.910	2
Japan	.744	2.399	.157	4.177	-.856	6

Notes:

1. Standard deviation of the log difference in bilateral real exchange rate against deutsche mark.
2. "n.a" denotes that no adequate series are available.
3. Country rankings of employment protection legislation (1980s) are from the OECD. The rank for Germany is 13.

II. Cluster analysis

Cluster analysis is proposed in this paper to examine the similarities and dissimilarities of economic structure which appear in the variables proposed to proxy OCA criteria (Table 1), and to uncover homogeneous subgroups. With the EMU agenda in mind, we have measured variables suggested by OCA theory, relative to Germany, which is taken as the centre country. The objective is to discover whether the data yield sub-groups among the set of countries considered such that we might be able to label one of these groups a "core" group and the others as "peripheral" groups.In the terminology of cluster analysis there are N objects (countries) and p variables (features) in a data set (with N=18 and p=6 in this study[5]), which are denoted as $X_1,...,X_N$, $(X_j=(x_{j1},...,x_{jp})$ for j=1,2,...,N). We take the dissimilarity coefficient or distance, d(j,k), between two objects, X_j and X_k, to be defined by the Euclidean distance[6]

$$d(j,\ k)\ =\ \sqrt{\sum_{l=1}^{p}(x_{jl}-x_{kl})^2} \qquad (1)$$

The definition of the dissimilarity coefficient between two clusters is important in determining the shape of the homogenous groups. There exist a few agglomerative algorithms which differ only in the definition of dissimilarity between clusters. We discuss this only briefly here (see, for example, Kaufman and Rousseeuw (1990), Anderberg (1993), for more details). In order to examine the robustness of the results, two of the most often used approaches are adopted in this analysis: the group-average clustering and centroid clustering methods. Both of these produce ball-shaped clusters.

The dissimilarity coefficient, $d(\omega_j,\omega_k)$, of two clusters, ω_i and ω_j, defined by the group-average clustering method may be expressed as:

5. Missing values are interpolated by other variables.

6. With only 18 observations in our sample, it is difficult to choose a proper mathematical form to express the distribution of this data set.

$$d(\omega_j, \omega_k) = \frac{1}{|\omega_j|\ |\omega_k|} \sum_{j\in\omega_j,\ k\in\omega_k} d(j, k) \qquad (2)$$

where $|\omega_j|$ denotes the number of objects in the cluster. For the centroid clustering method, a cluster, ω_j, once formed is represented by its centroid $\bar{x}(\omega_j)$, which, together with its coordinates $\bar{x}_k(\omega_j)$ (for k=1,2,...p), may be expressed as:

$$\bar{x}(\omega_j) = (\bar{x_1}(\omega_j), \bar{x_2}(\omega_j),..., \bar{x_p}(\omega_j)), \qquad \bar{x_f}(\omega_j) = \frac{1}{|\omega_j|} \sum_{k\in\omega_j} x_{kf} \quad \text{for } f=1,2,...p \qquad (3)$$

The dissimilarity coefficient, $d(\omega_j,\omega_k)$, between two clusters, ω_j and ω_k, is then defined as the Euclidean distance between two centroids.

Both methods start from a classification denoted $\Omega_0=[\omega_1^0,...,\omega_N^0]$ with N clusters in it, and each cluster containing only one object. The algorithms proceed by successively merging two clusters into one at each stage until a single cluster is obtained. The merging criterion at each stage is to choose two clusters which have the least dissimilarity between them. A new classification at stage i, $\Omega_i=[\omega_1^i,...,\omega_{N-i}^i]$, is identified after two clusters have been merged and the dissimilarities between clusters may be updated. For example, ω_j^{i-1} and ω_k^{i-1} at stage i-1 may be merged to form a new cluster ω_l^i at stage i, the dissimilarity $d(\omega_l^i,\omega_m^{i-1})$ of ω_l^i to any other cluster ω_m^{i-1} may be updated in centroid clustering by using the following formula

$$d^2(\omega_l^i,\omega_m^{i-1}) = \frac{|\omega_j^{i-1}|}{|\omega_l^i|} d^2(\omega_j^{i-1},\omega_m^{i-1}) + \frac{|\omega_k^{i-1}|}{|\omega_l^i|} d^2(\omega_k^{i-1},\omega_m^{i-1}) - \frac{|\omega_j^{i-1}||\omega_k^{i-1}|}{|\omega_l^i|^2} d^2(\omega_j^{i-1},\omega_k^{i-1}) \qquad (4)$$

The centroid of ω_l^i may always be written as a function of those of ω_j^{i-1} and ω_k^{i-1}, as

$$\bar{x}(\omega_l^i) = \frac{|\omega_j^{i-1}|}{|\omega_l^i|}\bar{x}(\omega_j^{i-1}) + \frac{|\omega_k^{i-1}|}{|\omega_l^i|}\bar{x}(\omega_k^{i-1}) \qquad (5)$$

In a similar way, the dissimilarity of a new cluster to any other cluster may also be updated using the group-average clustering method.

III. The results: identifying homogeneous groups

We begin by commenting on some features of the data as summarized in Table 2, where three clusters are distinguished for each variable, rated "high" "medium" and "low". Some features that stand out are the high business cycle correlation with Germany, that is enjoyed by Japan; and, whereas many European countries also share this feature, there are a number which do not, including the UK, Ireland and the Scandinavian group, with Finland's position being notably low (-0.075 according to Table 1). ERM countries occupy the low exchange rate volatility position, though Austria, Switzerland and Norway have also maintained a non-volatile exchange rate vis-à-vis the DM; Italy, Spain and Portugal, also ERM participants, occupy the middle position whilst the USA, Canada, Japan and the UK have maintained the most volatile exchange rate relationships. The highest correlations with German monetary policy are maintained by the Netherlands, France, Belgium and Switzerland. Austria is placed in the middle group. When it comes to trade, Austria is in a class of its own, whilst all the other European countries are grouped together in a large middle group; the USA, Canada and Japan are in a different, lower, category. Inflation differentials of most countries are mostly low, only Portugal and Greece being in a "high" group, Italy and Spain in a "middle" group with the remaining countries in the "low" group. The final variable is that of the employment protection legislation (EPL) ranking. This shows the US, Canada and the UK among the least heavily protected and the Mediterranean countries (Italy, Spain, Portugal) among the most heavily protected.

The basis for cluster analysis is recognition of similarity. Using the variables suggested by optimal currency area theory in this context sorts countries into groups with similar characteristics in the space of these criteria. In most cases it is easy to interpret how belonging to a particular group is "favourable" from the point of view of functioning in a currency union with Germany; for example, a high business cycle correlation is favourable; a high proportion of

trade is favourable, and so on. There is one characteristic where there is some ambiguity - namely the measure of employment protection legislation. Here OCA theory suggests that a low EPL ranking is good; yet Germany's own ranking is relatively high. Is it "good" to be "like Germany" in this "bad" respect? Is it better to be unlike Germany? OCA theory suggests a positive answer to the last question. Our techniques, though, will tend to put into the core group countries that are similar to Germany in this "bad" respect as in others. This needs to be borne in mind in the interpretation to be placed on the results.

Table 2. Classification of three clusters by single variable (group average clustering)

Characteristic	Three clusters
High correlation in business cycle	{France, Italy, Netherlands, Belgium, Austria, Spain, Portugal, Japan}
Medium correlation in business cycle	{Denmark, Ireland, Switzerland, Sweden, Norway, Greece, UK, US, Canada}
Low correlation in business cycle	{Finland}
High volatility in exchange rate	{UK, US, Canada, Japan}
Medium volatility in exchange rate	{Italy, Spain, Portugal, Sweden, Finland, Greece}
Low volatility in exchange rate	{France, Netherlands, Belgium, Denmark, Austria, Ireland, Switzerland, Norway}
High correlation in interest rate	{France, Netherlands, Belgium, Switzerland}
Medium correlation in interest rate	{Italy, Denmark, Austria, Ireland, Portugal, Sweden, Norway, Finland, UK, US, Canada, Japan}
Low correlation in interest rate	{Spain}
High proportion in trade	{Austria}
Medium proportion in trade	{France, Italy, Netherlands, Belgium, Denmark, Ireland, Spain, Portugal, Switzerland, Sweden, Norway, Finland, Greece, UK}
Low proportion in trade	{US, Canada, Japan}
High inflation differential	{Portugal, Greece}
Medium inflation differential	{Italy, Spain}
Low inflation differential	{France, Netherlands, Belgium, Denmark, Austria, Ireland, Switzerland, Sweden, Norway, Finland, UK, US, Canada, Japan}
High employment protection	{Italy, Belgium, Austria, Spain, Portugal}
Medium employment protection	{France, Netherlands, Ireland, Sweden, Norway, Finland, Japan}
Low employment protection	{Denmark, Switzerland, UK, US, Canada}

The groups

The groups identified by applying cluster analysis to the whole data set described in Table 1[7] are shown in Table 3 and, graphically, in the two dendograms, Figures 1 and 2.

Table 3. Merging process by group average /centroid clustering

	Group average clustering			Centroid clustering		
Clusters	Clusters joined	Pseudo F[1]	RMS distance[2]	Clusters joined	Pseudo F[1]	RMS distance[2]
17	{US, Canada}	31.1	.18	{US, Canada}	31.1	.18
16	{Ireland, Norway}	28.7	.21	{Ireland, Norway}	28.7	.21
15	{Sweden, UK}	17.0	.36	{UK, Sweden}	17.0	.36
14	{France, Belgium}	13.8	.40	{Cluster-15, Cluster-16}	9.7	.40
13	{Finland, Cluster-16}	11.9	.44	{Finland, Cluster-14}	9.0	.38
12	{Cluster-13, Cluster-15}	9.6	.45	{France, Belgium}	9.6	.40
11	{Portugal, Greece}	9.8	.47	{Portugal, Greece}	9.8	.47
10	{Italy, Spain}	9.5	.56	{Denmark, Cluster-13}	8.7	.52
9	{Netherlands, Cluster-14}	9.4	.56	{Netherlands, Cluster-12}	8.7	.53
8	{Denmark, Cluster-12}	9.3	.58	{Italy, Cluster-11}	8.9	.55
7	{Cluster-10, Cluster-11}	9.2	.65	{Spain, Cluster-8}	9.2	.57
6	{Austria, Cluster-9}	9.0	.77	{Austria, Cluster-9}	9.0	.71
5	{Switzerland, Cluster-8}	8.9	.81	{Cluster-7, Cluster-10}	5.9	.72
4	{Japan, Cluster-17}	10.0	.82	{Switzerland, Cluster-6}	6.7	.76
3	{Cluster-4, Cluster-5}	9.3	.91	{Japan, Cluster-17}	8.7	.81
2	{Cluster-3, Cluster-7}	7.6	1.04	{Cluster-3, Cluster-5}	8.6	.83
1	{Cluster-2, Cluster-6}	.	1.19	{Cluster-2, Cluster-4}	.	.91

Notes:

1. The pseudo F statistic measures the separation among all the clusters at the current level and may be used as an indicator of the number of clusters (see SAS/STAT User's Guide for more technical details).
2. "RMS distance" stands for the normalized root-mean-square distance.

7 In applying the cluster analysis, the data were normalized to mean zero, unit variance: in this sense the criteria are equally weighted. All the variables in Table 1 are continuous except the labour market indicator which is an ordinal variable. In this study, the ranks of the labour market indicator are treated as interval-scaled and normalized to mean zero and unit variance in order to obtain equal weighting of the variables. In Appendix B, we report some results achieved by using an explicit weighting.

Figure 1. Merging process by group average clustering

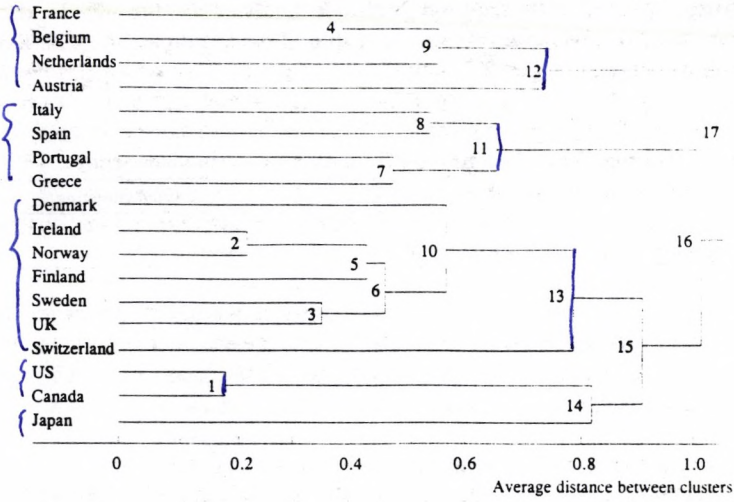
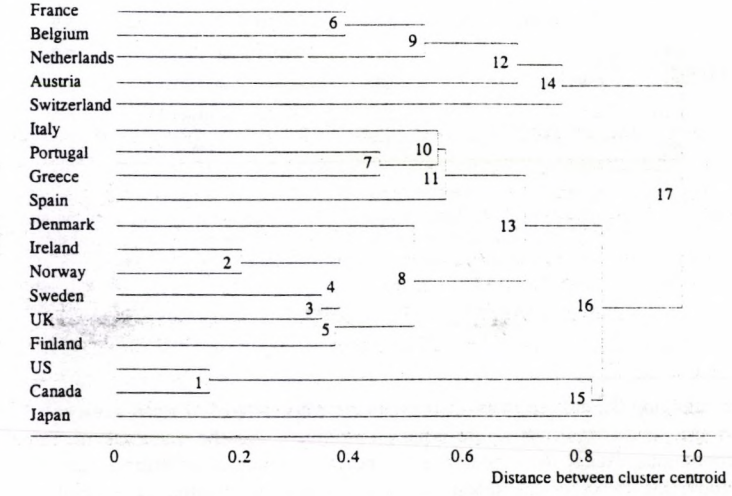


Figure 2. Merging process by centroid clustering



Two alternative clustering methods are applied to ensure that the results are not over-sensitive to the agglomerative criterion employed, which it immediately appears from Table 3 that they are not. Thus, for convenience, we may concentrate on the results achieved using group average clustering method in the following discussion. As a general remark, we may note that the agglomerative coefficient (AC) yielded by the application of this method here is satisfactorily high, at a value of 0.61, suggesting that a "reasonable" amount of structure has been identified in the data[8]. The pseudo-F statistic for this method peaks at 10 indicating that there might be 4 clusters in the data, though we are not concerned here to search for an optimal number of clusters so much as to describe the data in a *hierarchical* way.

A clear pattern which may be observed is that various distinct groups are formed at various stages and one of most interesting features of Figure 1 is that a classification containing 5 groups is identified at stage 12 which may described as consisting of:

1) the core group {France, Netherlands, Belgium, Austria};
2) the Northern periphery group {Denmark, Ireland, the UK, Switzerland, Sweden, Norway, Finland};
3) the Southern periphery group {Italy, Spain, Portugal, Greece};
4) the North American group {the US, Canada};
5) the Japanese group {Japan}.

The core group

The core group is identified as one containing France, the Netherlands, Belgium and Austria. The merging process for this group has France merging with Belgium with the dissimilarity coefficient at 0.40 at stage 4 and then being joined by the Netherlands and Austria with coefficients at 0.56 and 0.77 at stage 9 and 12 respectively. The merging process for the core group suggests that the economies of France and Belgium are the most alike within the core group. It is of interest to note that no other single country is allowed to be merged into this group until the final stage when all countries are grouped, indicating that the countries in the core group have some distinct common features not fully shared by other countries. These features are readily apparent in Table 2 and include 1) a high business cycle correlation with Germany; 2) a low volatility of the real

8. A value of the AC close to 1 indicates that a clear structure has been identified and a value close to 0 indicates that there is no structure in the data set: (see Kaufman and Rousseeuw (1990) for a discussion).

exchange rate against the DM; 3) synchronization in monetary policy with Germany; 4) high percentage of trade with Germany; 5) convergence of inflation towards the German level and 6) similar rankings of employment protection legislation as Germany. On this evidence, the economies in the core group are much more symmetrical than the EMU group as a whole, suggesting that countries in the core group are the best candidates to form a monetary union. It is in this sense then that we can refer to this subgroup as a core group: France, Belgium, the Netherlands and Austria, together with Germany.

The Northern periphery group

The Northern periphery group, {Denmark, Ireland, the UK, Switzerland, Sweden, Norway, Finland}, has 7 countries which are merged at stage 13. The merging process for this group is also striking in that a group of five countries, {Ireland, the UK, Sweden, Norway, Finland}, is formed at a very early stage of the merging process (stage 6) with Denmark joining in at stage 10 and Switzerland much later at stage 13. The group thus contains the Scandinavian countries, UK-Ireland and then Switzerland.

The merging process of this group suggests that economies measured by the OCA criteria are much more similar within the group than between groups. We can refer to this subgroup as a peripheral group in the sense that it distances itself from the core. The distance between the two groups predominantly reflects the phenomena in the periphery group that 1) the business cycle is less synchronised with the German cycle; 2) the exchange rate against the DM is more volatile and 3) there is less protection in the labour market.

It may be of interest to note that Switzerland is quite a different case among the European countries in the sense that it is merged into the periphery group when the group average clustering method is used, and merged into the core group when the centroid clustering method is used, but in both cases only at a very late stage. This reflects the phenomena that its business cycle is not in phase with the German cycle and its labour market is different from the German one, whilst at the same time Switzerland has a large trade with Germany and a sympathetic monetary policy.

The Southern periphery group

The merging process for the Southern periphery or Mediterranean group is as follows: Portugal and Greece are grouped at stage 7; Italy and Spain are merged at stage 8; the two groups are fused into one at stage 11. This group becomes quite independent in the sense that it merges neither with the core nor with the

Northern periphery group until a very late stage, suggesting that the intra-group structure in Mediterranean countries is much more similar than the inter-group structure.

The predominant features in the group may be described as 1) a medium volatility in the exchange rate against the DM; 2) low synchronisation in the interest rate cycle; 3) dispersion in the rate of inflation against the German one and 4) high employment protection legislation in their labour markets.

The North American group

The US and Canada are merged into one group at stage one with the lowest dissimilarity coefficient (0.18) among all countries, indicating that the two countries have the most similar economic structure (recall that, by construction, the relevant similarity here is distance from Germany). The group has distinct features in the sense that no single country is allowed to be merged into this group until stage 14 when Japan joins in. As mentioned earlier the purpose of including these three countries was to introduce a control on the power of the methods adopted in the study. Given our *a priori* economic knowledge, these countries should be sharply distinguished from the European countries and the method would have failed had this feature not appeared in our results.

Are certain criteria dominant ?

A subsidiary motivation for this paper was to examine whether certain of the OCA criteria could be described as dominant, meaning by this whether the results arrived at in Table 3 and Figures 1 and 2 could not have been reached by processing, say, only two OCA criteria. In particular, it seems an interesting speculation to test whether a concentration on trade and output shocks alone would not produce a similar identification of core and periphery.

Table 4 provides material for an answer to this question. It identifies five clusters from a data set initially consisting in only two variables - the trade and business cycle correlation variables; then performs the identification afresh with reference to a data set augmented by a third variable (exchange rate volatility), then again with a data set augmented by a fourth variable, and so on. Every combination identifies Japan and the North American group as separate groups. Every combination identifies in the core group the four countries:

Table 4. Merging process by different sets of variables (Group average clustering)

Variables:	Five clusters
1. Correlation in business cycle	{France, Netherlands, Belgium}
2. Trade	{Italy, Denmark, Ireland, Spain, Portugal, Switzerland, Sweden, Norway, Greece, UK}
	{Finland, US, Canada}
	{Austria}
	{Japan}
1. Correlation in business cycle	{France, Netherlands, Belgium}
2. Trade	{Italy, Denmark, Ireland, Spain, Portugal, Switzerland, Sweden, Norway, Finland, Greece, UK}
3. Volatility in exchange rate	{US, Canada}
	{Austria}
	{Japan}
1. Correlation in business cycle	{France, Netherlands, Belgium, Switzerland}
2. Trade	{Italy, Denmark, Ireland, Spain, Portugal, Sweden, Norway, Finland, Greece, UK}
3. Volatility in exchange rate	{US, Canada}
4. Correlation in interest rate cycle	{Austria}
	{Japan}
1. Correlation in business cycle	{France, Netherlands, Belgium, Austria, Switzerland}
2. Trade	{Italy, Denmark, Ireland, Spain, Portugal, Sweden, Norway, Finland, UK}
3. Volatility in exchange rate	{US, Canada}
4. Correlation in interest rate cycle	{Greece}
5. Inflation differentials	{Japan}
1. Correlation in business cycle	{France, Netherlands, Belgium, Austria}
2. Trade	{Denmark, Ireland, Switzerland, Sweden, Norway, Finland, UK}
3. Volatility in exchange rate	{Italy, Spain, Portugal, Greece}
4. Correlation in interest rate cycle	{US, Canada}
5. Inflation differentials	{Japan}
6. Labour market indicator	

Germany, France, Belgium and the Netherlands; and every combination identifies a European "periphery" group. But it is only when the EPL variable is added that the separate identity of a Southern or Mediterranean group within the periphery is clearly established. For three out of the five criteria sets Austria is identified as a separate group (a super-core).

Thus it seems that whilst some of the major features identified on the full data set are already present when only the trade and output shocks criteria are deployed, additional variables do add value and help to identify the features noted in Table 3. A related issue to the one explored here is that of weighting. Are some variables more important that others? Those processed here are not expressed in a common scale, and although they are normalized and equally weighted in that sense it is not obvious how important each criteria is relative to another. For this reason we have taken an agnostic approach in arriving at our main results. In Appendix B we explore a weighting scheme which, however, does not yield any major conclusions that conflict with those reported here.

IV. Conclusions

To summarize, our application of cluster analysis to a data set constructed to reflect OCA criteria indicates that the potential European Monetary Union countries consist in a core group revolving around Germany, which comprises France, Belgium, Austria and the Netherlands, with two peripheral groups - a "Northern group" containing the Scandinavian countries together with the UK and Ireland, and a "Southern group" containing Italy, Spain, Portugal and Greece. The USA and Canada are separately identified as a "North American" group, whilst Japan also stands out as having individual features. This summary can be expressed graphically using the technique of the "faces" representation of multivariate data.

A Faces representation of OCA criteria

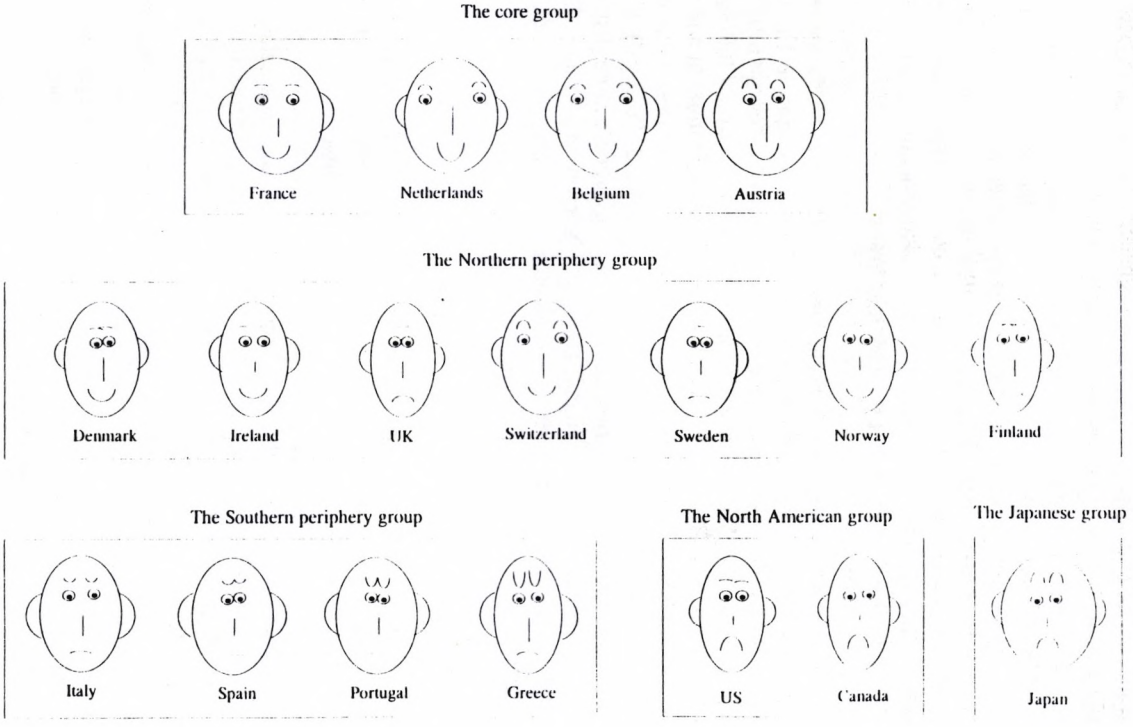
"Faces" representation of multivariate data has been proposed by Chernoff (1973) and by Flury and Riedwyl (1981). This technique may be helpful in viewing interesting patterns or structure in a sample. Six features suggested in the paper are represented by a set of cartoon faces shown in Figure 3. In the Figure, each observation depicts one feature of the face: 1) correlation in business cycle by the fatness of the face; 2) volatility in the exchange rate by the curve of the mouth; 3) correlation in interest rate by the distance between the eyes; 4) percentage of total trade by the length of the nose; 5) inflation differentials by the shape of the eyebrow and 6) labour market flexibility by the

size of the ears. The appearance of the faces indeed suggests that there is a clear similarity between the faces in the groups and that the intra-group structure is much more similar than the inter-group structure.

Comparisons

How do our identifications compare with those made by others using different methods (and criteria)? Our definition of a core with one or more one periphery groups is very close to some of the other identifications of groups to be found in the literature. For example, a core group ready for EMU and a group not ready for EMU as viewed by Taylor (1995) consists of, respectively, a group formed by Germany, the Netherlands, Luxembourg, Belgium, Denmark (if willing), Austria plus (tentatively) France; and a group of four: Portugal, Greece, Spain plus (tentatively) Italy. He also views Finland, Sweden, Ireland and the UK as countries which are left in between. Canzoneri *et al.* (1996) examine a smaller set of countries (Austria, the Netherlands, France, Spain, the UK and Italy) using a VAR approach

Figure 3. Faces representation of the TOCA criteria



to answer the question whether or not nominal exchange rate changes appear to act as a shock absorber for market disturbances. Their largely negative answer leads them to identify an inner core of Austria, the Netherlands and France as fit for monetary union, but with little to distinguish that group from Spain and the UK, where also nominal exchange rate changes appear to be responding to promptings arising in the financial markets rather than in the goods markets. Italy is the most exceptional country in their analysis. Bayoumi and Eichengreen (1993) define a core and periphery based on identifying cross-correlations of supply and demand disturbances. That core contains, along with Germany, Belgium, the Netherlands, Denmark and France.

In later work (Bayoumi & Eichengreen 1997a, 1997b), the same two authors extend their criteria set and identify three groups among the eligible countries (with Norway and Switzerland also included). In (1997a) a "fully convergent" group, centred on Germany, comprises also Austria, Belgium and the Netherlands but excludes France whilst also admitting Ireland and Switzerland. A second group of "converging" countries is identified as comprising the Mediterranean countries (Italy, Greece, Spain and Portugal) together with Sweden, whilst there is a third group of "unconverged", more distant, countries which includes the UK, Finland, Denmark, Norway and France. The results in (1997b) are similar. Clearly these identifications are similar to, though not identical with, our own.

Implications

What are the implications of results like these? In the introduction to this paper we suggested that the analysis might help rationalize the position of various countries vis-à-vis EMU. The caution of the UK, Sweden and Denmark could indeed be regarded as underlined by our results, as also the reserved position (even on membership of the EU) taken by Norway and Switzerland. Enthusiasm in Finland and Ireland and in all the Mediterranean countries, on the other hand, does not appear to be explained by our findings, which place all these countries in a peripheral position. Of course, there are some economic advantages, not to mention perceived political benefits which may accrue to these countries that are not recognised in our criteria set. We also mentioned that a finding of inhomogeneity in the ranks of the putative EMU must suggest that a "one-size-fits-all" monetary policy will be inappropriate to certain member countries and could threaten the union's sustainability. A key issue here, which this analysis cannot comment upon, is how far this problem will prove transitory (as the "endogeneity" literature suggests) or, on the other hand, persistent.

Appendix A: Data[1] definitions and Source[2]

Table A Data definitions and periods

Country	IIP[3]	Exchange rate[4]	Interest rate	Period	PPI/WPI[5]	CPI[5]	Trade[6]
Germany	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	WPI: 79:4-95:8	79:1-96:10	--
France	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	PPI: 80:1-95:8	79:1-96:10	79-95
Italy	1979:4-95:10	79:4-95:9	Interbank deposit rate (3-month)	79:4-95:8	PPI: 81:1-95:6	79:1-96:10	79-95
Netherlands	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	PPI: 79:4-95:7	79:1-96:10	79-95
Belgium	1979:4-95:4	79:4-95:9	3-month treasury certificates	79:4-95:8	PPI: 80:1-95:7	79:1-96:10	79-94
Denmark	1979:4-95:10	79:4-95:9	3-month interbank rate	79:4-95:8	PPI: 74:1-95:6	79:1-95:10	79-95
Austria	1979:4-95:10	79:4-95:9	3-month LIBOR	79:4-95:8	WPI: 79:4-95:10	79:1-95:10	79-95
Ireland	1979:4-95:9	79:4-95:9	Call money rate	79:4-95:8	WPI: 79:4-94:11	79:1-95:10	79-94
Spain	1979:4-95:9	79:4-95:9	Call money rate	79:4-95:8	PPI: 79:4-95:6	79:1-95:10	79-95
Portugal	1979:4-95:9	79:4-95:9	Treasury bill rate (91-day)	85:8-95:8	CPI: 79:4-95:8	79:1-95:10	79-95
Switzerland	1979:4-95:10	79:4-95:9	3-month Euro-deposit	79:4-95:8	WPI: 79:4-95:8	79:1-95:10	80-95
Sweden	1979:4-95:10	79:4-95:9	3-month treasury discount notes	79:4-95:8	PPI: 82:1-95:8	79:1-95:10	80-95
Norway	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	WPI: 79:4-95:8	79:1-95:10	79-95
Finland	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	PPI: 79:4-95:8	79:1-95:10	79-95
Greece	1979:4-95:8	79:4-95:9	n.a.[7]	n.a.[7]	CPI: 79:4-95:8	79:1-95:10	79-94
UK	1979:4-95:10	79:4-95:9	Call money rate	79:4-95:8	PPI: 79:4-95:8	79:1-95:10	79-95
US	1979:4-95:10	79:4-95:9	Federal fund rate	79:4-95:8	PPI: 79:4-95:8	79:1-96:10	79-95
Canada	1979:4-95:10	79:4-95:9	90-day deposit receipts	79:4-95:8	PPI: 79:4-95:8	79:1-95:10	79-95
Japan	1979:4-95:10	79:4-95:9	Certificates of deposit	79:5-95:8	WPI: 79:4-95:8	79:1-95:10	79-95

Notes:

1. All series are monthly except stated otherwise.
2. All series are from the OECD database except for trade data which are abstracted from the IMF-DOTS database.
3. IIP for industrial production index, seasonally adjusted.
4. Original exchange rate series are rates against the US dollar, exchange rates against the deutsche mark are derived assuming triangular arbitrage.
5. PPI for producer price index; WPI for wholesale price index; CPI for consumer prices index
6. Trade data are annual.
7. Adequate series are not available.

Appendix B: Weighting the criteria

The data employed in the main analysis of this paper are weighted equally. However, it might be argued that whilst one of the variables employed (bilateral trade intensity) represents a measure of benefit, four of the others (business cycle correlation; real interest rate correlation, real exchange rate volatility and EPC ranking) are in effect different measures of cost, whilst the inflation differential variable is a kind of normalizing variable. Hence it might seem (that "costs" are being given a bigger weight than "benefits". We have to reiterate that this is not clear, because the variables are not initially measured in a common metric (say as GDP gain or loss); but it is instructive to consider what happens when an explicit weighting is introduced. Accordingly, in Table B we present the results of weighting the "benefit" (trade) variable equally with the sum of the four "cost" variables and the normalizing variable (inflation differential).

The table compares the results obtained for 3, 4, 5 and 6 clusters with criterion-variables weighted and unweighted. One difference that can be seen is that weighting trade highly promotes Austria to a "super-core" group: however many clusters are distinguished. Then, also, the additional weight given to inflation tends to isolate Portugal and Greece. Switzerland and Denmark join the core group when trade is given more weight. But the core remains otherwise the same as when the variables are unweighted, and the Northern peripheral countries remain the same except that Denmark leaves whilst Italy and Spain join that group. The core-periphery structure, in other words, remains substantially the same as it appears in the main analysis.

Table B. Merging process for equal and for weighted criteria (centroid clustering method)

Clusters	Equal weightings	Different weightings
6	1. {France, Belgium, Netherlands, Austria} 2. {Switzerland} 3. {Denmark, Sweden, Norway, Finland, Ireland, UK} 4. {Italy, Spain, Portugal, Greece} 5. {US, Canada} 6. {Japan}	1. {Austria} 2. {France, Belgium, Netherlands, Denmark, Switzerland} 3. {Italy, Spain, Sweden, Norway, Finland, Ireland, UK} 4. {Portugal} 5. {Greece} 6. {US, Canada, Japan}
5	1. {France, Belgium, Netherlands, Austria} 2. {Switzerland} 3. {Denmark, Sweden, Norway, Finland, Ireland, UK, Italy, Spain, Portugal, Greece} 4. {US, Canada} 5. {Japan}	1. {Austria} 2. {France, Belgium, Netherlands, Denmark, Switzerland} 3. {Italy, Spain, Sweden, Norway, Finland, Ireland, UK} 4. {Portugal, Greece} 5. {US, Canada, Japan}
4	1. {France, Belgium, Netherlands, Austria, Switzerland} 2. {Denmark, Sweden, Norway, Finland, Ireland, UK, Italy, Spain, Portugal, Greece} 3. {US, Canada} 4. {Japan}	1. {Austria} 2. {France, Belgium, Netherlands, Denmark, Switzerland, Italy, Spain, Sweden, Norway, Finland, Ireland, UK} 3. {Portugal, Greece} 4. {US, Canada, Japan}
3	1. {France, Belgium, Netherlands, Austria, Switzerland} 2. {Denmark, Sweden, Norway, Finland, Ireland, UK, Italy, Spain, Portugal, Greece} 3. {US, Canada, Japan}	1. {Austria} 2. {France, Belgium, Netherlands, Denmark, Switzerland, Italy, Spain, Sweden, Norway, Finland, Ireland, UK, US, Canada, Japan} 3. {Portugal, Greece}

Note: The weights given are as follows: 0.330 to the trade variable; 0.330 to the inflation differential and 0.085 to each of the other variables.

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