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On Identifying the Core of EMU: An Exploration of Some Empirical Criteria

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EUROPEAN UNIVERSITY INSTITUTE, FLORENCE

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Abstract

The paper reports strikingly high correlations of the cyclical components of industrial production between the participant countries in the ERM. Supplementing these correlations with criteria based on real exchange rate volatility, trade and monetary policy conformity, cluster analysis is used to identify a core group of countries for which monetary union with Germany seems less controversial and to define other groups for which monetary union might be less advisable.

JEC Classification Number: C14, E32, F15, F31

Keywords: Business cycles, Real exchange rates, ERM, Cluster analysis.

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Introduction

The issues explored in this paper spring from observing the phenomenon of business cycle affiliation. In earlier work (Artis and Zhang, 1996, 1997) we established that a recognizable "European" business cycle exists, centred on Germany. The identity of the countries involved and the timing of the appearance of this separate cycle led us to suggest a more specific provisional identification of this cycle with the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS). As explained in more detail below, the ERM has not been a homogeneous regime and participation in it might be expected to encourage a business cycle affiliation with the centre country in more than one way. The ERM is the crucible for EMU. In this paper we go on to explore additional dimensions which, together with that of business cycle affiliation, might be good indicators of fitness to join a monetary union centred on Germany. (Loosely) following criteria suggested by optimal currency area (OCA) theory, we identify real exchange rate volatility and trade as central factors, along with the monetary policy discipline implied by ERM membership.

In the next section (section I) we briefly recall the basis for our assertions about business cycle affiliation and restate the central facts on the basis of an extended data sample and a changed methodology. In the following section (section II) we then examine some explanatory factors - relative real exchange rate stability, monetary policy discipline and trade - in relation to business cycle affiliation. These different factors can be treated as separate dimensions (if partially overlapping), with the aid of which it is possible to delineate an overall degree of linkage with the anchor country: further, by cluster analysis based on these dimensions, it is possible to ask whether there is a distinct "core" of countries inside the ERM which are most closely bound to the anchor country. This task is undertaken in Section III of the paper. The distinction between "core" and " periphery" has been heavily used in discussions of the fitness of ERM countries for EMU membership;[1] our measurements lend some weight to these distinctions.

1. The classic reference is Bayoumi and Eichengreen (1993).

I. Business cycle affiliations

Synchronization in the world business cycle

A number of studies have addressed the relationship between the exchange rate regime and the stochastic process driving the world economy (viz., the business cycle). Among the more recent of these, those by Gerlach (1988), Baxter and Stockman (1989) and Ahmed *et al.* (1993) deserve particular mention. These studies take the sample separation between the Bretton Woods period and after as marking a change of exchange rate regime and examine whether the international business cycle has changed between the two periods.[2] The results have been mixed. Gerlach, for example, finds that output movements have been correlated across countries under both regimes and suggests that there is evidence of a world business cycle. Baxter and Stockman emphasize that there is a decline in the cross correlations between business cycles in the flexible rate period, suggesting that the cycle has become more country-specific. Ahmed *et al.* using an alternative approach based on a structural macroeconometric model, argue that the interactions between output, relative prices and relative policy variables as between the United States and other countries remain much the same in the flexible as in the previous fixed rate period and conclude that there is no evidence of differences in the transmission properties of economic disturbances between the two regimes. McKinnon (1996) has pointed to speculation for or against the dollar as the monetary mechanism behind what he sees as a decline in the coherence of a "world" business cycle since the mid-1980s; in particular, periods when there was speculation against the dollar gave rise to coordinated inflationary booms whilst when the dollar was strong there would be global deflationary pressure. Since the Plaza Accord and subsequent agreements leading to a smoothing of the dollar exchange rate the world cycle has become less synchronized.

In Artis and Zhang (1997) we suggested an account of the world business cycle in which business cycles become more group-specific after 1979, with the German cycle appearing to offer an alternative pole of attraction for a group of European countries to that afforded by the cycle in the US. More specifically, in that study we used monthly data on industrial production for a sample of 15 countries over the period from January 1961 to December 1993 with a sample

2. Because the adoption of an exchange rate regime is itself an endogenous decision and because the abandonment of the Bretton Woods system coincided with the first oil shock, a potential problem of two-way causation is involved in this identification; Baxter and Stockman (1989) additionally examine two other episodes of exchange rate regime change where the problem is less acute.

split in March 1979. Cross-correlations of the cyclical components of these series for each country with the cyclical components of the two reference cycles (for the US and for Germany) established that a "European cycle" became visible in the second sub-sample.[3] More specifically, the study suggested that this European cycle was confined to member countries of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS), since other European countries were not implicated. The study also confirmed that the basic finding was robust to the detrending method employed; whilst the principal results reported (and the graphical displays) used OECD business cycle components which are derived by the application of the "phase-average-trend" (PAT) method of detrending (see Nilsson, 1987), we alternatively identified cyclical components by application of the Hodrick-Prescott filter (with two different settings of the dampening parameter) and by estimating a linear trend. Non-parametric tests for independence of the results obtained using the alternative detrending techniques were strongly rejected.

In Artis and Zhang (1996) we updated (to October 1995) and extended the size (to 19 countries) of the sample examined, confirming the results obtained previously. In this study OECD-detrended cyclical components were employed. We can conveniently begin this paper by restating the central conclusions of that paper in graphical form, using the extended data set, but employing - for reasons that will become clear below - a Hodrick-Prescott filter for detrending.[4] Figure 1 thus shows the business cycle cross-correlations of the countries in our extended data set vis-vis the two reference cycles, of the USA and Germany, in the period from April 1979 to October 1995. Including the two reference

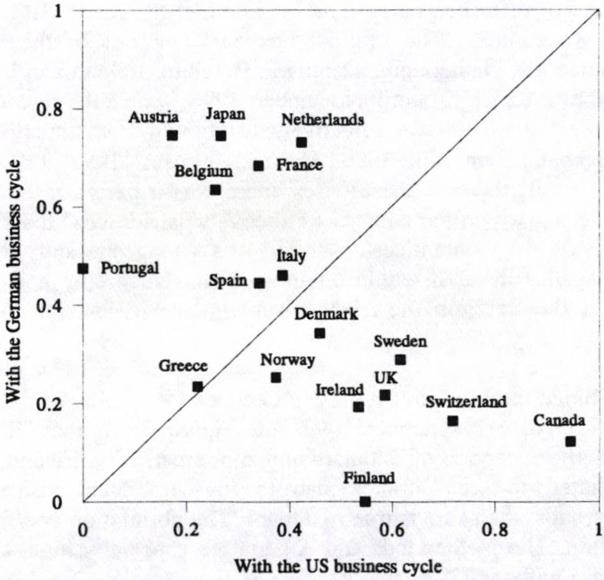
3. Other researchers have also identified the emergence of a European cycle. A recent example is Lumsdaine and Prasad (1997), who employ an entirely different ("common component") approach and whose identification of a European cycle is based on data for the whole period from 1963 to 1994.

4. The Hodrick-Prescott filter is based on minimizing the following expression with respect to g_t:

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

where y_t is the raw series, g_t the growth component and $(y_t - g_t)$ the cyclical component. The choice of dampening parameter λ may be significant in our case, where we have chosen a relatively high value of λ=500,000. This reflects the fact that our data frequency is monthly and that industrial production is a relatively noisy series, together with the constraints that a) g should be assumed to be basically increasing and b) the resultant series of cyclical components should closely follow those implied by the OECD's PAT (phase-average-trend) detrending method.

Figure 1. Cross-correlation with the US/German business cycle



Note: Negative correlation is replaced by zero.

countries the data set comprises 19 countries in all, including all ERM member countries together with some other European countries, Japan, Canada and the United States. For reference purposes it is important that we should define the group of ERM countries. The original member countries of the ERM are: Germany, France, the Netherlands, Denmark, Belgium, Ireland and Italy. From the date of the 1992 crisis until November 1996, when it "re-entered" the Mechanism, the Italian lira was effectively withdrawn from the ERM. Spain joined the Mechanism in June 1989, Portugal in April 1992 and Austria in January 1995; in all three of these cases, there was a period prior to formal membership during which the countries effectively "shadowed" the DM or the ECU. For Austria this apprenticeship period was a long one and the schilling was targeted against the DM within a narrow band (Hochreiter and Winckler, 1995). Finland did not join the Mechanism until 1996, outside our sample period.

The UK joined the Mechanism only in October 1990 and was forced out in the speculative crisis of September 1992. The Figure shows that all the ERM countries, with the exception of Denmark and, more markedly, Ireland, are more strongly affiliated to the German than to the American business cycle (Curiously, perhaps, the same is true of Japan). The correlation coefficients for France, Belgium, The Netherlands and Austria are especially high, above 0.6 whilst their links with the US business cycle are much weaker. The UK, together with Sweden and Finland, exhibits quite a strong link with the US cycle.

The ERM has not been a homogeneous regime: as indicated, some countries joined late with a prior apprenticeship period of variable length and rigour; some countries have taken more advantage of the realignment procedures for changing the central exchange parity than others; the width of the exchange rate band, generally set at +/- 2.25% before the crisis of 1993, was then enlarged to +/- 15%, whilst for some countries (Italy until 1991, Spain), the band of fluctuation was set at +/- 6% prior to the crisis. Furthermore, some countries availed themselves of controls over capital flows until the mid-80s, which allowed them to deviate from the monetary policy discipline exerted by the centre country.

We start with a presumption that enduring membership of an exchange rate union is likely to imply a conformity in the business cycle with partner countries or with the anchor country (Canzoneri (1982)) explores related issues in a theoretical model of intervention policy).[5] There are various ways in which this

5. A contrary presumption might be thought to arise from the fact that if a country has dedicated its policy instruments to sustaining an exchange rate peg it cannot at the same time use them to deal with idiosyncratic shocks. But this overlooks the fact that in such

might come about - most notably, through the discipline exerted by the monetary policy of the anchor country and through the strengthening of trade links implied by the stabilization of exchange rates. The non-homogeneity of the ERM as a regime means that to examine these facets of the issue we need to find some continuous measures with respect to which we might associate a country's business cycle affiliation. This is the task of the next section of the paper.

II. Monetary union criteria

In the previous section of this paper we examined the affiliation of the business cycles of the economies we have under study with the reference cycles of Germany and the USA. In this section we probe these affiliations more deeply.

OCA theory advises 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), provided that they do not suffer too markedly from asymmetric shocks (since this would raise the costs of monetary union, implicit in the surrender of an independent monetary policy). Our choice of variables to investigate can be motivated by appeal to these criteria. We select four variables for investigation: these are real exchange rate volatility, monetary policy linkage and export and import linkages. In each case, these are defined in respect of the two reference economies, the US and Germany, and results are presented in terms of correlations with the reference economy values. Table 1 collects together the numerical results of this cross-correlation analysis, which will be

circumstances membership of the union is unlikely to endure.

Table 1. Cross-correlation coefficients

	Correlation in business cycle with		Volatility[1] in real exchange rate against		Correlation in real interest rate cycle with		Correlation in import-export[2] cycle with		Correlation in export-import[3] cycle with	
	US	Germany	US dollar	Deutschemark	US	Germany	US	Germany	US	Germany
US	--	.106	--	2.838	--	.066	--	.310	--	-.088
Germany	.106	--	2.838	--	.066	--	-.088	--	.310	--
France	.339	.683	2.949	1.118	.138	.334	-.178	.355	-.002	.451
Italy	.386	.459	2.891	1.732	.208	.207	.109	.441	.218	-.074
Netherlands	.424	.730	2.822	.582	-.232	.587	.195	.450	.033	.386
Belgium	.256	.634	2.725	.864	-.109	.529	.050	.510	.285	.101
Denmark	.459	.343	2.808	1.039	-.384	-.015	.254	.281	.066	.228
Ireland	.534	.193	2.514	1.244	-.084	.136	.148	.417	.399	-.039
Spain	.340	.444	2.704	1.617	-.095	-.141	-.106	.109	.011	.038
Portugal	-.253	.474	2.834	1.629	-.409	.031	-.107	.270	.343	.223
Austria	.173	.745	3.013	.907	.061	.216	.164	.521	.200	.464
Switzerland	.718	.164	3.178	1.297	.071	.420	.351	.500	.340	.253
Sweden	.617	.289	2.632	1.835	.087	-.031	.265	.164	.405	-.258
Norway	.373	.253	2.359	1.277	-.147	.088	.324	.185	-.147	.406
Finland	.547	-.075	2.646	1.769	-.176	.095	.264	.110	.348	-.356
Greece	.221	.235	2.583	1.710	n.a[4]	n.a[4]	-.020	.209	.083	.137
UK	.586	.217	2.898	2.174	.196	.017	.361	.361	.186	.055
Canada	.944	.123	1.002	2.787	.467	.161	.646	.158	.650	-.146
Japan	.266	.744	2.644	2.399	.000	.157	-.094	.253	-.108	.268

1. Standard deviation ($\times 10^2$) of the log difference in bilateral real exchange rate.
2. "Correlation in import-export cycle" denotes the correlation coefficient between the import cycle in other countries and the export cycle in the benchmark countries.
3. "Correlation in export-import cycle" denotes the correlation coefficient between the export cycle in other countries and the import cycle in the benchmark countries.
4. "n.a" denotes that no adequate series are not available.

Table 2. The Kendall τ statistic of rank correlation

Variables	N[1]	τ statistic[2]
Correlation in business cycle with the US Correlation in business cycle with Germany	17	-0.500***
Correlation in business cycle with the US Volatility in real exchange rate vs. the US dollar	18	-0.150
Correlation in business cycle with Germany Volatility in real exchange rate vs. the deutschemark	18	-0.399**
Correlation in business cycle with the US Correlation in real interest rate with the US	17	0.206
Correlation in business cycle with Germany Correlation in real interest rate with Germany	17	0.191
Correlation in business cycle with the US Correlation in import-export cycle with the US	18	0.621***
Correlation in business cycle with Germany Correlation in import-export cycle with Germany	18	0.255*
Correlation in business cycle with the US Correlation in export-import cycle with the US	18	0.242*
Correlation in business cycle with Germany Correlation in export-import cycle with Germany	18	0.503***

1. The number of observations.
2. '***' indicates the τ statistic is significant at the 1% level, '**' at the 5% level and '*' at the 10% level.

discussed as we consider each of these relationships in turn. The association between values of these variables and the business cycle correlations is graphed in Figure B1 - B4 in appendix B, whilst Table 2 reports rank correlations across the variables.

Real Exchange Rate Volatility
We begin with the relationship between real exchange volatility and the reference business cycle. It was noticeable from Figure 1 that most of the countries of the ERM, with the principal exclusion of Ireland and the newcomer, Finland, are more strongly affiliated to the German business cycle than to that of the United States. We might expect that this has something to do with the fact that the ERM regime stabilised exchange rates between countries. There is a literature which suggests (though weakly) that exchange rate volatility may discourage trade: to this extent, volatility would undermine the extent to which trade could transmit the cycle. The classical optimum currency area literature also implies that asymmetric shocks between countries might be buffered by real exchange rate variation: to this extent, lower exchange rate volatility might suggest an absence (other things equal) of asymmetric shocks and, to this extent, greater business cycle conformity.[6]

Although the proximate declared targets of the ERM are nominal exchange rates, its operation, particularly in the earlier stages, exemplified a desire to stabilise *real* exchange rates. It was this that supported the European Commission's (1990) finding that there was no cointegration between nominal and real bilateral DM exchange rate within the ERM. The extent to which real exchange rates were stabilised has varied between countries (and, to an extent, over time). On the other hand, the dollar exchange rates of our sample of countries have been floating relatively freely during the period under examination and the volatility of nominal rates has, through persistence in prices, translated into volatility in real rates, as Krugman (1996), for example, has pointed out. These distinct experiences are reflected in Figure B1. In the top half of this Figure we plot bilateral real dollar exchange rates for each country against that country's business cycle cross-correlation with the US cycle. In the bottom half we plot real bilateral DM exchange rates against cross-correlations with the German cycle. Real exchange rates are obtained by deflating by relative wholesale (or producer) prices, whilst volatility is measured by the standard deviation of the logarithm of the series over the whole sample period.

6. It must be said that the paper by Canzoneri *et al.* (1996) explores a related issue and does not appear to give the contention under consideration much support.

It is immediately apparent that dollar volatility is much greater than DM volatility and that it bears essentially very little relationship to the degree of affiliation of a country to the US business cycle. Canada is an obvious outlier. In the case of the DM, however, there is a strong negative relationship between volatility in a country's real bilateral exchange rate and that country's affiliation with the German business cycle: Japan is an obvious outlier in this case. This difference between the association of business cycle correlation and real exchange rate volatility is borne out in Table 2, where the rank correlation is shown to be strongly significantly negative in the case where Germany is the reference country and insignificant in the case where the US is the reference country. Countries in what is often termed the EMU "core" (correctly, according to our further results) - France, the Netherlands, Austria and Belgium - have high cyclical cross-correlations and low volatility, whilst the US and Canada have low cyclical correlations and relatively high exchange rate volatility. Among the ERM members, the newcomer, Finland, has the highest exchange rate volatility and the lowest cyclical correlation; the UK - after the US, Canada and Japan, exhibits the greatest exchange rate volatility - and the lowest business cycle correlation among the European countries, after Finland and Ireland.

Monetary Policy Effects

The defence of the nominal exchange rate bands to which ERM member countries are committed has been undertaken by a mix of sterilized foreign exchange market intervention, both within and at the edge of the bands and, more importantly, by interest rate policy. As the anchor country of the ERM, Germany has generally been assumed to have undertaken monetary policy leadership. The extent to which this would be reflected in a correlation between the interest rates in the non-German countries and those in Germany itself would be moderated by the existence, for part of the period, of capital exchange controls in certain of the countries (notably, France, Italy, Spain and Belgium), which broke the arbitrage between on- and off-shore interest rates; idiosyncratic factors associated with speculative attacks would also moderate the correlation. Finally, the bands of fluctuation would allow for changes in the interest rate linkage, whether those bands were accepted as credible or not.[7] To the extent to which a correlation exists between interest rates in Germany and those in other countries, however, we might be entitled to conclude, first, that this implies a common policy component in the business cycle; second, that it may reflect a comparative absence of asymmetric shocks between the countries; third,

7. The "honeymoon effect" inducing an inverse relationship between the interest differential and the currency's position within the band (implying a strengthening belief in the appreciation of a currency as it approaches its ceiling) has not been a noted feature of the ERM.

that it conveys a "revealed commitment" to the anchor country's counter-inflationary policies.[8]

In order to examine the monetary policy linkages, we have computed and detrended series of real interest rates for each country. The interest rates concerned are short, 3-month, rates which we assume largely reflect the monetary authorities' policy stance and real rates are computed using actual inflation (CPI) data. The detrending is undertaken through the Hodrick-Prescott filter, using the same dampening parameter as for the business cycle series. The data are monthly. Table 1 shows the computed cross-correlations between the cyclical components of the interest rate cycle and the business cycle; the results are displayed in Figure B2, where the upper panel pertains to correlations with the US interest rate cycle and the US business cycle, whilst the lower panel pertains to correlations with Germany.

With the exception of Canada, few of the cross-correlations between the interest cycle and the business cycle in the US are at all high among our sample; for a number of European countries, the correlation is negative. Within the group of ERM countries, however, there are a number of quite high correlations to be found with the German interest rate cycle; the Netherlands and Belgium exhibit the highest cross-correlations, with France, Italy and Austria showing a more moderate degree of positive correlation. All these countries exhibit high cross-correlations in their business cycles. Switzerland is an example of a non-ERM country with a high correlation in its interest rate cycle, though, as already noted, it has a relatively low attachment to the German business cycle. As Table 2 shows, however, rank correlations across the whole sample are insignificant in this case.

The trade linkage
The "ERM effect" creating a high degree of business cycle affiliation with Germany might be a straightforward trade phenomenon. That is, trade linkages provide an obvious channel for the transmission of cyclical impulses, whilst the optimal peg literature simply shows that in choosing an exchange rate peg a country should use a bilateral trade criterion (see, *e.g.*, Edison and Melvin (1990)). A recent paper by Frankel and Rose (1996) indeed demonstrates a strong positive relationship between bilateral trade intensity and the cross-

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8. A willingness to commit to partner (anchor) country policies of high counter-inflationary credibility is an objective of the "new" optimal currency area criteria (*eg*. Tavlas (1993)) not found among the classical OCA list.

correlation of GDP shocks.[9] In this paper we examine the cross correlations between the cyclical components of exports and imports of our sample of countries *vis-a-vis* the reference countries and the relationship between these correlations and the business cycle correlations. Specifically, monthly time series of exports and imports of goods are detrended using the same Hodrick-Prescott filter as applied to the industrial production series; we then examine the correlation between the cyclical components of the reference country's import (export) series and the other country's export (import) series.

The results, noted in the last four columns of Table 1, are displayed in Figures B3 and B4. Note that these refer to series of total exports and imports, not, as might be preferred, bilateral trade. It may be the sheer size of US trade which yields the strong positive relationship revealed in the top half of Figure B3 (less so in Figure B4) between trade and business cycle components. There is a similar positive relationship to be found for Germany as the reference country in Figure B4 (much less so in Figure B3). Table 2 reports significant positive rank correlations in all cases, however.

The results reported in Tables 1-2 and graphed in Figures B1-B4 serve to provide partial evidence on what it is about the ERM grouping that serves to support the business cycle affiliation revealed in Figure 1. The ERM has not been a homogeneous regime and countries differ in the extent to which their participation in it has implied a high degree of correlation in their monetary policy cycles with that of Germany, the extent to which their trade impulses are linked and the extent to which volatility in their exchange rates has been contained. All these variables can be measured in a continuous fashion and it seems that, whilst they may overlap to some extent, each provides a dimension along which, it is possible to argue, a closer affiliation to the anchor country can be obtained. In the next section we explore this idea further, using cluster analysis to do so.

III. Cluster analysis

In this section, cluster analysis is proposed to examine the similarities and dissimilarities of economic structure and to uncover homogeneous subgroups in the data set without any attempt at formal definitions of groups. With the EMU agenda in mind, we specialize to consider five variables, with Germany as the benchmark: these are 1) synchronisation in business cycle; 2) volatility in real

9. Their empirical finding resolves a theoretical ambiguity, for, as Frankel and Rose point out, more trade might imply more specialization and, to that extent, more exposure to asymmetric shocks.

exchange rates; 3) synchronisation in real interest rate cycle; 4) synchronisation in import-export cycle and 5) synchronisation in import-export cycle, which are reported in Table 1.

The agglomerative nesting algorithms used in this paper are discussed here very briefly: see, for example, Kaufman and Rousseeuw (1990), Anderberg (1993), for more details. In the terminology of cluster analysis there are N objects and p variables in a data set with N=18 and p=5 in this study,[10] which are denoted as $X_1,...,X_N$, ($X_j=(x_{j1},...,x_{jp})$ for j=1,2,...,N)[11]. The dissimilarity coefficient or distance, d(j,k), between two objects, X_j and X_k, is defined as the Euclidean distance[12]

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

The definition of the dissimilarity coefficient between two clusters is important in determining the shape of the homogenous groups. There exist many agglomerative algorithms which differ only in the definition of dissimilarity between clusters. In order to examine the robustness of the results, two of the most often used approaches are adopted in this analysis: centroid clustering and the group-average clustering method. Both of these produce ball-shaped clusters (Kaufman and Rousseeuw (1990)).

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:

10. Missing values for the Greek interest rate are interpolated by group averages.

11. It is often suggested that each variable should be standardized so that they are treated as having equal importance in determining the structure. Since four variables in this study are measured by the cross-correlation coefficients which are already "standardised", we only standardise the remaining variable, real exchange rate volatility, by normalizing its mean and standard deviation to the average values those moments have in the other four variables.

12. With only 18 observations in our sample, it is difficult to choose a proper mathematical form to express the distribution of this data set. In this paper, we use the distance to measure the dissimilarity between objects.

$$\bar{x}(\omega_j) = (\bar{x}_1(\omega_j), \bar{x}_2(\omega_j), \ldots, \bar{x}_p(\omega_j)), \qquad \bar{x}_f(\omega_j) = \frac{1}{|\omega_j|} \sum_{k \in \omega_j} x_{kf} \quad for\ f=1,2,\ldots,p \tag{2}$$

where $|\omega_j|$ denotes the number of objects in the cluster. 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. The dissimilarity of two clusters defined by the group-average clustering method may be expressed as:

$$d(\omega_j, \omega_k) = \frac{1}{|\omega_j|\,|\omega_k|} \sum_{j \in \omega_j,\, k \in \omega_k} d(j, k) \tag{3}$$

Both methods start from a classification denoted as $\Omega_0=[\omega_1^0,\ldots,\omega_N^0]$ 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, $\Omega_i=[\omega_1^i,\ldots,\omega_{N-i}^i]$, 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}, are 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

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

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

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

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

The main purposes of this analysis are to investigate 1) whether the data set itself presents a structure and 2) how a gradual merging of groups reveals itself if the data indeed present a structure, which may be examined by the value of the agglomerative coefficient (AC).[13] Two sets of results produced by centroid clustering and group-average clustering are reported in Table 3, 4 and the tree diagrams shown in Figure 2, 3 reproduce the information given in Table 3. The two methods provide similar pictures; in particular, they identify the identical core group, a robust finding which deserve emphasis. For convenience, we may concentrate on the results achieved using the centroid clustering method in the following discussion.

A clear pattern may be observed in Figure 2 in that various groups are formed at various stages. For example, a classification containing 5 groups is identified at stage 13: the US group {US, Canada, Sweden, Finland}; the European group {Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain}; the core group {France, Austria, Netherlands, Belgium}, with Switzerland and Japan forming two separate groups. The cases of Switzerland and Japan are worth noting as they can not be merged into any groups even at this late stage, suggesting that there are features of these two countries which are quite different from those of the merged groups.

13. The AC is a quantity between 0 and 1 by definition. A value of the AC close to 1 indicates that a clear clustering structure has been identified and a value close to 0 indicates that there is no structure in the data set (see, for example, Kaufman and Rousseeuw (1990) for detailed information). It is also indicated that values between 0.26 to 0.50; between 0.51-0.70 and between 0.71 -1.00 respectively suggest a 'weak', 'reasonable' and 'strong' structure.

Table 3. Merging process

Number of clusters	Centroid clustering: Clusters joined	Pseudo F	Centroid distance	Group-average clustering: Clusters joined	Pseudo F	RMS distance
17	{US, Canada}	12.99	.2853	{US, Canada}	12.99	.2853
16	{France, Austria}	11.52	.3363	{France, Austria}	11.52	.3363
15	{Denmark, Portugal}	11.12	.3564	{Denmark, Portugal}	11.12	.3564
14	{Cluster 15, Norway}	9.43	.4022	{Greece, UK}	10.32	.4134
13	{Cluster 14, Greece}	8.64	.4044	{Cluster 15, Norway}	9.59	.4399
12	{Italy, Ireland}	8.59	.4818	{Italy, Ireland}	9.32	.4818
11	{Cluster 12, UK}	8.29	.4815	{Netherlands, Belgium}	9.39	.4887
10	{Netherlands, Belgium}	8.78	.4887	{Cluster 12, Cluster 14}	8.86	.5349
9	{Cluster 11, Cluster 13}	6.69	.5079	{Spain, Sweden}	9.23	.5453
8	{Cluster 9, Spain}	6.87	.5227	{Cluster 16, Cluster 11}	8.41	.6310
7	{Cluster 16, Cluster 10}	6.96	.5570	{Cluster 10, Cluster 13}	7.43	.6446
6	{Sweden, Finland}	8.04	.6034	{Cluster 7, Cluster 9}	7.19	.7104
5	{Cluster 17, Cluster 6}	8.67	.6023	{Cluster 17, Finland}	7.95	.7261
4	{Cluster 8, Switzerland}	9.65	.7140	{Cluster 6, Switzerland}	8.65	.8648
3	{Cluster 5, Cluster 4}	7.39	.7383	{Cluster 4, Japan}	10.21	.9452
2	{Cluster 3, Japan}	11.13	.8889	{Cluster 5, Cluster 3}	11.13	.9874
1	{Cluster 2, Cluster 7}	--	1.0586	{Cluster 2, Cluster 8}	--	1.2512
Agglomerative coefficient	not available			0.55		

Note: The Pseudo F statistic measures the separation among all the clusters at the current level (see SAS for more details).

Table 4. Countries in clusters

Number of clusters	Centroid clustering: Countries in clusters	Group-average clustering: Countries in clusters
7	{US, Canada}	{US, Canada}
	{Sweden}	{Finland}
	{Finland}	{Italy, Ireland, Greece, UK, Denmark, Portugal, Norway}
	{Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain}	{Spain, Sweden}
	{Switzerland}	{Switzerland}
	{Japan}	{Japan}
	{France, Austria, Netherlands, Belgium}	{France, Austria, Netherlands, Belgium}
6	{US, Canada}	{US, Canada}
	{Sweden, Finland}	{Finland}
	{Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain}	{Italy, Ireland, Greece, UK, Denmark, Portugal, Norway, Spain, Sweden}
	{Switzerland}	{Switzerland}
	{Japan}	{Japan}
	{France, Austria, Netherlands, Belgium}	{France, Austria, Netherlands, Belgium}
5	{US, Canada, Sweden, Finland}	{US, Canada, Finland}
	{Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain}	{Italy, Ireland, Greece, UK, Denmark, Portugal, Norway, Spain, Sweden}
	{Switzerland}	{Switzerland}
	{Japan}	{Japan}
	{France, Austria, Netherlands, Belgium}	{France, Austria, Netherlands, Belgium}
4	{US, Canada, Sweden, Finland}	{US, Canada, Finland}
	{Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain, Switzerland}	{Italy, Ireland, Greece, UK, Denmark, Portugal, Norway, Spain, Sweden, Switzerland}
	{Japan}	{Japan}
	{France, Austria, Netherlands, Belgium}	{France, Austria, Netherlands, Belgium}
3	{US, Canada, Sweden, Finland, Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain, Switzerland}	{US, Canada, Finland}
	{Japan}	{Italy, Ireland, Greece, UK, Denmark, Portugal, Norway, Spain, Sweden, Switzerland, Japan}
	{France, Austria, Netherlands, Belgium}	{France, Austria, Netherlands, Belgium}

Figure 2. Merging process (centroid clustering)

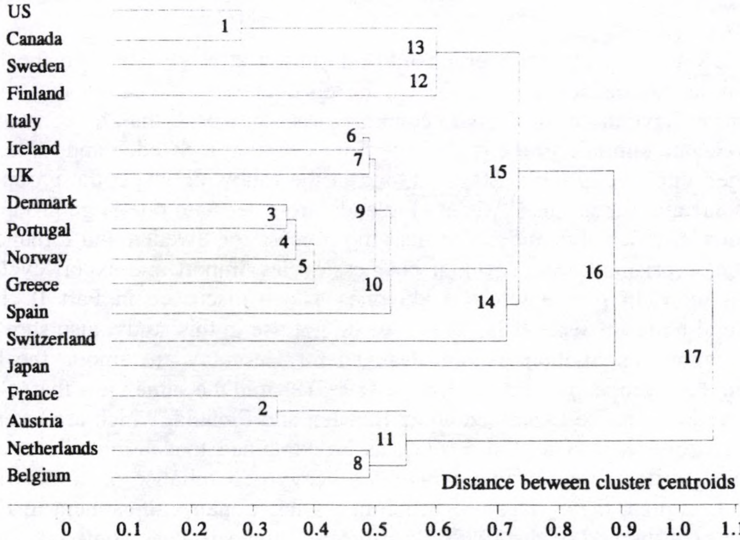
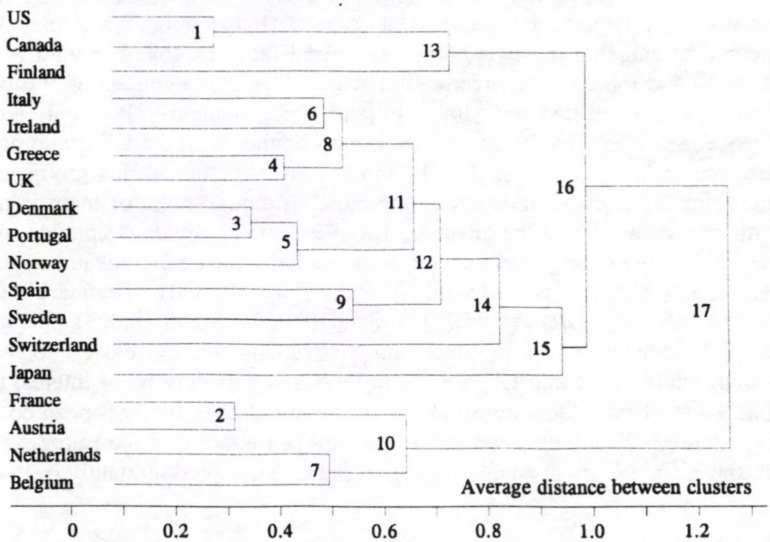


Figure 3. Merging process (group-average clustering)



The US group

The US and Canada are merged into one group at stage one with the lowest dissimilarity coefficient (0.2853) 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). Sweden and Finland are merged into one group at stage 12, and in the following stage, the group {US, Canada} and the group {Sweden, Finland} are fused into one large group {US, Canada, Sweden, Finland}. The merging process for Sweden and Finland may not be surprising given that their business cycles, import and export cycles are much more in phase with the US ones as we discussed in Part II. Indeed bilateral trade intensity data, which we do not use in this study, also shows that the proportions of their exports destined for Germany are among the lowest within the European countries. Taylor (1995) shared the same view that "Similar reservations can be expressed about Sweden and Finland, which are often held to be strong candidates for EMU", as he explained that "Finland's structural problem reflects mainly that economy's heavy past reliance on trade with the Comecon area, the collapse of which necessitated major adjustment in Finnish industry at the end of the 1980s. That process may still have some way to go".

The European group

The European group may be observed at various stages: Denmark, Portugal, Norway and Greece are grouped at stage 5; Italy, Ireland and the UK are merged at stage 7; the two groups are fused into one together with Spain at stage 10 and joined by Switzerland at stage 14. A group containing 9 European countries is identified as: {Italy, Ireland, UK, Denmark, Portugal, Norway, Greece, Spain, Switzerland}, which merges neither with the US group nor with the core group, suggesting that the intra-group structure in this group is much more similar than the inter-group structure. Although none of them is merged with the core group, the distance between each individual country and the centroid of the core group may be calculated and their rankings are as follows: Portugal (0.559),[14] Switzerland (0.562), Italy (0.600), Denmark (0.602), Norway (0.634), Greece (0.678), Ireland (0.709), Spain (0.809) and the UK (0.818), indicating that Portugal and Switzerland are the closest to the core group, while Spain and UK are the furthest away. It may be of interest to note that Switzerland is quite close to the core group among the European countries, even though the country can still not be merged either into the European group or the core group even at very late stage. This predominantly reflects the

14. The figures in brackets denote the Euclidean distance between each individual country and the centroid of the core group.

phenomenon that the business cycle in Switzerland is in phase more often with the US cycle, while Switzerland has large trade with Germany.

The core group

One of the most interesting features observed in Figure 2 is the merging process for the group {France, Austria, Netherlands Belgium}: France with Austria and the Netherlands with Belgium are linked at the stages with relatively small dissimilarities. Once two groups are merged into a cluster at 0.5570, no 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 common features which may not be fully shared by other countries. Although clustering analysis only reveals that more homogeneous subgroups have been found in the data set, the discussions in Part II have already shown that the structure of this subgroup is most similar to that of Germany. It is in this sense that we may be able to refer this subgroup to a core group of four countries around Germany. With a core of four countries, France, Belgium, the Netherlands and Austria around Germany, there is a European group of 9 countries, within which Portugal, Switzerland, Italy and Denmark are closer to the core group and the UK, Spain and Ireland are less close. The structure of the Sweden and Finland group is more similar to that of the US group than to the European group's.

The agglomerative coefficient for the group-average clustering method is 0.55, suggesting that a reasonable structure has been found in the data set. The pseudo F statistic in centroid clustering peaks at 9.65, indicating there might be 4 clusters in the data, although this method is not used to search for the optimal number of clusters, but rather to describe the data in a *hierarchical* way.

To summarise, by using clustering analysis, the classification of the core group together with the US and European group partially agrees and partially disagrees with the "common" definitions of the groups in the literature. For example, a core group ready for the EMU and a "peripheral" group not ready for the 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 to answer the question whether nominal exchange rate changes appear or not to act as a shock absorber for goods 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.

IV. Conclusions

The starting point for this study was a previous identification of a rather striking correlation between the business cycles of Germany and its partner countries in the ERM; only Ireland and the UK prove a strong exception to this identification. Using a Hodrick-Prescott filter on monthly data for industrial production, we began this paper by restating that correlation for the period since the start of the ERM to September 1995. The ERM has not been a homogenous regime and member countries have engaged in it on terms that differ by the length of time of their participation in it, the rigour and length of their prior apprenticeship periods, the size of the fluctuation band within which they maintained their parities, the frequency of the recourse made to realignments and the presence or absence of capital exchange controls and so on. It does seem, though, that the lower the degree of real bilateral DM exchange rate volatility, the higher the business cycle correlation with Germany.

The ERM can be thought of as the crucible for EMU. Under the terms of the Treaty of European Union (the Maastricht Treaty), European Union member countries are bound to the objective of moving forward to full monetary union. Whilst the Treaty sets out "entry criteria" which relate to sustainable low inflation and sustainable fiscal policies that do not conflict with the maintenance of a "stability culture", economists have typically preferred to appeal to OCA criteria to determine which countries might be most fit to join a monetary union with Germany. Bayoumi and Eichengreen (1993) define a "core" group of countries and a "periphery" based on identifying cross-correlations of supply and demand disturbances. That core contains Belgium, the Netherlands, Denmark and France.[15] Canzoneri *et al* (1996) examine a smaller set of countries (Austria, the Netherlands, France, Spain, the UK and Italy) using a VAR approach to answer the question whether nominal exchange rate changes appear or not to act as a shock absorber for goods market disturbances.

15. This group is characterized by distinctively high correlations of supply disturbances with those in Germany; perhaps surprisingly, the Netherlands does not display a high correlation in its demand disturbances with those in Germany.

In our paper we approach the identification of a core by using cluster analysis based on several variables chosen loosely to reflect OCA considerations. Whilst the analysis of section II shows that there is some association between these variables the overlap is much less than complete, so our cluster analysis includes all five - business cycle correlations with Germany, volatility in the real bilateral DM exchange rate, correlations between the cyclical components of the real interest rate cycle in Germany and in the country concerned and correlations of the cyclical components of imports and exports with those found for Germany. This monetary policy variable might be thought of as corresponding to a criterion of the "new OCA" approach in so far as it points to a revealed commitment to a "stability-oriented" monetary policy.

On this basis the cluster analysis identifies a core group consisting of Germany, France, Belgium, the Netherlands and Austria: this is similar to the core group identified by Bayoumi and Eichengreen, save that they do not include Austria in their sample and we do not find Denmark to belong to the core. Subject to the more limited sample covered and the important caveat that they do not consider the inner core group to be especially well defined against the rest, our results also parallel those of Canzoneri et al. in this respect.

According to our analysis there are two substantial additional groups comprising, on the one hand, the US group {US, Canada, Sweden, Finland} and on the other the European group {Portugal, Switzerland, Italy, Denmark, Norway, Greece, Ireland, Spain, UK}. Within these two groups, Portugal, Switzerland, Italy and Denmark are viewed as the "least peripheral" and Spain and the UK may still have some way to go, while Sweden and Finland distance themselves from the core group.

Clearly, the groupings detected are a function, *inter alia*, of the variables which are included.[16] It would be easy to suggest alternatives and supplements. Supplements would probably make rather little difference, given the number already included, but alternatives might change the discriminating power of the cluster analysis.

16. We have also experimented on other variables such as the bilateral trade intensity with Germany where the core group is identified as {France, Austria, Netherlands, Belgium, Switzerland} with Switzerland joining the core at a late stage.

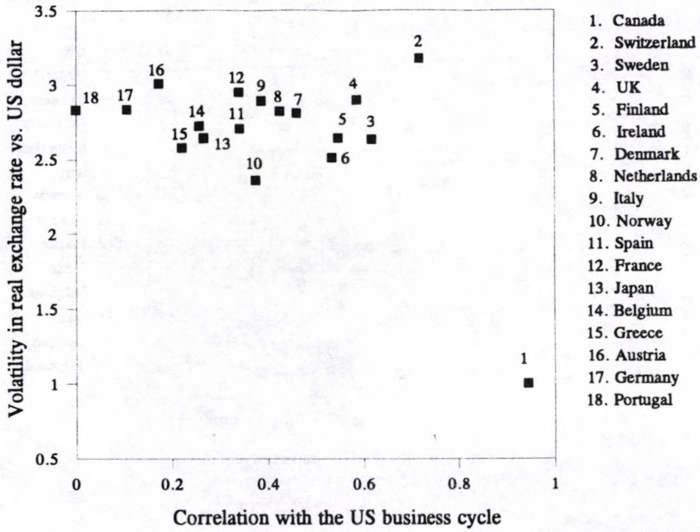
Appendix A: Data definitions and periods[1]

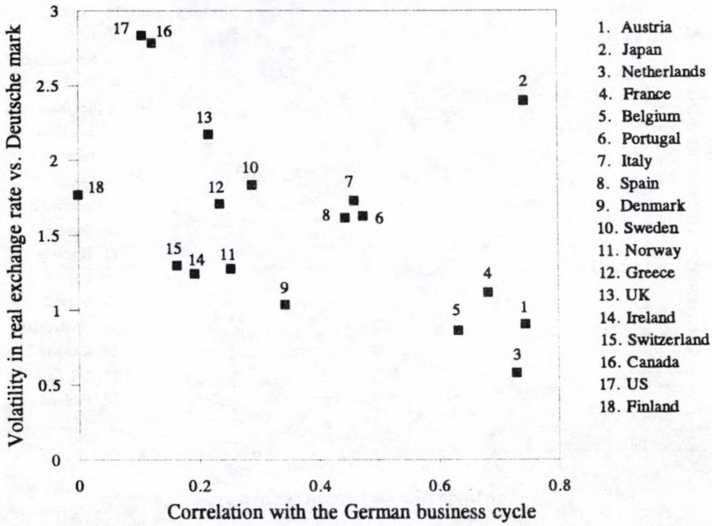
Table A Data definitions and periods

Country	IIP[2]	Exchange rate[3]	Interest rate: Definition	Interest rate: Period	PPI/WPI[4]	CPI[5]	Import[6]	Export[6]
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-94:12	79:4-94:12
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	79:4-95:5	79:4-95:5
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	79:4-95:2	79:4-95:2
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	79:4-94:5	79:4-94:5
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	79:4-95:5	79:4-95:5
Austria	1979:4-95:10	79:4-95:9	3-month VIBOR	79:4-95:8	WPI: 79:4-95:8	79:1-95:10	79:4-94:12	79:4-94:12
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:4-95:1	79:4-95:1
Greece	1979:4-95:8	79:4-95:9	n.a.	n.a.	CPI: 79:4-95:8	79:1-95:10	79:4-94:8	79:4-94:8
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	79:4-95:5	79:4-95:5
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	79:4-95:5	79:4-95:5
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	79:5-95:5	79:4-95:5

1. All series are from the OECD database.
2. IIP for industrial production index, seasonally adjusted.
3. Exchange rate series are rates against the US dollar, exchange rates against the Deutschemark are derived assuming triangular arbitrage.
4. PPI for producer prices index; WPI for wholesale prices index.
5. CPI for consumer prices index.
6. Import and export totals are measured in the national currency and deflated by the PPI/WPI, seasonally adjusted.

Figure B1. Correlation in business cycle and volatility in real exchange rate





Note: Negative correlation is replaced by zero.

Figure B2. Correlations in business cycle and in interest rate cycle

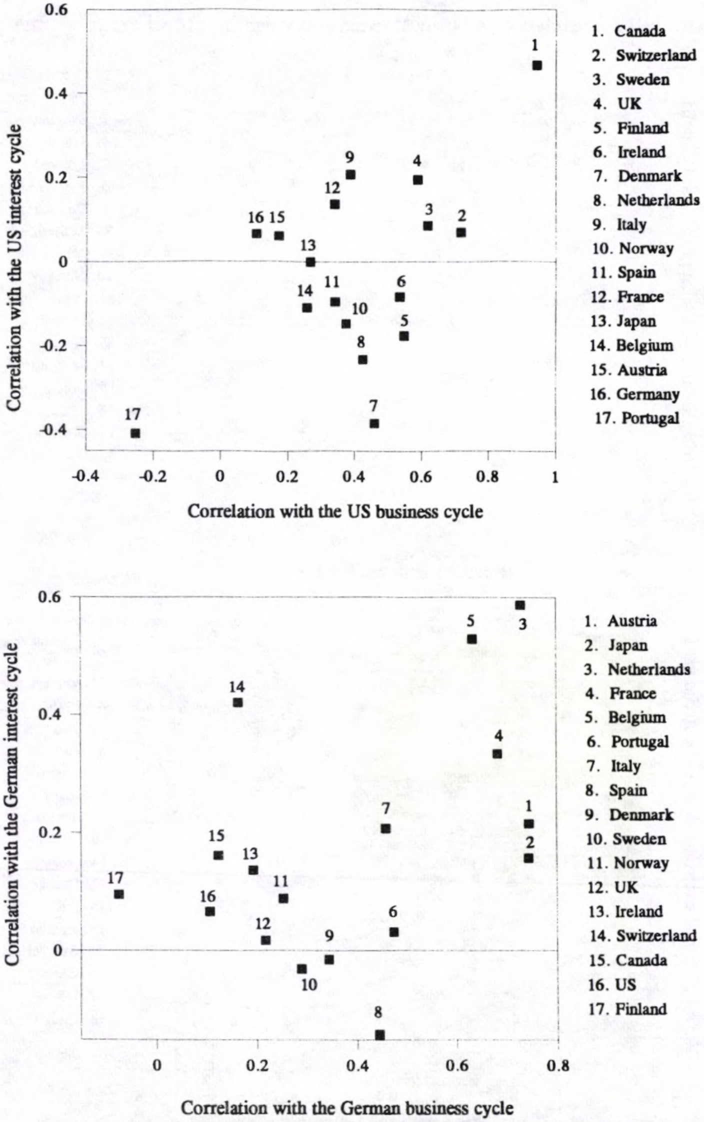
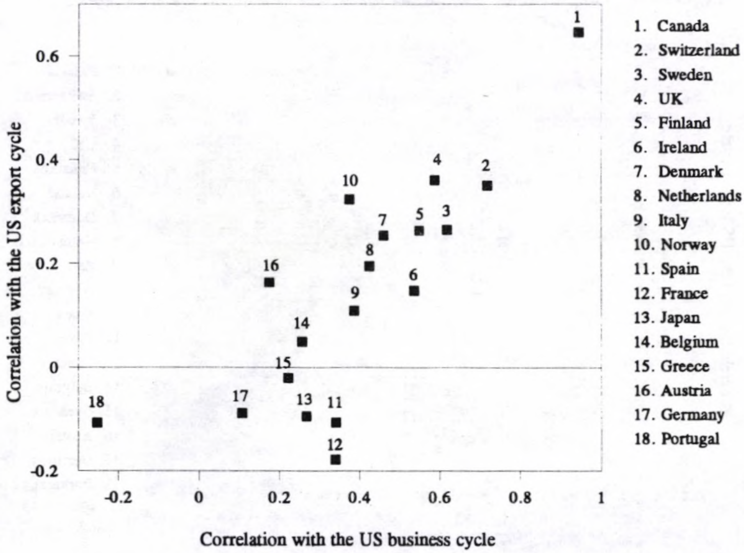


Figure B3. Correlations in business cycle and in import-export cycle



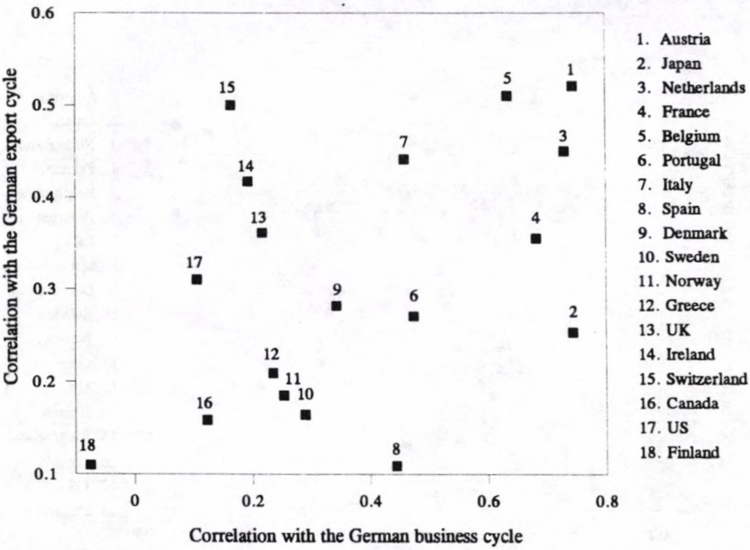
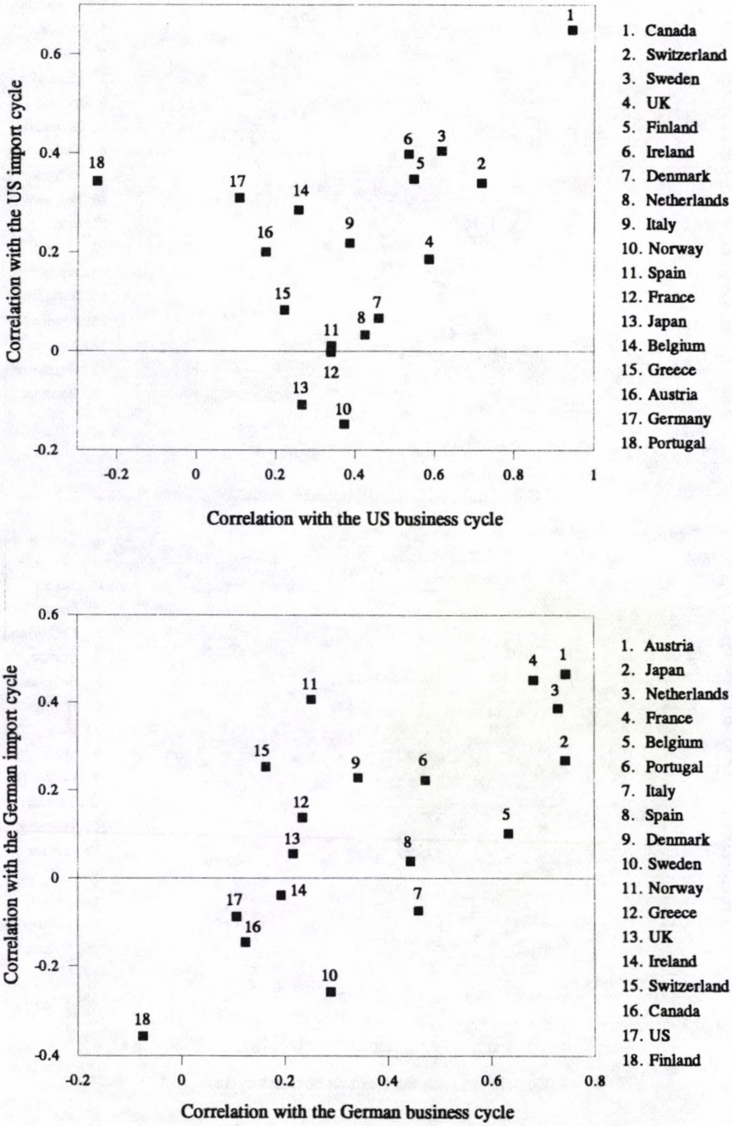


Figure B4. Correlations in business cycle and in export-import cycle



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