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Business Cycles, Core and Periphery in Monetary Unions: Comparing Europe and North America*

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Abstract

We compare Europe with the USA and Canada as regards business cycle synchronization and core-periphery patterns. A long sample (1950-2005) makes it possible to study how these aspects have evolved over time. Results support the economic viability of EMU. Average cyclical correlations among European countries have risen significantly, reaching levels close to, or even higher than, those of North American regions. Applying fuzzy clustering to the analysis of core-periphery issues, we find Europe to actually outperform North America: the core-periphery divide is milder, and peripheral status seems generally less protracted.

JEL Classification: C65, E32, E42, F33.

Keywords: European Union, Canada, United States, Monetary Unions, Business Cycles, Fuzzy Clustering.

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1 Introduction

This paper studies how Europe compares with two other currency areas - the USA and Canada - from the viewpoint of the prevalence of asymmetric shocks. Drawing on annual data starting in 1950, we analyze the degree of business cycle synchronization among the members of each of the three areas, and how it has evolved over time.[1] We also consider whether cyclical developments have tended to conform to a core-periphery pattern, with an economically large subset of regions (the "core") closely aligned among themselves, and whether some regions are particularly vulnerable to finding themselves in a peripheral situation.

The literature has generally taken the USA as the benchmark of an optimum (or at least workable) currency area, against which Europe has been assessed with unfavorable results. Bayoumi and Eichengreen (1993) make a comparison for the period 1960-1988 between the then 12 European Union (EU) member countries and 8 USA regions. For output growth, inflation, and supply and demand structural disturbances, they find that correlations with anchor areas (Germany and the Mid-East) were generally higher in the USA than in Europe. Wynne and Koo (2000) compare business cycles in the pre-2004 15 EU members (EU-15 in the remainder) with those in the twelve Federal Reserve Districts. With annual data for the period 1963-1992, they document that pairwise output gap correlations are clearly higher in the USA than in Europe. However, the authors suggest that cyclical synchronization may be increasing in the latter, as extending the European sample back to the 1950s would tend to decrease correlation coefficients. Clark and van Wincoop (2001) also compare bilateral correlations of the business cycle component of aggregate output in 14 EU countries (EU-15 minus Luxemburg) and 9 USA Census regions, drawing on annual data from 1963 to 1997. They formally test whether the average pairwise correlation among American regions is significantly higher than the corresponding figure for European countries - the so-called border effect, as the former group, unlike the latter, are not separated by national borders. A large and significant border effect indeed exists, decreasing only marginally (from 0.28 to 0.24) from the first to the second half of the sample.

Studies focussing on regional cyclical co-movements in a single monetary union are much more numerous. As those in the previous paragraph, they often take into account that the degree of business cycle synchronization may change over time, in line with the argument that the criteria defining an optimum currency area (OCA) are endogenous (Frankel and Rose, 1998). Tootell (1990) applied the theory of OCAs to three levels of regional detail in the USA, analyzed cyclical correlations and found that some regions would probably be better off having their own currencies. Carlino and Sill (1997, 2000), using quarterly data for personal income, report that business cycle correlations are quite different across regions, although they still find a core group - the Eastern part of the USA. Partridge and Rickman (2005), using time series for USA state employment, find a decline in regional correlations over time (the analyzed period is 1971-98), associated to a decline in the volatility of business cycles. Beine and Coulombe (2003) use quarterly data between 1961 and 2001 to study cyclical correlations between the provinces of Canada and the USA. They find that Quebec, Ontario, and British Columbia would benefit from joining the US dollar.

As for Europe, there is a huge and fast-expanding literature investigating whether national business cycle affiliations have changed in the wake of the major milestones in European monetary

[1] In the remainder, the territorial units forming a monetary union will be generically designated by "members" or "regions", be they Canadian provinces, American states or Census regions, or European countries. Further, Europe will often be referred to as a monetary union, although the euro only came into existence in the final years of our sample, and has not been adopted by all the countries under study. In some instances, the analysis will be explicitly circumscribed to euro area members.

integration - the inception of the Exchange-Rate Mechanism (ERM) of the European Monetary System (EMS) and the move to a single currency. Artis and Zhang (1997) find evidence of stronger cyclical correlation between European economies after the start of the ERM, with most participating countries shifting their cyclical affiliations from the USA to Germany. Perez et al. (2007), using rolling window contemporaneous and maximum (lead/lag) correlations, report an increase in business cycle correlations of EMU countries with Germany, though it also holds that the American cycle has led European countries' cycles by one to two quarters, especially since 1993. Angeloni and Dedola (1999) report that cyclical correlations of European countries with Germany increased in the pre-EMU years (1993-1997) relative to previous periods, especially 1986-1992. Artis et al. (2004) find some evidence for the existence of a common European business cycle for 8 countries, except partially for the case of the UK. Gayer (2007) concludes that since 1999 average bilateral correlations among euro area countries have essentially stabilized at the high level attained in the first half of the nineties. Other studies, however, cast doubt on the existence of a European business cycle. For instance, Inklaar and de Haan (2001) report a decrease in business cycle synchronization of countries belonging to the EMS with the German economy since the 1970s. Camacho et al. (2006) fail to find evidence of the existence of a common driving force or attractor in European countries' business cycles. Mink et al. (2007) conclude that business cycle synchronization and co-movement for the euro area do not exhibit a clear upward trend in the 1970-2005 period, and that national business cycles are still significantly different.

This paper also looks at core-periphery patterns in cyclical co-movements. Bayoumi and Eichengreen (1993) raised this issue, and suggested that there was a core of countries in the European Union (then with 12 members), formed by Germany and its closest neighbors (France, the Benelux, and Denmark), with much more highly correlated shocks than the Southern and English-speaking peripheries. Peripheral regions make a monetary union more difficult to manage, and stand to lose as regards cyclical adjustment mechanisms, since the larger core will in general have a much stronger influence on the common monetary policy. Feldstein (2000) also stressed the potential for political conflict arising from "a sustained period of high cyclical unemployment in any country" (ibidem, p. 351). In normative terms, we therefore deem detrimental the existence of clear-cut core-periphery dichotomies, especially if the same regions repeatedly find themselves in a peripheral situation.

Cluster analysis can be used to identify core regions, as they present homogeneous characteristics. A number of studies have applied different versions of this technique in the context of OCA theory. For instance, Artis and Zhang (2001), using data for the 1979-1995 period and performing hard clustering, analyze (in)homogeneities among European countries, defining Germany as the core country, and Canada, the United States, and Japan as controls. They identify a cluster strongly connected to Germany (France, Belgium, Austria, and the Netherlands) and two peripheries: a Northern group and a Southern group. In related work, the same authors (Artis and Zhang, 2002) employ fuzzy clustering to test on the EU-15 members (bar Luxembourg) the OCA criteria and the Maastricht criteria. The same core cluster emerges (Germany, France, the Netherlands, Belgium, and Austria), as well as two sets of peripheral countries. Crowley (2008) uses model-based clustering (a maximum likelihood-based technique) in a sample of 32 countries (all European except the USA, Canada, and Japan) for the 1970-2005 period. National (dis)similarities are assessed not only with reference to Germany but also relative to euro area variables. The author finds some evidence of a geographical core-periphery pattern, where contiguous countries in the centre of Europe tend to cluster together. Boreiko (2003) uses fuzzy clustering to study the readiness of Central and Eastern European countries for EMU membership, whereas Tsangarides and Qureshi (2006) employ hard and fuzzy clustering techniques to evaluate the suitability of monetary integration arrangements involving West African countries.

In this paper we perform a rolling window analysis of pairwise cyclical correlations in each of the three monetary unions considered (Europe, Canada, and the USA). We compare average bilateral correlations across unions and across subsamples, checking whether some trends suggested by graphical rolling window representations are validated through formal statistical tests. We then turn to the core-periphery issue, and apply fuzzy clustering techniques also in a rolling window way (i.e., taking a succession of overlapping subsamples of fixed length). Hence we can study how core-periphery patterns evolve over time, and how the three currency areas compare on this count. We also compute a summary indicator of how entrenched peripheral status is. As it will turn out, the EU-15 countries (and the subset sharing the euro) fare well in the comparison with American or Canadian regions, in contrast to the unfavorable results *vis-à-vis* the USA often found in the literature.

Our study adds to previous work on three main counts. First, we have a wider and longer sample, covering three monetary unions and starting in 1950. Further, our treatment of deflators to derive real variables is more careful, in an attempt to minimize measurement error. This yields a broader perspective on cyclical patterns and more reliable statistical inference. Second, we compare core-periphery patterns in the three currency areas, and study their evolution over time. Finally, we make a novel application of the most prominent fuzzy clustering algorithm, forming clusters on the basis of the full matrix of bilateral cyclical correlations and thus allowing the core to be determined endogenously, instead of positing ex-ante that a certain region (say, Germany, as regards Europe) plays an anchor role.

The remainder of this paper is structured as follows. In section 2 we describe our dataset, providing details on the construction of some variables. In section 3 we analyze the behavior of bilateral output gap correlations in each monetary union, both using rolling windows and testing for the significance of differences between unions and between subsamples. Section 4 is devoted to the analysis of core-periphery patterns through fuzzy clustering. Section 5 concludes.

2 Data

For the three monetary unions under analysis, our sample runs from 1950 to 2005. This section briefly describes the territorial units and measures of aggregate economic activity considered. Appendix A provides details about data sources and the construction of regional deflators. Appendix B lists the regions of each monetary union and their relative economic weight.

In Canada available data is provincial personal income at current prices. The country is composed of ten provinces and three territories, though the latter have been excluded from the analysis. Their weight in Canada is residual, so the loss of this data is negligible.

In the case of the 50 USA States and the Washington District of Columbia (DC), available data is also for personal income at current prices. Besides analyzing business cycles at state level, we also consider a higher level of aggregation, collecting states into 9 Census regions (Table B3, Appendix B).

In both North American monetary unions we deflate personal income using consumer price indices (CPI). An original feature of our work is that we have constructed CPI series for each territorial unit (see Appendix A), rather than using a single, national-wide deflator for all provinces or states, as common in the literature.

For the European Union we use gross domestic product at 2000 prices. We analyze the pre-2004 member countries (EU-15) and also the euro area subset (EU-12, thus excluding Denmark, Sweden, and the United Kingdom).

We resort to personal income as a proxy for output for the regions of the USA and Canada in order to have the longest possible sample in these monetary unions. In the USA data for nominal Gross State Product (GSP) is only available from 1963, and the corresponding state-specific deflators do not exist before 1990. As for Canada, Gross Provincial Product (GPP) series only start in 1981. Due to these limitations, personal income is often used in the literature to study business cycle volatility and synchronization (e.g. Carlino and Sill, 2000; Karras, 2003).

The variable used throughout in the analysis is the annual output gap, defined as log actual output minus log potential output. To detrend the data we have resorted to two widely used methods, both with standard parameter values: the Hodrick-Prescott (HP) filter with $\lambda = 100$, and the Baxter and King (BK) band-pass filter with $L = 2$, $H = 8$, and $K = 3$. For conciseness, results presented in the main text are for the HP filter, whereas those obtained with the BK filter are reported in Appendix C.

3 Business Cycle Synchronization

3.1 Overview and Methodology

To study the dynamics of the output gap correlations between regions in each monetary union, we first perform a rolling windows analysis. We set a fixed window length of ten years, in line with the average duration of a complete business cycle.[2] The window is then successively moved forward by an increment of one year (i.e., first the 1950-1959 period, then 1951-1960, and so forth).[3]

In each window and for each monetary union, we compute the matrix of bilateral output gap correlation coefficients. For Z regions there will be $\frac{Z(Z-1)}{2}$ different pairwise correlations, which we summarize by their average and standard deviation, both for the HP and BK filters.

We then assess the statistical significance of the trends suggested by the rolling windows analysis, both as regards differences between monetary unions and between subsamples. As previous studies have done - e.g. Wynne and Koo (2000), Clark and van Wincoop (2001), and Beine and Coulombe (2003) - we estimate the variance-covariance matrix of the bilateral correlation coefficients by the generalized method of moments (GMM). More specifically, we compute Newey-West standard errors and covariances.

For each monetary union, we divide the full sample in two halves (1950-1977 and 1978-2005) and report individual bilateral correlation coefficients and their standard deviations. Further, we test whether the average pairwise correlation changes significantly from the first to the second half. Last but not least, it is also assessed if there is a significant difference in average bilateral correlations between each pair of monetary unions - what Clark and van Wincoop (2001) called the border effect in their Europe versus USA comparison. This exercise is performed for the full sample, as well as for subsamples that drop older observations.

3.2 Rolling Windows Results

In this section we present and discuss the rolling window evolution of the bilateral correlations' average and standard deviation for the three monetary unions. Each figure compares Europe

[2] See e.g. Sorensen and Whitta-Jacobsen (2005) or the seminal work of Burns and Mitchell (1946).

[3] Notice, however, that the computation of the output gap was performed only once, using the full sample.

(both EU-15 and EU-12) with one of the other two currency areas, with the mid (5th) year of each window in the horizontal axis.

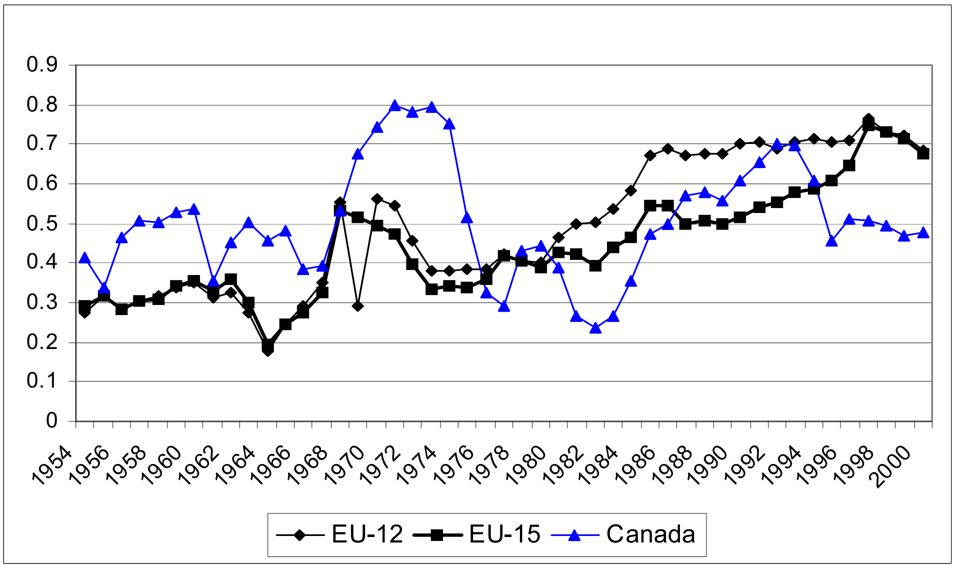

Figure 1 - Average Bilateral Correlations for the EU and Canada (10-year rolling windows)

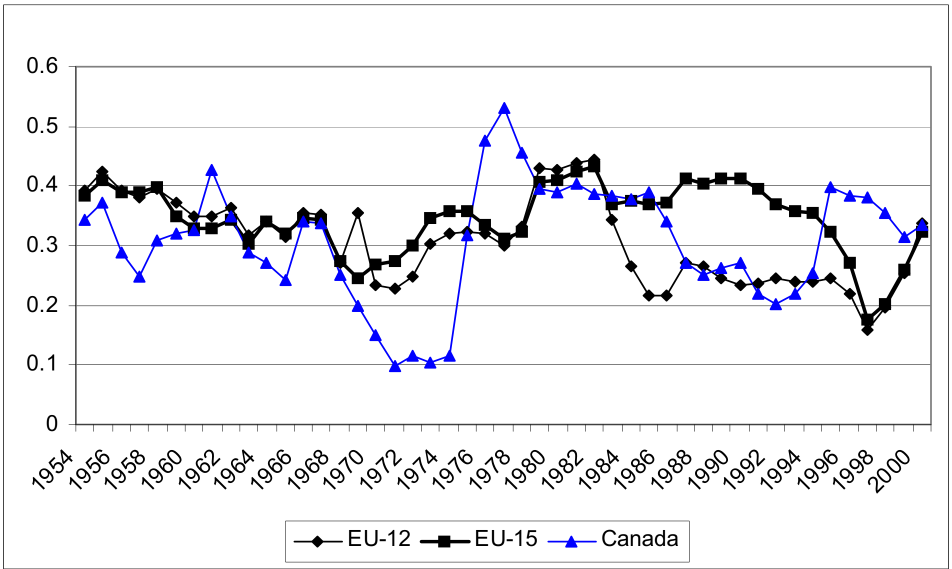

Figure 2 - Standard Deviation of Bilateral Correlations for the EU and Canada (10-year rolling windows)

Figure 1 presents average bilateral correlations for the EU-15, EU-12, and Canada. Until the 70s correlations were somewhat higher in Canada, the opposite taking place towards the end of the sample, due to a clear upward trend in European average correlations. Results for the EU-15 and EU-12 are very similar, with the exception of the windows corresponding to the 80s and 90s, when average synchronization in the euro area was slightly higher than in the EU-15. Standard deviations do not exhibit a clear trend in either of the analyzed monetary unions, as can be seen in Figure 2.

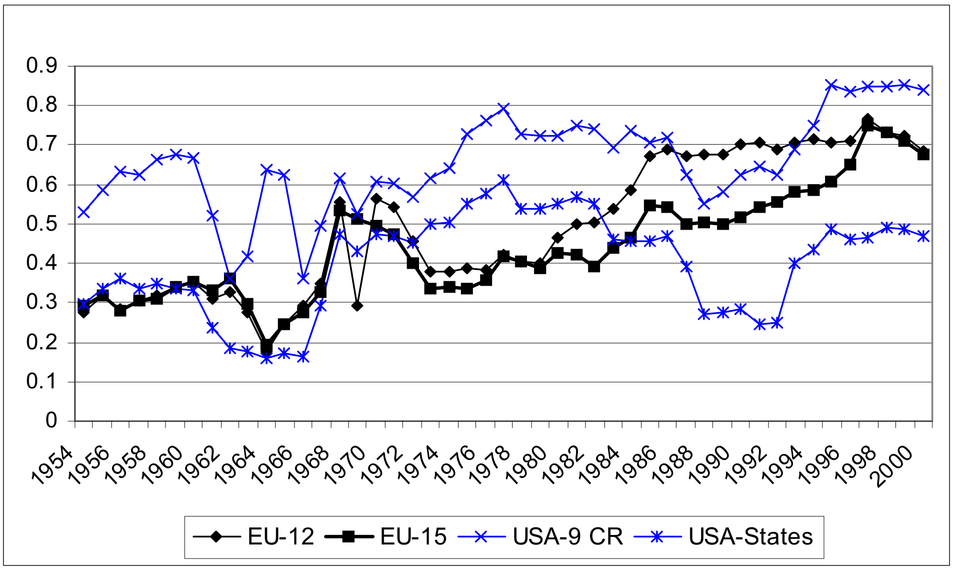

Figure 3 - Average Bilateral Correlations for the EU and the USA (10-year rolling windows)

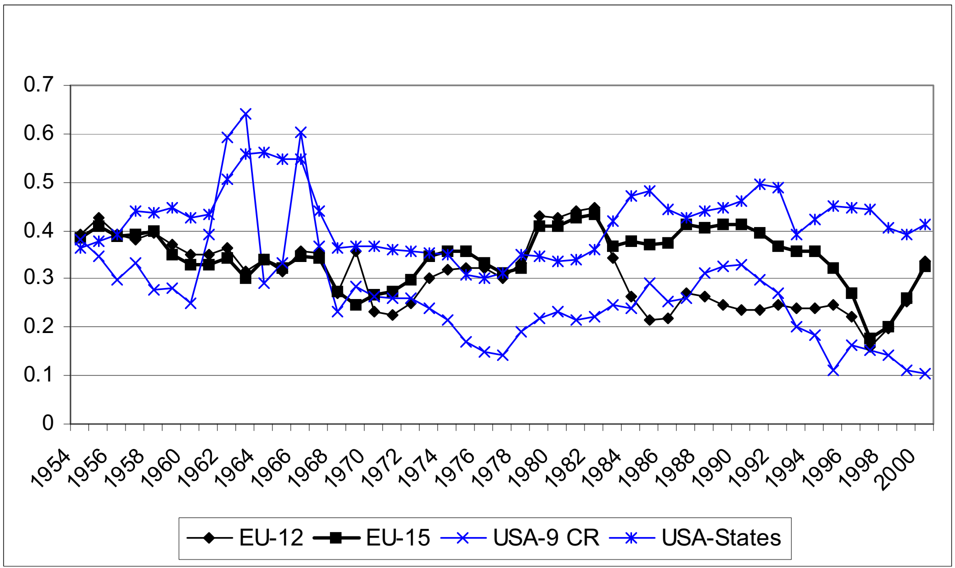

Figure 4 - Standard Deviation of Bilateral Correlations for the EU and the USA (10-year rolling windows)

Figures 3 and 4 compare Europe with the USA, the latter considered at the level of states and Census regions. Average bilateral correlations for these two levels of aggregation show broadly similar trends, but cyclical synchronization is systematically higher for the 9 Census regions (Figure 3). Correspondingly, standard deviations are generally larger at state level (Figure 4). This points to the fact that different levels of aggregation can lead to different results.[4] Standard deviations

[4]The work by Clark and van Wincoop (2001) already mentioned this fact, taking it into consideration when

for the 9 Census regions tend to decline over time.

While until the late 70s European average correlations were only comparable to (or even fell short of) those of the USA states, towards the end of the sample they become much closer to those of the Census regions.

Results obtained with the BK filter (Appendix C, Figures C1-C4) broadly confirm the above HP-based conclusions.[5]

3.3 Subsamples and Statistical Significance

In this section we report results for the statistical significance of individual bilateral correlation coefficients and their averages in the two halves of the full sample: 1950-1977 and 1978-2005. The upper panel of each table refers to the former period, while the lower panel shows results for the latter; numbers in parenthesis are GMM-estimated Newey-West standard errors.

Table 1 - Business Cycle Correlations for the Canadian Provinces

1950 - 1977

	ALB	BC	MAN	NB	NFD	NS	ONT	PEI	QUE	SAS
Alberta (ALB)										
British Columbia (BC)	0.46***									
	(0.08)									
Manitoba (MAN)	0.62***	0.63***								
	(0.09)	(0.1)								
New Brunswick (NB)	0.29*	0.74***	0.67***							
	(0.16)	(0.07)	(0.08)							
New Foundland and Labrador (NFD	0.05	0.67***	0.31*	0.71***						
	(0.16)	(0.07)	(0.19)	(0.12)						
Nova Scotia (NS)	0.25*	0.79***	0.65***	0.75***	0.79***					
	(0.14)	(0.05)	(0.14)	(0.08)	(0.08)					
Ontario (ONT)	0.37***	0.86***	0.66***	0.77***	0.71***	0.81***				
	(0.09)	(0.05)	(0.08)	(0.08)	(0.09)	(0.06)				
Prince Edward Island (PEI)	0.46***	0.30*	0.50***	0.41**	0.15	0.24	0.25			
	(0.11)	(0.17)	(0.13)	(0.18)	(0.22)	(0.20)	(0.16)			
Quebec (QUE)	0.37***	0.77***	0.53***	0.76***	0.86***	0.83***	0.77***	0.35**		
	(0.12)	(0.05)	(0.1)	(0.09)	(0.04)	(0.05)	(0.07)	(0.17)		
Saskatchewan (SAS)	0.74***	0.24	0.58***	0.25	0.01	0.14	0.22	0.58***	0.26*	
	(0.1)	(0.17)	(0.12)	(0.20)	(0.20)	(0.20)	(0.16)	(0.09)	(0.15)	

1978-2005

	ALB	BC	MAN	NB	NFD	NS	ONT	PEI	QUE	SAS
Alberta (ALB)										
British Columbia (BC)	0.62***									
	(0.11)									
Manitoba (MAN)	0.08	-0.01								
	(0.16)	(0.25)								
New Brunswick (NB)	0.11	0.33	0.61***							
	(0.15)	(0.23)	(0.17)							
New Foundland and Labrador (NFD	-0.01	0.46**	0.21	0.50***						
	(0.12)	(0.21)	(0.22)	(0.17)						
Nova Scotia (NS)	0.08	0.12	0.76***	0.85***	0.44**					
	(0.22)	(0.23)	(0.07)	(0.07)	(0.17)					
Ontario (ONT)	0.03	0.31	0.61***	0.79***	0.55***	0.85***				
	(0.24)	(0.20)	(0.13)	(0.07)	(0.16)	(0.06)				
Prince Edward Island (PEI)	-0.15	0.19	0.31	0.78***	0.54***	0.70***	0.79***			
	(0.22)	(0.25)	(0.20)	(0.09)	(0.14)	(0.10)	(0.06)			
Quebec (QUE)	0.20	0.62***	0.36	0.55***	0.70***	0.57***	0.79***	0.65***		
	(0.15)	(0.1)	(0.26)	(0.16)	(0.11)	(0.18)	(0.08)	(0.08)		
Saskatchewan (SAS)	0.43**	0.22	0.50***	0.34***	-0.06	0.26*	0.05	-0.01	-0.04	
	(0.21)	(0.21)	(0.12)	(0.11)	(0.15)	(0.13)	(0.18)	(0.23)	(0.17)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

Comparing the upper and lower panels of Table 1, we see that bilateral correlations tend to be lower and less significant in the second half of the sample. This decline is particularly visible

making comparisons with the European Union. The authors use the 9 Census regions instead of the states, due to significantly different geographic and economic dimensions.

[5] Given the values chosen for the BK filter parameters we lose three years of data at the beginning and at the end of the sample.

in the correlations regarding the provinces of Alberta, British Columbia, and Manitoba. Most Saskatchewan coefficients were not significant in either period.

Table 2 - Business Cycle Correlations for the 9 USA Census Regions

1950 - 1977	NENG	MATL	ENC	WNC	SATL	ESC	WSC	MTN	PAC
New England (NENG)									
Middle Atlantic (MATL)	0.82***								
	(0.04)								
East North Central (ENC)	0.62***	0.45***							
	(0.12)	(0.15)							
West North Central (WNC)	0.09	0.43**	0.03						
	(0.21)	(0.20)	(0.27)						
South Atlantic (SATL)	0.56***	0.37*	0.90***	0.14					
	(0.18)	(0.21)	(0.01)	(0.25)					
East South Central (ESC)	0.80***	0.67***	0.82***	0.27	0.84***				
	(0.07)	(0.10)	(0.05)	(0.23)	(0.05)				
West South Central (WSC)	0.70***	0.78***	0.70***	0.56**	0.73***	0.84***			
	(0.09)	(0.10)	(0.08)	(0.22)	(0.07)	(0.04)			
Mountain (MTN)	0.40***	0.63***	0.25*	0.58***	0.23	0.32**	0.63***		
	(0.14)	(0.13)	(0.13)	(0.18)	(0.20)	(0.16)	(0.15)		
Pacific (PAC)	0.61***	0.70***	0.65***	0.51**	0.66***	0.78***	0.85***	0.60***	
	(0.11)	(0.11)	(0.10)	(0.24)	(0.10)	(0.05)	(0.05)	(0.16)	
1978 - 2005	**NENG**	**MATL**	**ENC**	**WNC**	**SATL**	**ESC**	**WSC**	**MTN**	**PAC**
New England (NENG)									
Middle Atlantic (MATL)	0.90***								
	(0.05)								
East North Central (ENC)	0.66***	0.39***							
	(0.07)	(0.10)							
West North Central (WNC)	0.68***	0.57***	0.69***						
	(0.07)	(0.11)	(0.11)						
South Atlantic (SATL)	0.63***	0.34***	0.94***	0.69***					
	(0.08)	(0.11)	(0.01)	(0.12)					
East South Central (ESC)	0.76***	0.56***	0.95***	0.77***	0.85***				
	(0.06)	(0.12)	(0.01)	(0.09)	(0.04)				
West South Central (WSC)	0.80***	0.61***	0.88***	0.57***	0.82***	0.88***			
	(0.07)	(0.14)	(0.04)	(0.12)	(0.05)	(0.01)			
Mountain (MTN)	0.93***	0.81***	0.68***	0.74***	0.64***	0.77***	0.78***		
	(0.01)	(0.08)	(0.05)	(0.06)	(0.06)	(0.04)	(0.09)		
Pacific (PAC)	0.39***	0.20**	0.71***	0.79***	0.64***	0.68***	0.42***	0.55***	
	(0.11)	(0.10)	(0.13)	(0.07)	(0.14)	(0.13)	(0.14)	(0.09)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

In the case of the 9 USA Census regions (Table 2), pairwise correlations are usually high and significant in both periods. The few exceptions mainly concern the West North Central region in the first half of the sample.[6]

[6] We were unable to estimate standard errors for correlations between USA states: 51 territorial units translate into a vector of 1275 pairwise correlation coefficients, whose variance-covariance matrix has 813450 different elements. However, the correlation coefficients themselves are available upon request.

Table 3 - Business Cycle Correlations for the EU-15 Member Countries

1950 - 1977

	AT	BE	FIN	FR	DE	EL	IE	IT	LU	NL	PT	ES	DK	SE	UK
Austria (AT)															
Belgium (BE)	0.47***														
	(0.10)														
Finland (FIN)	0.41***	0.65***													
	(0.15)	(0.13)													
France (FR)	0.56***	0.63***	0.35**												
	(0.15)	(0.16)	(0.18)												
Germany (DE)	0.74***	0.50***	0.42***	0.65***											
	(0.11)	(0.10)	(0.15)	(0.14)											
Greece (EL)	0.08	0.16	-0.01	0.15	0.20										
	(0.13)	(0.15)	(0.18)	(0.20)	(0.20)										
Ireland (IE)	0.36***	0.62***	0.50***	0.37*	0.49***	-0.09									
	(0.12)	(0.12)	(0.16)	(0.21)	(0.09)	(0.18)									
Italy (IT)	0.34**	0.43***	0.41**	0.43***	0.34**	-0.25*	0.67***								
	(0.13)	(0.17)	(0.17)	(0.15)	(0.14)	(0.13)	(0.10)								
Luxembourg (LU)	0.34**	0.50***	0.34	0.42**	0.38**	0.27	0.13	0.05							
	(0.16)	(0.19)	(0.24)	(0.17)	(0.18)	(0.18)	(0.18)	(0.20)							
Netherlands (NL)	0.28**	0.56***	0.25	0.09	0.28	0.20	0.32**	0.08	0.28***						
	(0.12)	(0.14)	(0.22)	(0.30)	(0.19)	(0.14)	(0.16)	(0.21)	(0.11)						
Portugal (PT)	0.17	0.59***	0.44***	0.38*	0.28	0.30	0.52***	0.47***	0.40	0.25					
	(0.22)	(0.15)	(0.15)	(0.21)	(0.20)	(0.20)	(0.10)	(0.13)	(0.29)	(0.15)					
Spain (ES)	0.13	0.60***	0.53***	0.28	-0.07	0.10	0.27*	0.22	0.14	0.14	0.43***				
	(0.24)	(0.15)	(0.11)	(0.22)	(0.16)	(0.11)	(0.15)	(0.15)	(0.25)	(0.24)	(0.12)				
Denmark (DK)	0.37**	0.38***	0.18	0.38**	0.42**	0.05	0.46***	0.41**	0.27*	0.25	0.23	-0.15			
	(01.7)	(0.15)	(0.23)	(0.16)	(0.17)	(0.26)	(0.18)	(0.19)	(0.16)	(0.23)	(0.22)	(0.21)			
Sweden (SE)	0.15	0.64***	0.42***	0.23	0.07	-0.01	0.31	0.16	0.20	0.39***	0.01	0.32*	0.31		
	(0.12)	(0.10)	(0.15)	(0.20)	(0.19)	(0.16)	(0.23)	(0.23)	(0.13)	(0.10)	(0.17)	(0.17)	(0.21)		
United Kingdom (UK)	0.15	0.64***	0.44***	0.14	0.19	0.40**	0.46***	0.18	0.36	0.50***	0.71***	0.39***	0.26	0.33**	
	(0.18)	(0.11)	(0.17)	(0.28)	(0.19)	(0.19)	(0.13)	(0.20)	(0.25)	(0.13)	(0.13)	(0.13)	(0.20)	(0.13)	

1978 - 2005

	AT	BE	FIN	FR	DE	EL	IE	IT	LU	NL	PT	ES	DK	SE	UK
Austria (AT)															
Belgium (BE)	0.72***														
	(0.08)														
Finland (FIN)	0.08	0.36**													
	(0.15)	(0.14)													
France (FR)	0.68***	0.82***	0.54***												
	(0.08)	(0.07)	(0.14)												
Germany (DE)	0.83***	0.79***	-0.18*	0.57***											
	(0.06)	(0.07)	(0.11)	(0.10)											
Greece (EL)	0.51***	0.67***	0.04	0.50***	0.69***										
	(0.14)	(0.09)	(0.18)	(0.10)	(0.11)										
Ireland (IE)	0.41**	0.53***	0.37	0.50***	0.40**	0.48***									
	(0.17)	(0.08)	(0.25)	(0.12)	(0.19)	(0.17)									
Italy (IT)	0.63***	0.88***	0.53***	0.79***	0.65***	0.61***	0.58***								
	(0.09)	(0.04)	(0.14)	(0.08)	(0.13)	(0.12)	(0.11)								
Luxembourg (LU)	0.69***	0.76***	0.25	0.79***	0.70***	0.49***	0.30*	0.64***							
	(0.10)	(0.09)	(0.20)	(0.08)	(0.10)	(0.12)	(0.18)	(0.12)							
Netherlands (NL)	0.65***	0.78***	0.28*	0.69***	0.74***	0.58***	0.66***	0.75***	0.81***						
	(0.10)	(0.04)	(0.15)	(0.09)	(0.07)	(0.16)	(0.13)	(0.07)	(0.06)						
Portugal (PT)	0.67***	0.83***	0.38***	0.80***	0.61***	0.41***	0.52***	0.78***	0.65***	0.62***					
	(0.08)	(0.06)	(0.14)	(0.06)	(0.10)	(0.10)	(0.10)	(0.06)	(0.13)	(0.12)					
Spain (ES)	0.58***	0.82***	0.43**	0.87***	0.58***	0.52***	0.28**	0.73***	0.84***	0.69***	0.75***				
	(0.15)	(0.08)	(0.19)	(0.05)	(0.15)	(0.12)	(0.13)	(0.12)	(0.05)	(0.08)	(0.12)				
Denmark (DK)	-0.03	0.02	0.33*	0.09	-0.03	0.00	0.21	0.22	0.19	0.44**	-0.15	0.04			
	(0.26)	(0.24)	(0.18)	(0.21)	(0.24)	(0.19)	(0.26)	(0.18)	(0.25)	(0.18)	(0.20)	(0.22)			
Sweden (SE)	0.26	0.54***	0.80***	0.67***	0.15	0.27	0.25	0.70***	0.54***	0.53***	0.40***	0.68***	0.52***		
	(0.19)	(0.15)	(0.10)	(0.10)	(0.19)	(0.17)	(0.23)	(0.10)	(0.17)	(0.14)	(0.15)	(0.11)	(0.16)		
United Kingdom (UK)	0.13	0.40***	0.61***	0.50***	0.12	0.27	0.20	0.54***	0.51***	0.54***	0.30*	0.59***	0.60***	0.81***	
	(0.20)	(0.14)	(0.18)	(0.12)	(0.23)	(0.16)	(0.22)	(0.13)	(0.17)	(0.14)	(0.17)	(0.14)	(0.14)	(0.07)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

Table 3 gives results for the EU-15. We can clearly see correlation coefficients increasing from the first to the second half of the sample. In the first period, several countries - Greece, the Netherlands, Portugal, Spain, Denmark, Sweden, and the United Kingdom - often display low correlations. Except for the Netherlands, these are countries having joined the European Union in 1973 or later. In the second half, low and non-significant coefficients mainly involve Denmark and, to a lesser extent, Finland, Sweden and the United Kingdom. With the exception of Finland, these are precisely the countries which do not belong to the euro area.

Results for the BK band-pass filter (Appendix C, Tables C1-C3) are broadly consistent with those above, though conclusions for specific regions change in a few instances. The main difference relative to the HP filter is that in Europe the contrast between euro area economies and the three nations retaining monetary sovereignty is less marked.

We also test whether the change in average bilateral correlations from the first to the second half of the sample is statistically significant.[7] Results in Table 4 broadly corroborate the trends detected in the rolling windows analysis. In the 1978-2005 period cyclical synchronization in Europe surpasses Canada's and reduces the gap to USA Census regions. The increase relative to the first subsample is large and significant, particularly among euro area economies. Changes in North America are less marked and fail to reach statistical significance. BK-based results (Table C4), however, are less conclusive, as the rise in European correlations fails to reach significance as well.

Table 4 - Significance of Average Bilateral Correlations

Monetary Unions	Canada	EU-15	EU-12	USA-9 CR
1950 – 1977				
	0.51***	0.32***	0.33***	0.57***
	(0.07)	(0.08)	(0.08)	(0.09)
1978 – 2005				
	0.39***	0.50***	0.59***	0.69***
	(0.09)	(0.05)	(0.04)	(0.05)
Change	−0.12	0.18**	0.26***	0.12
	(0.09)	(0.09)	(0.07)	(0.09)

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively.

3.4 Differences between Monetary Unions

We now compare average bilateral correlations across currency areas, testing for each pair of monetary unions whether differences are significant. Table 5 reports these differences, and their Newey-West standard errors, for the full sample, its second half, and its final third. The latter corresponds to 19 observations, which still slightly exceeds the length of Clark and van Wincoop's (2001) subsamples when addressing a similar issue.[8]

[7] Unlike in Clark and van Wincoop (2001), our tests do not assume independence of coefficients between subsamples.

[8] Following their approach, the variance-covariance matrix for the coefficients in the two unions being compared is estimated using the full sample, and retained when analyzing shorter periods, normalizing by the number of observations in each case.

Table 5 - Average Bilateral Correlations: Comparing Monetary Unions

	USA-9 CR	EU-15	EU-12
1950 − 2005			
CAN	-0.17^{**}	0.07	0.03
	(0.08)	(0.07)	(0.07)
USA-9 CR		0.24^{***}	0.20^{***}
		(0.05)	(0.06)
1978 − 2005			
CAN	-0.30^{***}	-0.11	-0.20^{**}
	(0.11)	(0.10)	(0.10)
USA-9 CR		0.18^{***}	0.10
		(0.07)	(0.08)
1987 − 2005			
CAN	-0.16	0.03	-0.08
	(0.13)	(0.12)	(0.12)
USA-9 CR		0.19^{**}	0.08
		(0.08)	(0.10)

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively. Each entry is the difference in average pairwise correlations between the union in row and the one in column.

The most noteworthy result of Table 5 is the fading away of the difference between the USA Census regions and the euro area. It ceases to be significant in the final years, with both filters (results for the BK filter are provided in Table C5). With HP-filtered data the same holds for the whole of the 1978-2005 period; in this sample the comparison with Canada also becomes markedly favorable to the euro countries (a "border effect" upside down, to borrow some terminology from Clark and van Wincoop, 2001).

On the whole, our comparison of monetary unions turns out more favorable to Europe than the studies surveyed in the introductory section had suggested.

4 Core-Periphery Patterns: A Fuzzy Cluster Analysis

4.1 Overview and Methodology

We now investigate whether there are subsets of regions in a given monetary union which display a high internal degree of cyclical homogeneity, but tend to be less synchronized with outside regions. If the homogeneous subset accounts for a major share of total output, it corresponds to a monetary union "core" which will in general have a disproportionate influence on the common monetary policy, to the detriment of smaller, peripheral regions. We wish to study (i) how prevalent are core-periphery patterns in Europe, Canada, and the USA; (ii) whether such prevalence displays any clear trend over time; and (iii) whether peripheral regions tend to be the same in different subsamples, as opposed to a situation where, though a core might exist, its membership does not remain unchanged.

To identify groups of regions we perform fuzzy clustering, which is more flexible and general than hard (or crisp) clustering since it does not impose that clusters are mutually exclusive, but rather allows for intermediate degrees of membership. In keeping with section 3, we base our analysis on the full matrix of bilateral output gap correlations - which is, to our knowledge, a novel approach. One implication is that the core cluster is endogenously determined. As an alternative, one may posit that a certain region plays an anchor role, and therefore always belongs to the core (and indeed defines it), as other studies have done (e.g. Bayoumi and Eichengreen, 1993; Artis and Zhang, 2001, 2002). This assumption, however, may fail to be supported by the data: for instance, we often find that in subsamples comprising the post-reunification years Germany (the usual anchor region in Europe) actually belongs to a peripheral cluster.

We use the fuzzy C-means (FCM) algorithm, which is regarded as the most prominent method among several existing alternatives.[9] This algorithm is now briefly described, so as to show how it can be applied to the matrix of bilateral correlations. For c clusters and N objects (regions of a monetary union, in our case), the FCM algorithm yields a matrix U of Nc membership coefficients (of each object to each cluster) which minimizes a sum of squared Euclidean distances between objects and cluster centers. Formally, the objective function to be minimized is

$$J(u,v)=\sum_{i=1}^{N}\sum_{k=1}^{c}u_{ik}^{2}\sum_{f=1}^{m}\left(x_{if}-v_{kf}\right)^{2} \tag{1}$$

where the membership coefficients u_{ik} must verify the following constraints:

$$0\leq u_{ik}\leq 1 \tag{2}$$

$$\sum_{k=1}^{c}u_{ik}=1, 1\leq i\leq N \tag{3}$$

and

$$0<\sum_{i=1}^{N}u_{ik}<N, 1\leq k\leq c \tag{4}$$

m denotes the number of variables used in the analysis (i.e., criteria to assess similarities and dissimilarities between objects); and cluster centres are computed for each variable f as:

$$v_{kf}=\frac{\sum_{i=1}^{N}u_{ik}^{2}x_{if}}{\sum_{i=1}^{N}u_{ik}^{2}} \tag{5}$$

As shown by Kaufman and Rousseeuw (1990, p. 190), the FCM objective function can be rewritten as

$$\sum_{k=1}^{c}\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}u_{ik}^{2}u_{jk}^{2}\sum_{f=1}^{m}\left(x_{if}-x_{jf}\right)^{2}}{2\sum_{j=1}^{N}u_{jk}^{2}} \tag{6}$$

eliminating the reference to cluster centres and thus clarifying that the dissimilarity metric is the

[9] We use the MATLAB routines of Balasko *et al.* (2004), where one can also find a presentation of different algorithms.

squared Euclidean distance between pairs of objects.

We wish to measure dissimilarity using one minus the correlation coefficient $(1-r)$, rather than the Euclidean distance. However, the two are related. Let $\widehat{x}_{it}$ denote the output gap of region i in period t, and x_{it} its standardized version (obtained by subtracting the mean and dividing by the standard deviation, both computed in a sample of T observations). It is straightforward that, for regions i and j:

$$r_{ij} = corr(\widehat{x}_i, \widehat{x}_j) = corr(x_i, x_j) = cov(x_i, x_j) \tag{7}$$

If one now computes the squared Euclidean distance between regions i and j on the basis of the T standardized output gaps one obtains:

$$d_{ij}^2 = \sum_{t=1}^{T}(x_{it} - x_{jt})^2 = \sum_{t=1}^{T} x_{it}^2 - 2\sum_{t=1}^{T} x_{it}x_{jt} + \sum_{t=1}^{T} x_{jt}^2 = 2T(1 - cov(x_i, x_j)) \tag{8}$$

Hence

$$d_{ij}^2 = 2T(1 - r_{ij}) \tag{9}$$

showing that the two dissimilarity metrics (d^2 and $1-r$) only differ by a multiplicative constant. Therefore, the FCM algorithm is applied by regarding the standardized output gaps in a given period as one of the m variables (we will have $m = T$).

For consistency with section 3, we form clusters in a rolling window way, taking a succession of overlapping subsamples of 10 years each ($T = 10$). In each subsample, the largest cluster in economic terms is taken to be the core, the others being assimilated to peripheries; we compute the economic size of a cluster by summing regional incomes weighted by membership coefficients.[10] The column of matrix U containing the coefficients of the core cluster is retained, and used for the computation of the summary statistics described below.

Let $u_{i,s}^*$denote the coefficient of membership to the core for region i ($i = 1, ..., N$) in window s. Its standard deviation across i, $\sigma_i(u_{i,s}^*)$, yields, for each subsample, a measure of the dispersion of the core membership coefficients. The higher this indicator, the easier it is to find clear-cut clusters, and hence the sharper is the contrast between the core and the periphery(ies). Further, we average $u_{i,s}^*$ across s to obtain $\bar{u}_i^*$, which is a summary measure of region i belongingness to the (possibly evolving) core. The standard deviation of $\bar{u}_i^*$, $\sigma(\bar{u}_i^*)$, indicates how unequal regions are in terms of core membership; high values of this statistic suggest an entrenched core-periphery divide, with regions tending to have permanently high, or permanently low, degrees of core membership.

An issue unaddressed so far concerns the choice of c in equation (1). Several statistics (also called validity measures) have been proposed in the literature to assess how well a given number of clusters represent the data (see e.g. Balasko *et al.*, 2004 or Tsangarides and Qureshi, 2006). However, optimization of c based on any of those validity measures might pose a problem of comparability between different monetary unions or different subsamples (since $u_{i,s}^*$ will on average decrease with c). Hence, rather than optimizing c each time the fuzzy clustering algorithm is run, we keep c constant across subsamples and monetary unions, and perform some sensitivity analysis over its value. Bearing in mind that the number of regions is often limited (e.g. 10 Canadian provinces or 9 USA Census regions), we consider the existence of 2, 3, or 4 clusters.

[10] More formally, for each cluster we take the respective column of matrix U, transpose it, and multiply it by a column vector of average regional incomes in the sample period considered.

4.2 Results

Figures 5 to 10 report indicator $\sigma_i(u^*_{i,s})$ for different monetary unions and different choices of the number of clusters. As before, each figure compares Europe with either Canada or the USA, the horizontal axis contains the mid (5th) year of each window, and corresponding results for BK filtered data can be found in Appendix C.

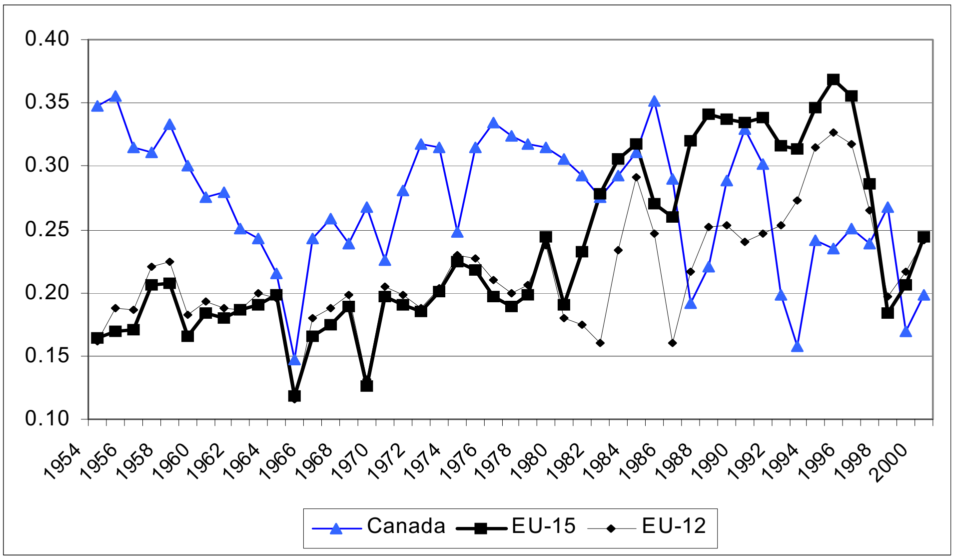

Figure 5 - Regional Dispersion of Core Membership for the EU and Canada (2 clusters)

Note: This and the following figures depict, for each 10-year window, the summary statistic $\sigma_i(u^*_{i,s})$, whose derivation is explained in the text.

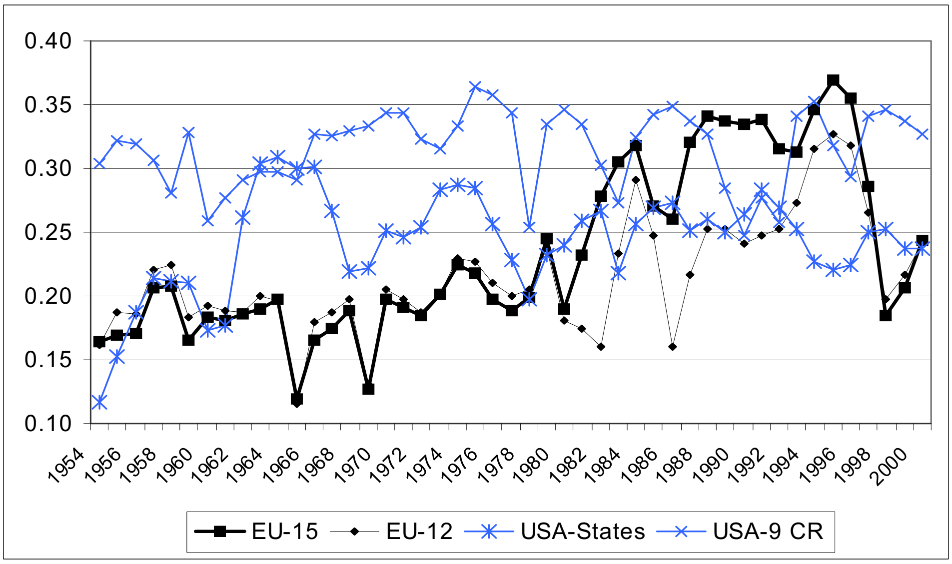

Figure 6 - Regional Dispersion of Core Membership for the EU and the USA (2 clusters)

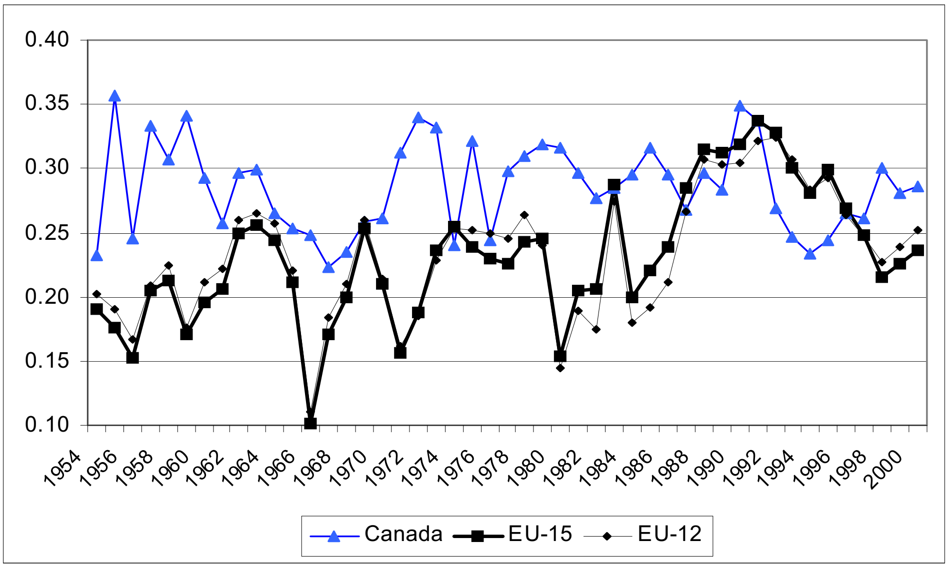

Figure 7 - Regional Dispersion of Core Membership for the EU and Canada (3 clusters)

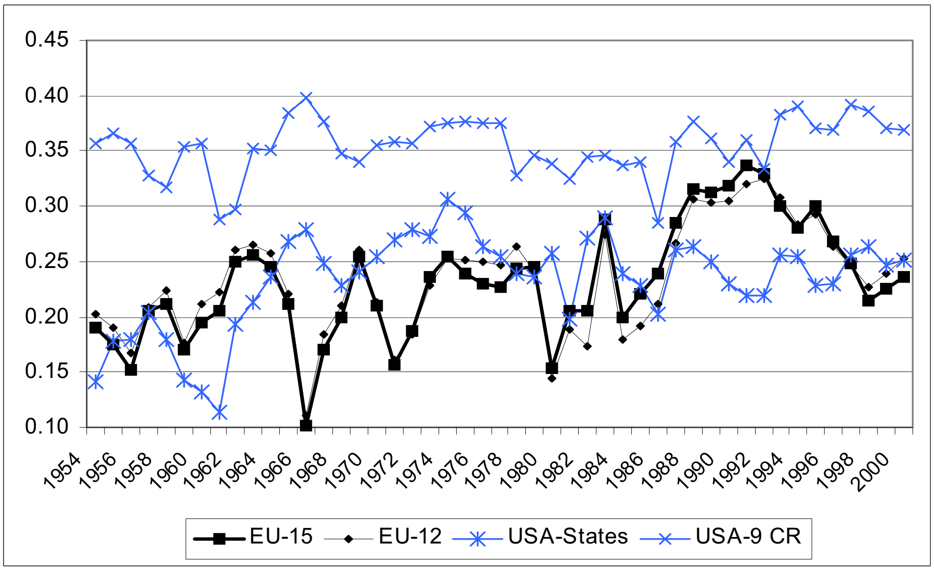

Figure 8 - Regional Dispersion of Core Membership for the EU and the USA (3 clusters)

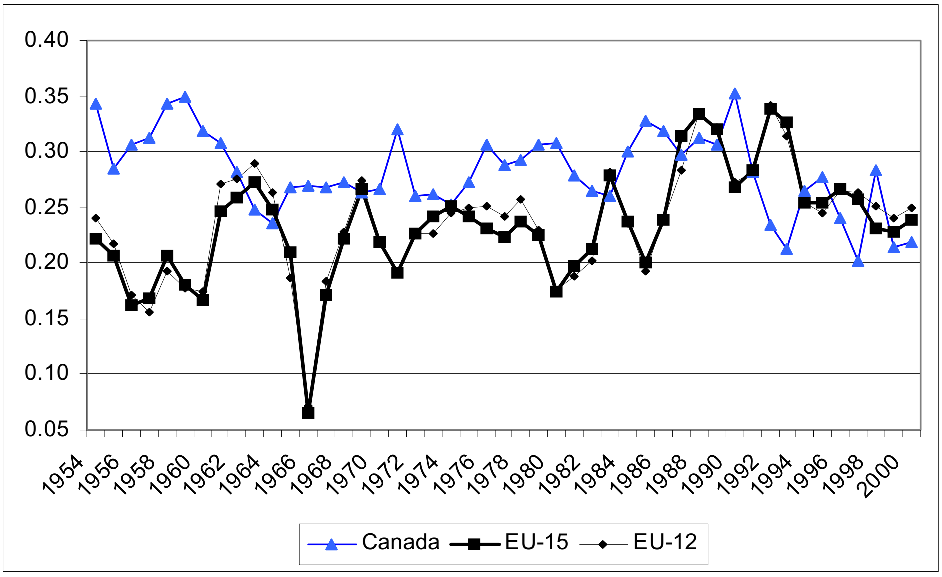

Figure 9 - Regional Dispersion of Core Membership for the EU and Canada (4 clusters)

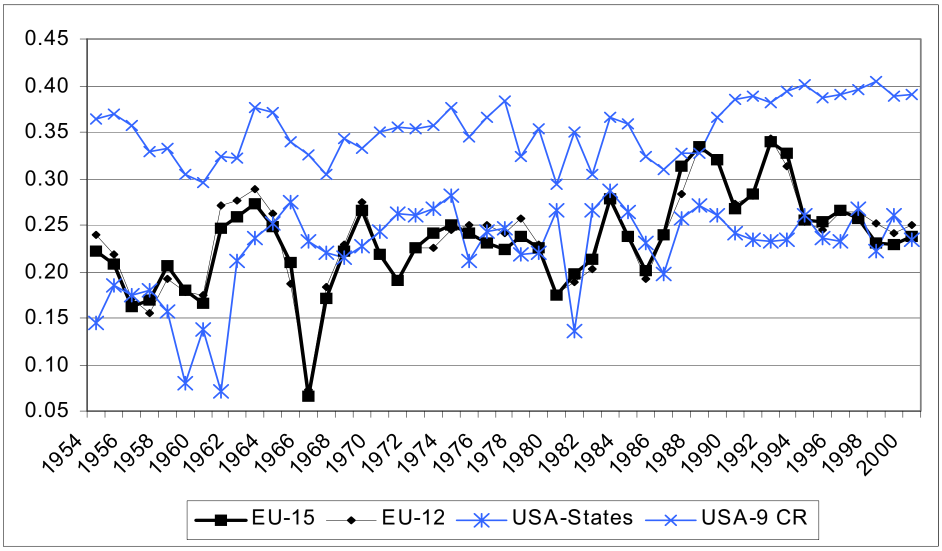

Figure 10 - Regional Dispersion of Core Membership for the EU and the USA (4 clusters)

Europe does not display a more intense core–periphery dichotomy than the North American unions. For both European aggregates, the values of the chosen indicator are roughly in line with those for USA states.[11,12] The same holds for the comparison with Canada, though the latter tends to have a more clear-cut core until the 70s. Further, with very few exceptions, the dispersion of core membership is considerably lower in Europe than in the USA Census regions, where easily identifiable core-periphery patterns are most prevalent.

[11] Throughout this section, results for the euro area (EU-12) are based on the coefficients ($u^*_{i,s}$) obtained when forming clusters in the EU-15 sample. An alternative would be to run the clustering algorithm for the 12 euro countries alone. We have checked that results would not be greatly changed.

[12] This comparison should be regarded with some prudence, due to the very different number of territorial units involved.

The said exceptions pertain to the 80s and 90s, when Europe shows an increase in the core-periphery contrast (especially under the assumption of two clusters), largely reversed in the very final years of the sample. In contrast, throughout 1950-2005 core membership dispersion remains high and fairly stable among USA Census regions. The reported statistic is more volatile in USA states (where no overall trend emerges) and in Canada (where the long-run trend, when discernible, is one of slight decline).

Results with BK-filtered data largely conform to the above paragraphs. The main differences are that core membership dispersion in Europe is now generally lower than in Canada, higher than among USA states, and with a more subdued rise in the 80s and 90s.

Table 6 (and Table C6 in Appendix C) display the statistic $\sigma(\bar{u}_i^*)$ in the different monetary unions (individual values of $\bar{u}_i^*$can be found in Appendix D, or are available upon request in the case of USA states). Values for Europe are consistently the lowest, suggesting, according to the interpretation presented before, that entrenched core-periphery divides are less of a problem in Europe than in North America. One remarks that the advantage (i.e., lower dispersion) of Europe is clearer in Table 6 than in the previous figures, suggesting that in Europe not only is the core-periphery contrast milder but also the core composition is more variable.

Table 6 - Regional Dispersion of Average Core Membership

	$c = 2$	$c = 3$	$c = 4$
Canada	0.16	0.16	0.18
EU-15	0.11	0.09	0.10
EU-12	0.09	0.08	0.09
USA-9 CR	0.15	0.21	0.20
USA-States	0.16	0.13	0.12

Note: The table reports the summary statistic $\sigma(\bar{u}_i^*)$, whose derivation is explained in the text.

As a whole, in the light of the preceding cluster analysis, Europe does not seem to fare any worse than the time-honoured North American monetary unions, and can even be regarded as outperforming them.

5 Conclusions

In this paper we have compared the degree of business cycle synchronization and the prevalence of core-periphery patterns in the European Union, Canada, and the USA. The territorial units considered are 15 EU member countries (those prior to the 2004 enlargement), 10 Canadian Provinces, and 50 USA states (plus Washington DC), which are alternatively aggregated into 9 Census regions. Results are also reported for the subset of EU-15 countries belonging to the euro area. Our sample spans more than half a century (1950-2005), and this long time dimension is exploited through rolling window analyses and formal statistical tests in and across subsamples. Data preparation has also been more detailed than in previous studies, particularly as regards the construction of individual deflators for the nominal income of each North American territorial unit. Throughout we cross-check results obtained with two detrending methods, the HP and BK filters.

Rolling window analysis suggests that cyclical correlations among European countries have substantially risen over time, reaching levels close to the most demanding benchmark in North America: the 9 USA Census regions. Both parts of this statement are corroborated by formal tests. Taking average pairwise correlations, the increase in the EU-15 from the first to the second half of the full sample is statistically significant, whereas the difference between the 9 USA regions and the euro area countries ceases to be so in subsamples excluding older observations. Clark and van Wincoop's (2001) border effect is therefore losing strength in the USA-euro area comparison.

We have applied fuzzy clustering to the analysis of core-periphery issues, working with the full matrix of bilateral correlations rather than with pre-defined anchor areas, and taking rolling window subsamples. The contrast between core and periphery(ies) in the EU-15 was strongest in the 80s and 90s. Apart from these decades, the core-periphery divide is less marked in Europe than in North America, especially when considering USA Census regions. Averaging across subsamples, we also find that European countries are much more similar in their degree of core belongingness than Canadian or USA territorial units. Our interpretation of this result is that in Europe the composition of the core is more variable, and therefore peripheral regions tend not to be always the same.

To sum up, our comparison exercise turns out clearly more favorable to Europe than what is common in the literature. From the viewpoint adopted - cyclical developments in economic activity, in line with the asymmetric shocks problem of OCA theory - Europe has developed into a workable monetary union.

References

[1] Angeloni, I., Dedola, L. (1999), From the ERM to the Euro: New Evidence on Economic and Policy Convergence Among EU Countries. European Central Bank Working Paper 4.

[2] Artis, M., Krolzig, H.M., Toro, J. (2004), "The European business cycle", *Oxford Economic Papers*, 56 (1): 1-44.

[3] Artis, M., Zhang, W. (1997), "International Business Cycles and the ERM: Is There an European Business Cycle?", *International Journal of Finance and Economics*, 2: 1-16.

[4] Artis, M., Zhang, W. (2001), "Core and Periphery in EMU: A Cluster Analysis", *Economic Issues*, 6 (2), September: 39-59.

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

[6] Balasko, B., Abonyi, J., Feil, B. (2004), Fuzzy Clustering and Data Analysis Toolbox: For Use with Matlab. Hungary, University of Veszpem.

[7] Bayoumi, T., Eichengreen, B. (1993), "Shocking Aspects of European Monetary Integration", in F. Torres and F. Giavazzi (Eds.) *Adjustment and Growth in the European Monetary Union*, Cambridge University Press.

[8] Baxter, M., King, R.G. (1999), "Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series", *The Review of Economics and Statistics*, 81 (4), November: 575-593.

[9] Beine, M., Coulombe, S. (2003), "Regional Perspectives on Dollarization in Canada", *Journal of Regional Science*, 43 (3): 541-569.

[10] Boreiko, D. (2003), "EMU and Accession Countries: Fuzzy Cluster Analysis of Membership", *International Journal of Finance and Econometrics*, 8 (4): 309-325.

[11] Burns, A.F., Mitchell, W.C. (1946), Measuring Business Cycles. NBER Studies in Business Cycles 2, New York: NBER.

[12] Camacho, M., Perez-Quiros, G., Saiz, L. (2006), "Are European Business Cycles Close Enough to Be Just One?", *Journal of Economic Dynamics and Control*, 30: 1687-1706.

[13] Carlino, G., Sill, K. (1997), "Regional Economies: Separating Trends from Cycles", *Business Review*, 1-13, Federal Reserve Bank of Philadelphia.

[14] Carlino, G., Sill, K. (2000), Regional Income Fluctuations: Common Trends and Common Cycles. Working Paper No. 00-08, Federal Reserve Bank of Philadelphia.

[15] Clark, T.E., van Wincoop, E. (2001), "Borders and Business Cycles", *Journal of International Economics*, 55: 59-85.

[16] Crowley, P.M. (2008), One money, several cycles? Evaluation of European business cycles using model-based cluster analysis. Bank of Finland Research Discussion Papers 3.

[17] DeJuan, J., Tomljanovich, M. (2005), "Income Convergence Across Canadian Provinces in the 20th Century: Almost but not quite there", *The Annals of Regional Science*, 39: 567-592.

[18] Feldstein, M. (2000), "The European Central Bank and the Euro: The First Year", *Journal of Policy Modeling*, 22 (3): 345-354.

[19] Frankel, J. A., Rose, A.K. (1998), "The Endogeneity of the Optimum Currency Area Criteria", *Economic Journal,* 108 (449): 1009-1025.

[20] Gayer, C. (2007), "A fresh look at business cycles synchronization in the euro area", *European Economy*, Economic Papers Number 287, September, Directorate-General for Economic and Financial Affairs.

[21] Heston, A., Summers, R., Aten, B. (2006), Penn World Table Version 6.2. Center for International Comparisons of Production, Income and Prices, University of Pennsylvania, September.

[22] Karras, G. (2003), "How homogenizing are monetary unions? Evidence from the U.S. states", The North American Journal of Economics and Finance, 14: 381-397.

[23] Kaufman, L., Rousseeuw, P. J. (1990), *Finding Groups in Data: An Introduction to Cluster Analysis*, Wiley Series in Probability and Mathematical Statistics, Wiley.

[24] Inklaar, R., Haan, J. (2001), "Is there really a European Business Cycle? A Comment", *Oxford Economic Papers*, 53 (2): 215-220.

[25] Maddison, A. (1989), *The World Economy in the 20th Century*, Development Centre Studies: OECD, Paris.

[26] Mink, M., Jacobs, J.P.A.M., Haan, J. (2007), Measuring Synchronicity and Co-movement of Business Cycles with an Application to the Euro Area. CESifo Working Paper No. 2112, October.

[27] Partridge, M.D., Rickman, D.S. (2005), "Regional Cyclical Asymmetries in an Optimal Currency Area: An Analysis using US State Data", *Oxford Economic Papers*, 57: 373-397.

[28] Perez, P.J., Osborn, D.R., Sensier, M. (2007), "Business Cycle Affiliations in the Context of European Integration", *Applied Economics*, 39: 199-214.

[29] Sorensen, P.B., Whitta-Jacobsen, H.J. (2005), *Introducing Advanced Macroeconomics: Growth and Business Cycles*, McGraw-Hill.

[30] Tootell, G.M.B. (1990), "Central Bank Flexibility and the Drawbacks to Currency Unification", *New England Economic Review*, May/June: 3-17.

[31] Tsangarides, C.G., Qureshi, M.S. (2006), What is Fuzzy About Clustering in West Africa? IMF Working Paper No. 06/90, March.

[32] Wynne, M.A., Koo, J. (2000), "Business Cycles under Monetary Union: A Comparison of the EU and US", *Economica,* 67: 347-374.

6 Appendix A - Data Sources and Deflators

Canada - Provincial data for Canada is from Statistics of Canada, Historical Statistics and Provincial Economic Accounts. Data is for Personal Income by Province at current prices. Data for the period 1947-1996 was kindly supplied by Marc Tomljanovich, from DeJuan and Tomljanovich (2005), and for 1996-2005 was taken from the "Provincial Economic Accounts, Selected Indicators", in the Statistics of Canada website (http://www.statcan.ca/start.html).[13] Canada has data available for Gross Provincial Product (GPP), but only for the period 1981-2005.

Provincial consumer price indices (CPI), used to deflate nominal personal income, are available only between 1981 and 2005 and were taken from the Statistics of Canada website. For the rest of the sample we use the CPI for regional cities (usually the capital of the province and/or its most important city), obtained as follows: for the period 1947-1971 we use the historical data provided by the Statistics of Canada, and for 1971-1981 we use data purchased from CANSIM, a data base from the Statistics of Canada. For each province, we then build a CPI series for 1947-2005 by applying the growth rates of the pre-1981 regional cities' CPI to the levels of the data for the provincial CPI.

Several details in the CPI series for the regional cities are worth noticing. The province of Prince Edward Island did not have an index for any of its cities; hence, between 1947 and 1980 we have applied the growth rate of the CPI of Montreal (in Quebec, the nearest province). For the province of Newfoundland and Labrador (which joined the Canadian Federation in 1949), the years between 1949 and 1951 did not present data for St. John's, its foremost city, so we have also used the growth rates of Montreal's CPI. Between 1971 and 1981, the data for the cities of Edmonton and Calgary (province of Alberta) and Regina and Saskatoon (province of Saskatchewan) were presented in separate indices, which was not the case in the historical data (1947-1971). In each of these provinces we have built a single CPI series for 1971-1981 by taking a population-weighted average of the CPI of the two cities.

[13] Though for most regions in the three monetary unions considered we have collected data from 1947 onwards, the sample used in the empirical work only starts in 1950, the first year in which no territorial units have missing values.

We have not considered the territories of Nunavut, Yukon, and Northwestern, given that data supplied by Marc Tomljanovich excluded these regions from the analysis. As can be seen from Table B1, their economic importance is residual.

European Union - Gross Domestic Product at 2000 constant prices for the EU-15 was taken from the Penn World Tables (PWT, version 6.2) for the 1950-2004 period. For 2005, not available in the PWT, we applied the real GDP growth rates from AMECO (Annual Macro Economic Database, European Commission). For the period between 1947 and 1950, also not available in the PWT, we use the real GDP growth rates from Maddison (1989), except for Luxembourg, which is not available there either. We also use growth rates from the Maddison database in two other instances of PWT missing values, namely Germany from 1950 to 1970 and Greece in 1951.

United States - The base variable is Personal Income by State at current prices, taken from the Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce, for the years 1947 to 2005, except for Alaska and Hawaii, for which data is available only from 1950. Nominal Gross State Product (GSP) is unavailable before 1963.

As state deflators were not available, we use the CPI of several cities in the USA, taken from the Bureau of Labor Statistics (BLS). Whenever data is available for the CPI of a city belonging to a given state, that specific CPI is used. If no such CPI exists, we use the CPI of the city located in the nearest state. If data exists for a city of a given state, but only for part of the sample, we fill in the missing years also with the growth rates of the CPI of the city located in the nearest state. Between 1950 and 1997 prices in Washington City and in Baltimore was presented as two distinct CPI, but afterwards as a single one; we have proceeded as in the cases of Edmonton-Calgary and Regina-Saskatoon.

7 Appendix B - List of Regions

Table B1 - Provinces of Canada

Canadian Provinces	Year of joining the Federation	Economic Weight (2005)
Alberta (ALB)	1905	11.9%
British Columbia (BC)	1871	12.6%
Manitoba (MAN)	1870	3.2%
New Brunswick (NB)	1867	2.0%
New Foundland and Labrador (NFD)	1949	1.3%
Nova Scotia (NS)	1867	2.6%
Ontario (ONT)	1867	40.8%
Prince Edward Island (PEI)	1873	0.4%
Quebec (QUE)	1867	22.0%
Saskatchewan (SAS)	1905	2.7%
Northwestern Territories (NWT)	1870	
Nunavut	1999	0.5%
Yukon (YUK)	1898	

Source: Statistics Canada

Table B2 - States of the USA

USA States	Year of joining the Federation	Economic Weight (2005)
Alabama (AL)	1819	1.3%
Alaska (AK)	1959	0.2%
Arizona (AZ)	1912	1.8%
Arkansas (AR)	1836	0.7%
California (CA)	1850	13.1%
Colorado (CO)	1876	1.7%
Connecticut (CT)	1788	1.6%
Delaware (DE)	1787	0.3%
District of Columbia (DC)	1790	0.3%
Florida (FL)	1845	5.8%
Georgia (GA)	1788	2.8%
Hawaii (HI)	1959	0.4%
Idaho (ID)	1890	0.4%
Illinois (IL)	1818	4.5%
Indiana (IN)	1816	1.9%
Iowa (IA)	1846	0.9%
Kansas (KS)	1861	0.9%
Kentucky (KY)	1792	1.2%
Louisiana (LA)	1812	1.1%
Maine (ME)	1820	0.4%
Maryland (MD)	1788	2.3%
Massachusetts (MA)	1788	2.8%
Michigan (MI)	1837	3.3%
Minnesota (MN)	1858	1.9%
Mississippi (MS)	1817	0.7%
Missouri (MO)	1821	1.8%
Montana (MT)	1889	0.3%
Nebraska (NE)	1867	0.6%
Nevada (NV)	1864	0.8%
New Hampshire (NH)	1788	0.5%
New Jersey (NJ)	1787	3.7%
New Mexico (NM)	1912	0.5%
New York (NY)	1788	7.6%
North Carolina (NC)	1789	2.6%
North Dakota (ND)	1889	0.2%
Ohio (OH)	1803	3.6%
Oklahoma (OK)	1907	1.0%
Oregon (OR)	1859	1.1%

Table B2 - States of the USA (cont.)

USA States	Year of joining the Federation	Economic Weight (2005)
Pennsylvania (PA)	1787	4.2%
Rhode Island (RI)	1790	0.4%
South Carolina (SC)	1788	1.2%
South Dakota (SD)	1889	0.2%
Tennessee (TN)	1796	1.8%
Texas (TX)	1845	7.2%
Utah (UT)	1896	0.7%
Vermont (VT)	1791	0.2%
Virginia (VA)	1788	2.8%
Washington (WA)	1889	2.2%
West Virginia (WV)	1863	0.5%
Wisconsin (WI)	1848	1.8%
Wyoming (WY)	1890	0.2%

Source: USA Census Bureau

Table B3 - Census Bureau Regions and Divisions

	Region 1 - Northeast	
New England (NENG)		*Middle Atlantic* (MATL)
(5.2%)		(14.6%)
Connecticut		New Jersey
Maine		New York
Massachusetts		Pennsylvania
New Hampshire		
Rhode Island		
Vermont		
	Region 2 - Midwest	
East North Central (ENC)		*West North Central* (WNC)
(15.4%)		(6.7%)
Indiana		Iowa
Illinois		Kansas
Michigan		Minnesota
Ohio		Missouri
Wisconsin		Nebraska
		North Dakota
		South Dakota
	Region 3 - South	
South Atlantic (SATL)	*East South Central* (ESC)	*West South Central* (WSC)
(18.8%)	(5.2%)	(11.2%)
Delaware	Alabama	Arkansas
Washington District of Columbia	Kentucky	Louisiana
Florida	Mississippi	Oklahoma
Georgia	Tennessee	Texas
Maryland		
North Carolina		
South Carolina		
Virginia		
West Virginia		
	Region 4 - West	
Mountain (MTN)		*Pacific* (PAC)
(6.3%)		(16.5%)
Arizona		Alaska
Colorado		California
Idaho		Hawaii
New Mexico		Oregon
Montana		Washington
Utah		
Nevada		
Wyoming		

Source: USA Census Bureau. For each region the table reports economic weight and comprised states.

Table B4 - Member Countries of the EU-15

EU Members	Year of Accession	Economic Weight (2005)*
Austria (AT)	1995	2.4%
Belgium (BE)	1957	2.9%
Denmark (DK)	1973	1.6%
Finland (FIN)	1995	1.4%
France (FR)	1957	16.1%
Germany (DE)	1957	21.6%
Greece (EL)	1981	2.2%
Ireland (IE)	1973	1.4%
Italy (IT)	1957	14.0%
Luxembourg (LU)	1957	0.3%
Netherlands (NL)	1957	4.9%
Portugal (PT)	1986	1.8%
Spain (ES)	1986	10.1%
Sweden (SE)	1995	2.5%
United Kingdom (UK)	1973	16.8%

* Based on PPS-adjusted GDP (Source: AMECO - Annual Macro Economic Database, European Commission, Spring 2007 release)

8 Appendix C - Results for the Baxter and King (BK) filter

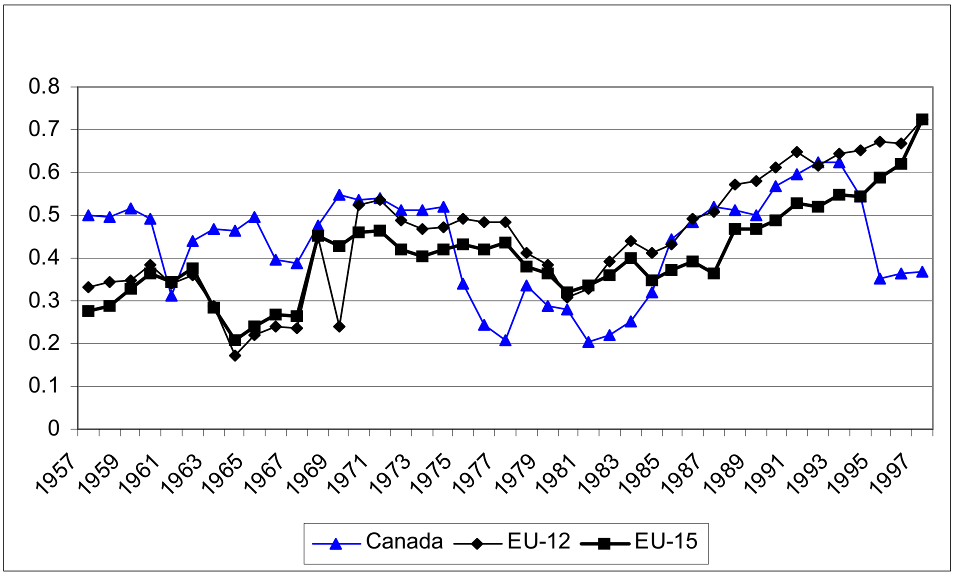

Figure C1 - Average Bilateral Correlations for the EU and Canada (10-year rolling windows)

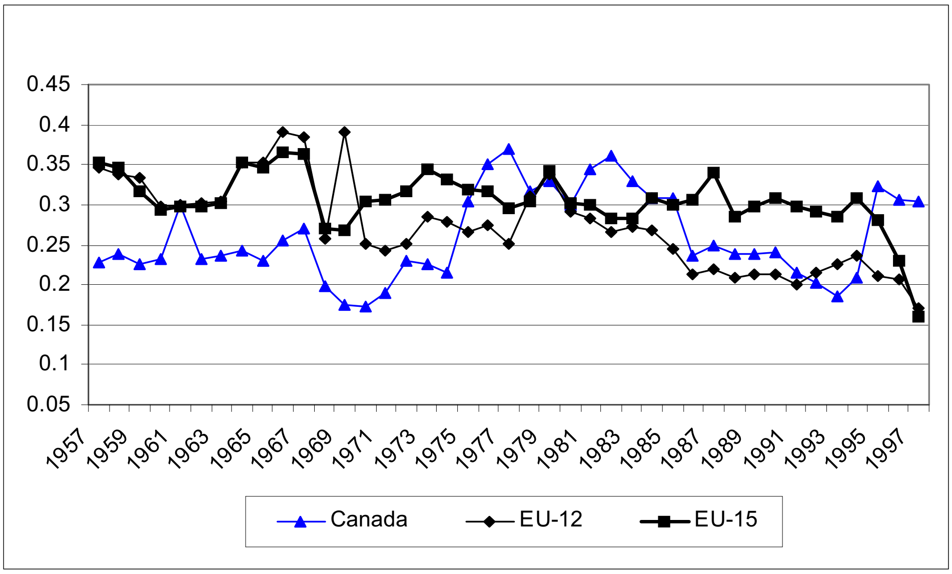

Figure C2 - Standard Deviation of Bilateral Correlations for the EU and Canada (10-year rolling windows)

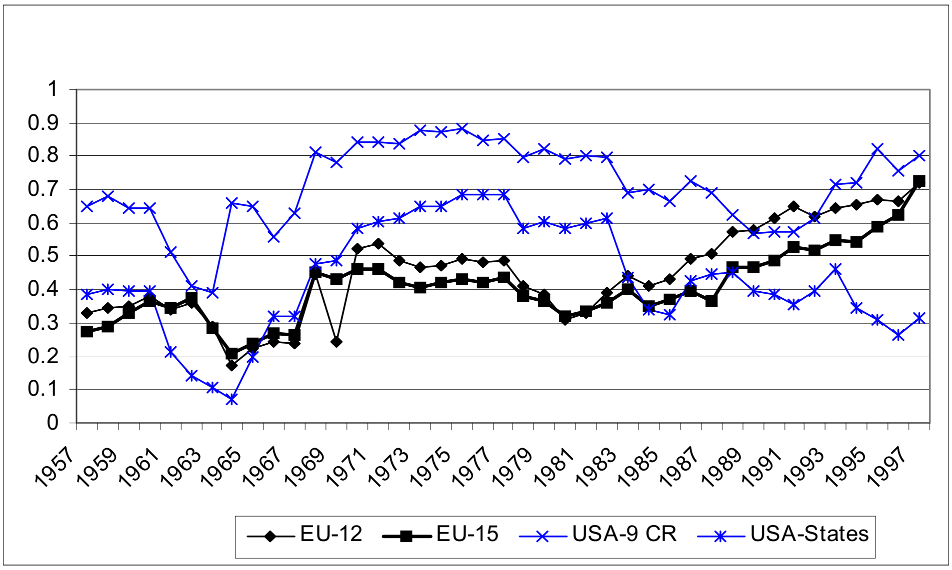

Figure C3 - Average Bilateral Correlations for the EU and the USA (10-year rolling windows)

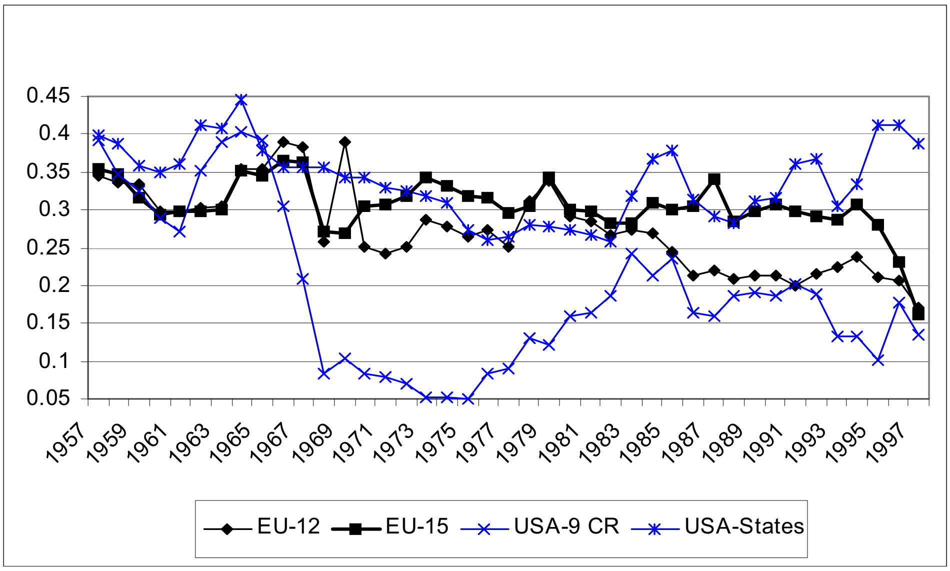

Figure C4 - Standard Deviation of Bilateral Correlations for the EU and the USA (10-year rolling windows)

Table C1 - Business Cycle Correlations for the Canadian Provinces (BK Filter)

	ALB	BC	MAN	NB	NFD	NS	ONT	PEI	QUE	SAS
1953 - 1977										
Alberta (ALB)										
British Columbia (BC)	0.57***									
	(0.15)									
Manitoba (MAN)	0.71***	0.50***								
	(0.10)	(0.19)								
New Brunswick (NB)	0.44***	0.50***	0.49***							
	(0.13)	(0.12)	(0.13)							
New Foundland and Labrador (NFI	0.20	0.41***	-0.06	0.37*						
	(0.15)	(0.14)	(0.19)	(0.20)						
Nova Scotia (NS)	0.32***	0.62***	0.50***	0.51***	0.43***					
	(0.11)	(0.10)	(0.12)	(0.13)	(0.13)					
Ontario (ONT)	0.63***	0.78***	0.57***	0.64***	0.41**	0.55***				
	(0.15)	(0.07)	(0.14)	(0.11)	(0.18)	(0.10)				
Prince Edward Island (PEI)	0.49**	0.37**	0.49***	0.55***	0.08	0.18	0.29**			
	(0.20)	(0.17)	(0.15)	(0.14)	(0.17)	(0.16)	(0.14)			
Quebec (QUE)	0.44***	0.66***	0.29*	0.55***	0.72***	0.59***	0.76***	0.26*		
	(0.14)	(0.10)	(0.15)	(0.13)	(0.07)	(0.10)	(0.08)	(0.15)		
Saskatchewan (SAS)	0.81***	0.43**	0.75***	0.43***	0.01	0.22	0.54***	0.34**	0.24*	
	(0.07)	(0.19)	(0.10)	(0.14)	(0.15)	(0.15)	(0.16)	(0.15)	(0.13)	
1978-2002										
	ALB	**BC**	**MAN**	**NB**	**NFD**	**NS**	**ONT**	**PEI**	**QUE**	**SAS**
Alberta (ALB)										
British Columbia (BC)	0.69***									
	(0.10)									
Manitoba (MAN)	0.43***	0.34*								
	(0.12)	(0.20)								
New Brunswick (NB)	0.24*	0.33*	0.53***							
	(0.14)	(0.17)	(0.19)							
New Foundland and Labrador (NFI	0.27**	0.32	0.35*	0.64***						
	(0.14)	(0.22)	(0.21)	(0.15)						
Nova Scotia (NS)	0.33***	0.22	0.69***	0.77***	0.57***					
	(0.13)	(0.23)	(0.10)	(0.09)	(0.17)					
Ontario (ONT)	0.26*	0.50***	0.40***	0.59***	0.40**	0.59***				
	(0.13)	(0.15)	(0.14)	(0.15)	(0.19)	(0.14)				
Prince Edward Island (PEI)	-0.23	-0.07	-0.03	0.56***	0.43***	0.37*	0.46***			
	(0.19)	(0.26)	(0.24)	(0.15)	(0.15)	(0.21)	(0.15)			
Quebec (QUE)	0.38***	0.71***	0.42*	0.29	0.36*	0.37	0.75***	0.15		
	(0.09)	(0.08)	(0.24)	(0.21)	(0.21)	(0.24)	(0.07)	(0.22)		
Saskatchewan (SAS)	0.47**	0.40*	0.57***	0.48***	0.25	0.39**	0.04	0.03	0.09	
	(0.23)	(0.21)	(0.18)	(0.15)	(0.21)	(0.19)	(0.14)	(0.23)	(0.17)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

Table C2 - Business Cycle Correlations for the 9 USA Census Regions (BK Filter)

1953 - 1977

	NENG	MATL	ENC	WNC	SATL	ESC	WSC	MTN	PAC
New England (NENG)									
Middle Atlantic (MATL)	0.87***								
	(0.04)								
East North Central (ENC)	0.86***	0.78***							
	(0.05)	(0.06)							
West North Central (WNC)	0.61***	0.74***	0.65***						
	(0.12)	(0.11)	(0.13)						
South Atlantic (SATL)	0.80***	0.72***	0.90***	0.67***					
	(0.09)	(01.0)	(0.03)	(0.11)					
East South Central (ESC)	0.85***	0.82***	0.88***	0.74***	0.91***				
	(0.06)	(0.07)	(0.04)	(0.09)	(0.03)				
West South Central (WSC)	0.86***	0.91***	0.87***	0.84***	0.83***	0.91***			
	(0.04)	(0.04)	(0.03)	(0.08)	(0.05)	(0.03)			
Mountain (MTN)	0.52***	0.60***	0.49***	0.63***	0.48**	0.44**	0.61***		
	(0.17)	(0.17)	(0.13)	(0.15)	(0.19)	(0.17)	(0.17)		
Pacific (PAC)	0.77***	0.88***	0.82***	0.76***	0.76***	0.82***	0.89***	0.65***	
	(0.07)	(0.05)	(0.04)	(0.14)	(0.08)	(0.06)	(0.05)	(0.18)	

1978 - 2002

	NENG	MATL	ENC	WNC	SATL	ESC	WSC	MTN	PAC
New England (NENG)									
Middle Atlantic (MATL)	0.93***								
	(0.03)								
East North Central (ENC)	0.77***	0.66***							
	(0.05)	(0.08)							
West North Central (WNC)	0.82***	0.74***	0.79***						
	(0.06)	(0.10)	(0.08)						
South Atlantic (SATL)	0.72***	0.59***	0.89***	0.68***					
	(0.04)	(0.07)	(0.04)	(0.13)					
East South Central (ESC)	0.78***	0.71***	0.89***	0.84***	0.75***				
	(0.05)	(0.10)	(0.03)	(0.05)	(0.07)				
West South Central (WSC)	0.88***	0.80***	0.92***	0.82***	0.82***	0.91***			
	(0.03)	(0.08)	(0.03)	(0.07)	(0.03)	(0.03)			
Mountain (MTN)	0.91***	0.87***	0.64***	0.80***	0.54***	0.72***	0.77***		
	(0.04)	(0.05)	(0.09)	(0.08)	(0.10)	(0.05)	(0.09)		
Pacific (PAC)	0.60***	0.53***	0.63***	0.71***	0.39**	0.55***	0.57***	0.67***	
	(0.08)	(0.11)	(0.12)	(0.06)	(0.18)	(0.12)	(0.11)	(0.07)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

Table C3 - Business Cycle Correlations for the EU-15 Member Countries (BK Filter)

1953 - 1977

	AT	BE	FIN	FR	DE	EL	IE	IT	LU	NL	PT	ES	DK	SE	UK
Austria (AT)															
Belgium (BE)	0.53***														
	(0.10)														
Finland (FIN)	0.63***	0.62***													
	(0.12)	(0.12)													
France (FR)	0.24	0.64***	0.19												
	(0.23)	(0.18)	(0.20)												
Germany (DE)	0.56***	0.56***	0.52**	0.46***											
	(0.07)	(0.09)	(0.16)	(0.16)											
Greece (EL)	0.07	0.12	-0.09	0.37***	0.39**										
	(0.14)	(0.13)	(0.15)	(0.13)	(0.19)										
Ireland (IE)	0.26*	0.46***	0.41**	0.10	0.43***	0.01									
	(0.14)	(0.13)	(0.18)	(0.25)	(0.11)	(0.19)									
Italy (IT)	0.26	0.55***	0.30	0.36*	0.22	-0.22*	0.50***								
	(0.17)	(0.19)	(0.19)	(0.20)	(0.20)	(0.13)	(0.09)								
Luxembourg (LU)	0.28*	0.62***	0.34**	0.70***	0.54***	0.27	0.35**	0.32							
	(0.16)	(0.15)	(0.17)	(0.07)	(0.11)	(0.19)	(0.19)	(0.26)							
Netherlands (NL)	0.52***	0.73***	0.60***	0.40**	0.55***	-0.11	0.42***	0.30	0.29**						
	(0.09)	(0.09)	(0.12)	(0.20)	(0.08)	(0.11)	(0.11)	(0.18)	(0.12)						
Portugal (PT)	0.38**	0.58***	0.18	0.51**	0.44**	0.20	0.56***	0.56***	0.51**	0.40***					
	(0.16)	(0.18)	(0.19)	(0.22)	(0.19)	(0.19)	(0.10)	(0.16)	(0.23)	(0.10)					
Spain (ES)	0.54***	0.54***	0.45***	0.34*	0.11	0.09	0.17	0.31**	0.31	0.30**	0.29**				
	(0.16)	(0.09)	(0.15)	(0.18)	(0.12)	(0.13)	(0.13)	(0.15)	(0.19)	(0.13)	(0.14)				
Denmark (DK)	0.18	0.44**	0.18	0.30	0.52**	0.30	0.33*	0.25	0.35**	0.32*	0.45***	-0.04			
	(0.20)	(0.14)	(0.22)	(0.21)	(0.22)	(0.22)	(0.19)	(0.22)	(0.16)	(0.17)	(0.15)	(0.12)			
Sweden (SE)	-0.08	0.39**	0.43***	-0.10	-0.01	-0.07	0.06	0.05	0.04	0.24	-0.26*	0.10	0.08		
	(0.16)	(0.16)	(0.13)	(0.17)	(0.22)	(0.17)	(0.21)	(0.20)	(0.19)	(0.15)	(0.15)	(0.11)	(0.20)		
United Kingdom (UK)	0.40***	0.64***	0.38***	0.32	0.59***	0.33	0.61***	0.37*	0.48***	0.51***	0.71***	0.16	0.50***	0.08	
	(0.11)	(0.09)	(0.14)	(0.26)	(0.12)	(0.22)	(0.07)	(0.19)	(0.16)	(0.12)	(0.12)	(0.14)	(0.15)	(0.18)	

1978 - 2002

	AT	BE	FIN	FR	DE	EL	IE	IT	LU	NL	PT	ES	DK	SE	UK
Austria (AT)															
Belgium (BE)	0.44***														
	(0.13)														
Finland (FIN)	0.27**	0.55***													
	(0.11)	(0.08)													
France (FR)	0.56***	0.68***	0.51***												
	(0.11)	(0.14)	(0.13)												
Germany (DE)	0.66***	0.65***	0.01	0.53***											
	(0.10)	(0.08)	(0.13)	(0.15)											
Greece (EL)	0.32	0.55***	0.15	0.44***	0.63***										
	(0.21)	(0.12)	(0.17)	(0.13)	(0.11)										
Ireland (IE)	0.29	0.53***	0.38**	0.53***	0.47***	0.53***									
	(0.19)	(0.11)	(0.19)	(0.11)	(0.10)	(0.14)									
Italy (IT)	0.56***	0.85***	0.53***	0.62***	0.70***	0.58***	0.50***								
	(0.09)	(0.05)	(0.10)	(0.14)	(0.09)	(0.13)	(0.14)								
Luxembourg (LU)	0.43***	0.51***	0.18	0.52***	0.60***	0.44***	0.30**	0.37***							
	(0.14)	(0.11)	(0.13)	(0.15)	(0.09)	(0.14)	(0.14)	(0.12)							
Netherlands (NL)	0.47***	0.67***	0.28**	0.56***	0.79***	0.62***	0.64***	0.66***	0.71***						
	(0.18)	(0.07)	(0.12)	(0.16)	(0.06)	(0.11)	(0.12)	(0.10)	(0.08)						
Portugal (PT)	0.36***	0.53***	0.41***	0.63***	0.27	0.09	0.31**	0.51***	0.30*	0.26					
	(0.11)	(0.14)	(0.11)	(0.08)	(0.19)	(0.15)	(0.14)	(0.13)	(0.17)	(0.21)					
Spain (ES)	0.36*	0.75***	0.48***	0.80***	0.53***	0.33**	0.46***	0.65***	0.53***	0.61***	0.71***				
	(0.20)	(0.06)	(0.14)	(0.07)	(0.16)	(0.16)	(0.12)	(0.11)	(0.12)	(0.11)	(0.11)				
Denmark (DK)	0.31*	0.27	0.12	0.32	0.45***	0.38***	0.22	0.40**	0.35*	0.52***	-0.10	0.11			
	(0.17)	(0.22)	(0.22)	(0.21)	(0.15)	(0.14)	(0.22)	(0.17)	(0.18)	(0.11)	(0.20)	(0.24)			
Sweden (SE)	0.48***	0.70***	0.71***	0.64***	0.45***	0.30*	0.43**	0.79***	0.36**	0.58***	0.34**	0.60***	0.53***		
	(0.13)	(0.09)	(0.10)	(0.12)	(0.15)	(0.16)	(0.18)	(0.06)	(0.18)	(0.12)	(0.17)	(0.11)	(0.17)		
United Kingdom (UK)	0.16	0.24**	0.52***	0.39***	0.14	0.24	0.22	0.33***	0.33**	0.36**	0.12	0.33*	0.50***	0.54***	
	(0.20)	(0.12)	(0.20)	(0.13)	(0.27)	(0.19)	(0.20)	(0.10)	(0.16)	(0.16)	(0.20)	(0.17)	(0.19)	(0.09)	

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively

Table C4 - Significance of Average Bilateral Correlations (BK Filter)

Monetary Unions	Canada	EU-15	EU-12	USA-9 CR
1953 – 1977				
	0.46***	0.33***	0.37***	0.75***
	(0.06)	(0.06)	(0.08)	(0.06)
1978 – 2002				
	0.38***	0.45***	0.49***	0.74***
	(0.09)	(0.05)	(0.05)	(0.05)
Change	−0.08	0.12	0.12	0.01
	(0.11)	(0.07)	(0.09)	(0.07)

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively.

Table C5 - Average Bilateral Correlations: Comparing Monetary Unions (BK Filter)

1953 – 2002			
	USA-9 CR	EU-15	EU-12
CAN	−0.32***	0.05	0.02
	(0.06)	(0.07)	(0.07)
USA-9 CR		0.37***	0.34***
		(0.05)	(0.05)
1978 – 2002			
	USA-9 CR	EU-15	EU-12
CAN	−0.36***	−0.07	−0.12
	(0.08)	(0.10)	(0.10)
USA-9 CR		0.29***	0.25***
		(0.06)	(0.07)
1986 – 2002			
	USA-9 CR	EU-15	EU-12
CAN	−0.19*	−0.02	−0.12
	(0.10)	(0.12)	(0.12)
USA-9 CR		0.18**	0.08
		(0.08)	(0.08)

Note: (*), (**), and (***) denote significance at 10%, 5%, and 1% levels, respectively. Each entry is the difference in average pairwise correlations between the union in row and the one in column.

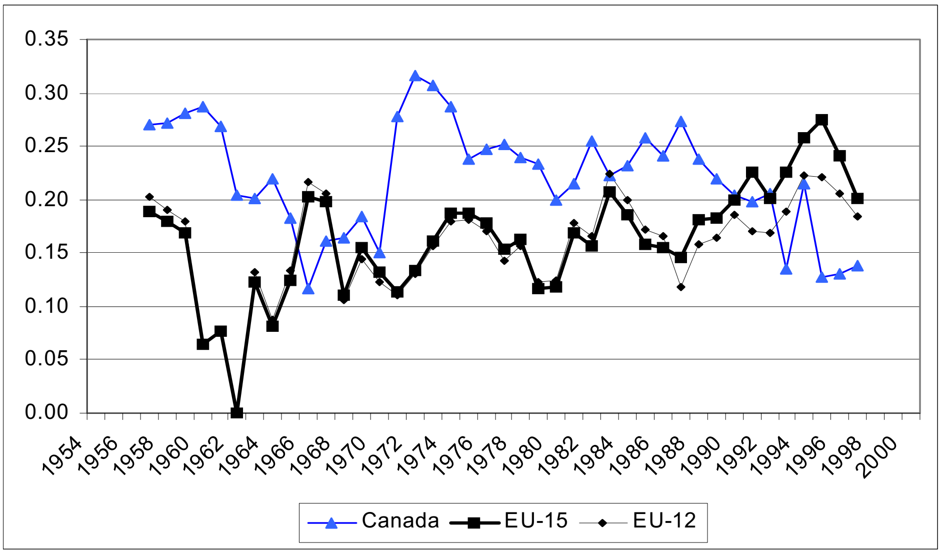

Figure C5 - Regional Dispersion of Core Membership for the EU and Canada (2 clusters)

Note: This and the following figures depict, for each 10-year window, the summary statistic $\sigma_i(u^*_{i,s})$, whose derivation is explained in the text. There are a few cases of very low dispersion, and indeed one window (1958-1967) where the clustering algorithm, despite different initializations, always converged to virtually identical coefficients for the 15 European countries. Excluding these "outlier" subsamples from the analysis would not change our conclusions to any significant degree.

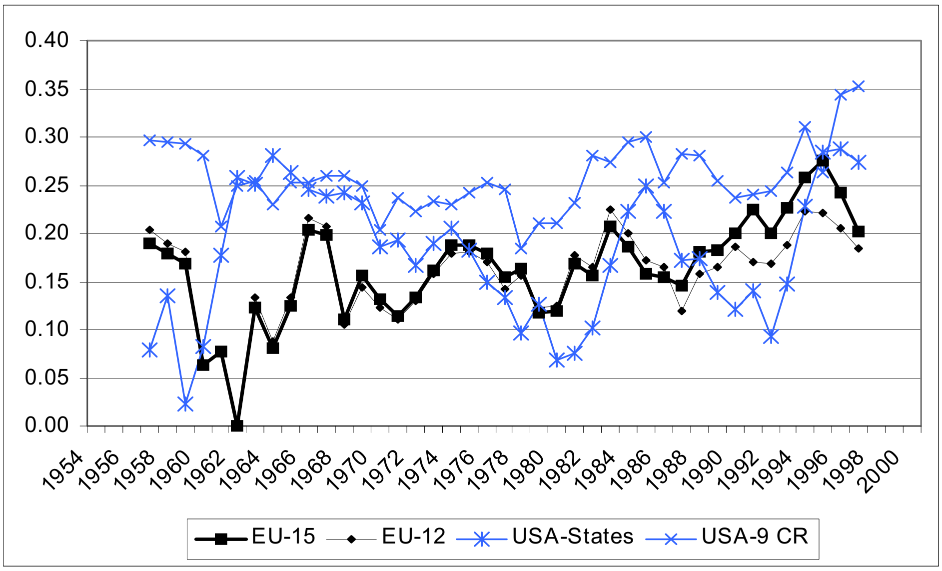

Figure C6 - Regional Dispersion of Core Membership for the EU and the USA (2 clusters)

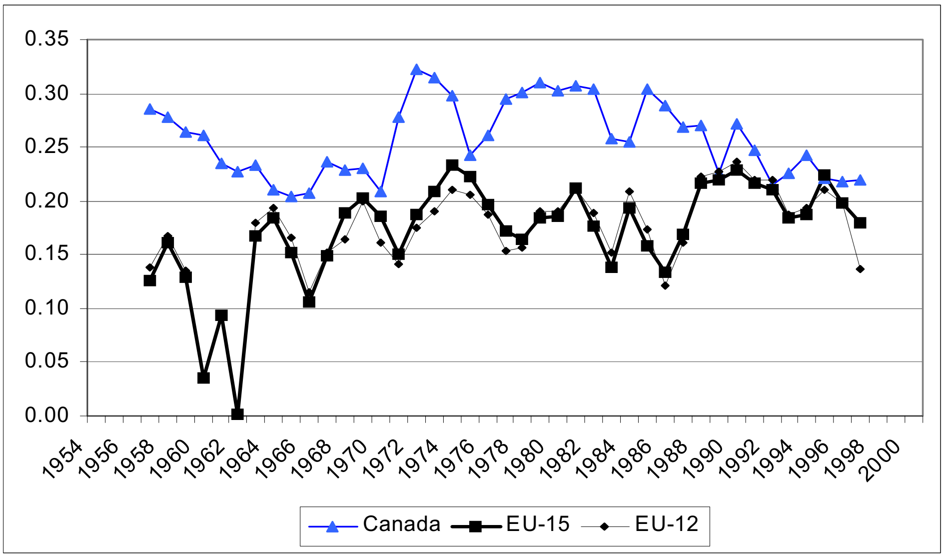

Figure C7 - Regional Dispersion of Core Membership for the EU and Canada (3 clusters)

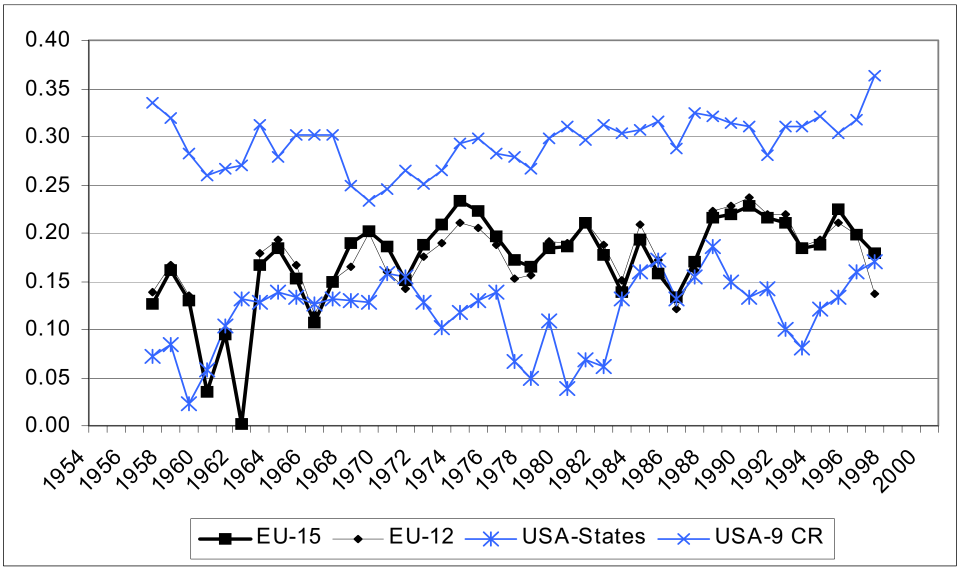

Figure C8 - Regional Dispersion of Core Membership for the EU and the USA (3 clusters)

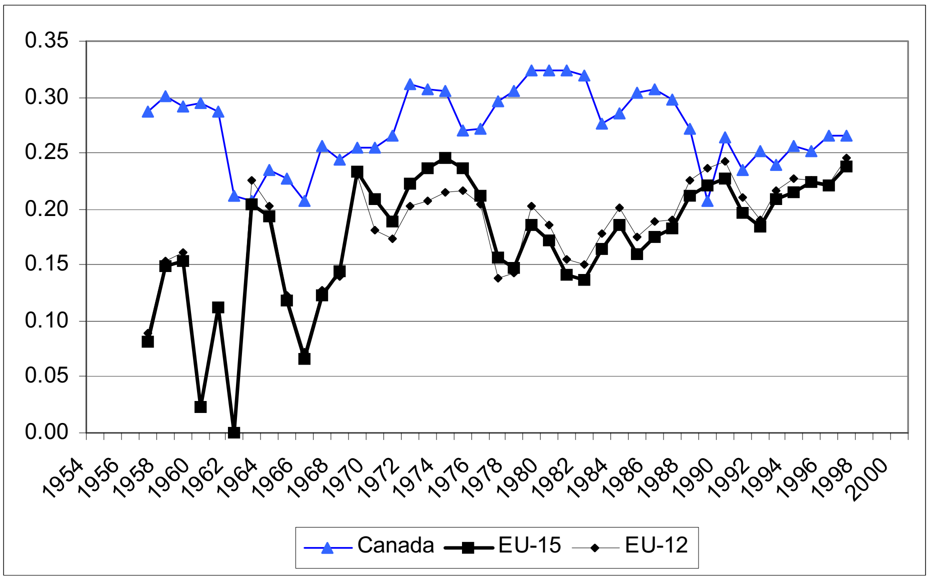

Figure C9 - Regional Dispersion of Core Membership for the EU and Canada (4 clusters)

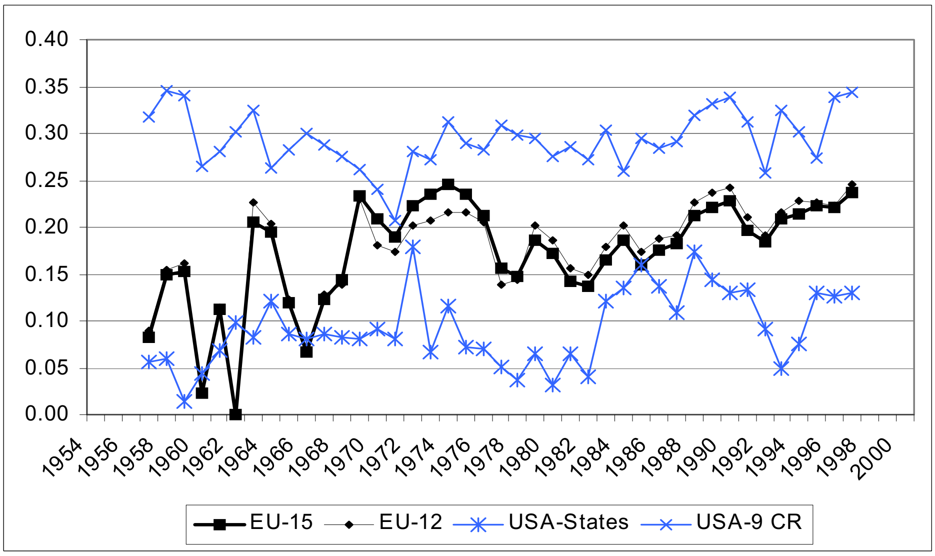

Figure C10 - Regional Dispersion of Core Membership for the EU and the USA (4 clusters)

Table C6 - Regional Dispersion of Average Core Membership (BK Filter)

	$c = 2$	$c = 3$	$c = 4$
Canada	0.10	0.15	0.18
EU-15	0.06	0.06	0.07
EU-12	0.07	0.05	0.07
USA-9 CR	0.15	0.13	0.13
USA-States	0.12	0.09	0.06

Note: The table reports the summary statistic $\sigma(\bar{u}_i^*)$, whose derivation is explained in the main text.

9 Appendix D - Further Results of Cluster Analysis

Table D1 - Average Core Membership: Canada

	HP filter			BK filter		
	c = 2	c = 3	c = 4	c = 2	c = 3	c = 4
Alberta	0.31	0.22	0.16	0.45	0.22	0.15
British Columbia	0.50	0.40	0.33	0.55	0.41	0.35
Manitoba	0.55	0.34	0.23	0.43	0.22	0.21
New Brunswick	0.76	0.54	0.30	0.44	0.32	0.19
New Foundland and Lab.	0.64	0.38	0.18	0.48	0.33	0.15
Nova Scotia	0.77	0.54	0.41	0.50	0.29	0.26
Ontario	0.82	0.75	0.75	0.68	0.61	0.63
Pr. Edward Island	0.55	0.44	0.29	0.41	0.29	0.16
Quebec	0.61	0.45	0.38	0.68	0.64	0.59
Saskatchewan	0.36	0.16	0.07	0.38	0.15	0.08

Note: This and the following tables report the summary statistic $\bar{u}_i^*$, whose derivation is explained in the main text.

Table D2 - Average Core Membership: USA Census Regions

	HP filter			BK filter		
	c = 2	c = 3	c = 4	c = 2	c = 3	c = 4
East North Central	0.65	0.43	0.32	0.56	0.46	0.43
East South Central	0.56	0.26	0.20	0.53	0.42	0.29
Middle Atlantic	0.78	0.74	0.66	0.79	0.64	0.55
Mountain	0.35	0.17	0.09	0.47	0.25	0.18
New England	0.71	0.62	0.49	0.66	0.42	0.26
Pacific	0.81	0.75	0.63	0.72	0.56	0.40
South Atlantic	0.81	0.55	0.44	0.77	0.54	0.44
West North Central	0.46	0.22	0.14	0.28	0.24	0.19
West South Central	0.55	0.34	0.24	0.51	0.31	0.16

Table D3 - Average Core Membership: European Union

	HP filter			BK filter		
	c = 2	c = 3	c = 4	c = 2	c = 3	c = 4
Austria	0.61	0.34	0.27	0.58	0.35	0.28
Belgium	0.64	0.47	0.40	0.51	0.37	0.27
Denmark	0.45	0.31	0.23	0.57	0.45	0.35
Finland	0.36	0.25	0.18	0.45	0.29	0.20
France	0.68	0.54	0.49	0.54	0.40	0.35
Germany	0.72	0.50	0.45	0.69	0.51	0.45
Greece	0.65	0.47	0.36	0.60	0.43	0.35
Ireland	0.56	0.33	0.24	0.51	0.34	0.24
Italy	0.59	0.40	0.31	0.45	0.35	0.25
Luxembourg	0.49	0.33	0.22	0.51	0.33	0.23
Netherlands	0.56	0.41	0.27	0.57	0.33	0.26
Portugal	0.64	0.38	0.30	0.49	0.31	0.21
Spain	0.54	0.49	0.38	0.48	0.36	0.30
Sweden	0.36	0.25	0.18	0.47	0.29	0.20
United Kingdom	0.36	0.25	0.16	0.52	0.36	0.22