MEASURING THE INTERMITTENT SYNCHRONICITY OF MACROECONOMIC GROWTH IN EUROPE

By

Patrick M. Crowley* and Aaron P. Schultz**

*College of Business
Texas A&M University – Corpus Christi
6300 Ocean Drive,
Corpus Christi, TX 78412
USA
Tel.: +1 361.825.6011
e-mail: patrick.crowley@tamucc.edu

**Athinoula A.Martinos Center for Biomedical Imaging and Massachusetts General Hospital,
149 Thirteenth Street, Suite 2301,
Charlestown, MA 02129,
USA
e-mail: aschultz@nmr.mgh.harvard.edu

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Abstract

Synchronization of growth rates are an important feature of international business cycles, particularly in relation to regional integration projects such as the single currency in Europe. Synchronization of growth rates clearly enhances the effectiveness of European Central Bank monetary policy, ensuring that policy changes are attuned to the dynamics of growth and business cycles in the majority of member states. In this paper a dissimilarity metric is constructed by measuring the topological differences between the GDP growth patterns in recurrence plots for individual countries. The results show that synchronization of growth rates were higher among the euro area member states during the second half of the 1980s and from 1997 to roughly 2002. Apart from these two time periods, euro area member states do not appear to be more synchronized than a group of major international countries, signifying that globalization was the major cause of international business cycle synchronization.

Keywords: Euro area, business cycles, growth cycles, recurrence plots, synchronicity, convergence

JEL classification: C49, E32, F49

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1 Introduction

In economics, economic growth is one of the most important variables indicating the expansion of economic activity taking place in a country. Traditionally economic growth is measured as the rate of change in the real (inflation-adjusted) gross domestic product (GDP) per capita of a country. Because of new linkages between countries through such mechanisms as a greater relative volume of international trade, capital flows and the diverse operations of multinational corporations, there is perhaps an increased likelihood that growth rate movements will be more synchronized between countries. Logically one would expect that this is particularly true in the case of countries that are part of regional trade agreements or a single currency for example, so one might expect that euro area growth rates would be more synchronous than for member states/countries outside the single currency area. Regionalization though has also occurred against the backdrop of increased globalization in recent decades, with foreign trade and capital flows becoming a much more important feature of the global economic landscape than previously, so it is not clear which will dominate.

In this short paper we explore this issue within a very simple framework of the pattern of growth rates between countries. This is what most economists refer to as synchronicity - that is, the co-movement of growth rates through time - and we use this definition of synchronization in this paper rather than the physicist's definition. The starting point for the methodology used in this paper is Crowley (2008), where the intermittency of synchronization in the euro area was noted by using recurrence plot methods. The motivation of the paper is to extend this research by constructing a different measure of synchronization to ascertain the extent of this synchronicity, rather than focusing on both synchronization and convergence, as the cross recurrence plot method does.

The paper is organized as follows: in section 2 we review the economic issues surrounding synchronization of growth rates in the euro area, while in section 3 we outline the general approach taken here. Section 4 presents the results and section 5 concludes.

2 Business and growth cycles synchronization and convergence

2.1 Background

In macroeconomics, we first distinguish between the concepts of convergence and synchronization. By convergence we mean the proximity of growth rates with growth rates of other countries/member states or collections thereof. By synchronicity we mean the similarity of movement in these growth rates over time. Clearly growth rates do not have to converge to have high levels

of synchronicity and also high levels of convergence do not have to be associated with high levels of synchronicity[1]. Although monetary policy will likely be an important factor in determining the level of both convergence and synchronicity between countries/member states, many other factors other than monetary policy are likely to also be relevant, factors such as the dominant transmission mechanism, the level of public sector indebtedness, and the stage of development of the financial system. Indeed, in terms of European Central Bank (ECB) monetary policy, given that monetary policy varies over the business cycle, convergence in growth rates is likely to be less important than synchronicity of growth rates between member states. Putting the issue of business cycles aside, clearly the level of convergence in growth rates is likely to be an important determinant of long-run growth rates in the euro area as

The synchronicity in movement of economic growth rates is economically important for 2 underlying reasons:

1. the more globalized the world becomes, the more likely that trade and financial flows will cause greater "synchronization" in growth rates between countries - known in the literature as the "international business cycle"; and

2. for collections of countries that use the same currency (such as the euro area member states of the European Union), similar movements in economic growth rates can either indicate

i) *ex-ante* the suitability for adopting the same monetary policy (- known as the optimal currency area (OCA) theory[2]); or

ii) *ex-post*, the fact that monetary policy has been a factor in making these countries have similar patterns of growth (- known as the endogenous OCA theory).

There has long been recognition of the propagation phenomenon of business cycles between countries (- the main mechnanisms being trade and capital flows). The main indicator of this propagation is the synchronicity of turning points in business cycles (noted by Backus and Kehoe (1992) and Backus, Kehoe, and Kydland (1995) in the real business cycle literature) but what is not recognized is that the economic growth dynamic between these turning points (usually the recessions or peaks of business cycles) can be radically different between countries. This observation has given rise to the notion and study of growth cycles in the context of the dynamic of economic growth between these turning points (see Kontolemis (1997) and Zarnowitz and Ozyildirim (2002)). From an empirical perspective there have been some efforts to empirically extract

[1] As for example if growth rates were mean reverting and the amplitudes of cyclical activity were small.
[2] The original and seminal contribution here was made by Mundell (1961).

cycles for measurement and comparison across countries using frequency domain techniques (see Gallegati and Gallegati (2007), Crowley and Lee (2005) and Crivellini, Gallegati, Gallegati, and Palestrini (2004)) but only limited research has been conducted in this area.

In the euro area context, there has been a recognition for some time that with closer cooperation in monetary policy, firstly under the exchange rate mechanism (ERM) of the European Monetary System (EMS) and the run up to Economic and Monetary Union (EMU), and then secondly during the shift to the adoption of the euro within the EMU process (- using specified economic convergence criteria), that synchronisation of euro area growth rates would likely increase. But measuring this has been more problematic for a variety of reasons - notably the short data span available and the exceptional circumstances surrounding events in the early part of this decade (9/11, Iraq invasion, German structural problems etc). Despite these issues, there has been a variety of empirical research of different types done on this topic, with a good summary of the literature in de Haan, Inklaar, and Jong-a Pin (2008b), and other notable contributions by Artis and Zhang (1997) who first recognized the existence of a separately identifiable European business cycle, followed by Artis and Zhang (1999), and then mostly studies that have tried to measure whether the "European business cycle" has become stronger since the inception of EMU and the introduction of the euro and a single monetary policy (see Altavilla (2004), Sensier, Artis, Osborn, and Birchenhall (2004), Valle e Azevedo (2002), De Haan, Inklaar, and Sleijpen (2002), Süssmuth (2002), and more recently Böwer and Guillemineau (2006), Giannone and Reichlin (2006), and de Haan, Inklaar, and Jong-a Pin (2008a)).

This is an important issue for the ECB for several reasons:

a) First, the OCA theory suggests that similar growth rates in member states will ease the problems associated with the differential impact of monetary policy on these countries.

b) Second, not only do growth rates matter, but also the dynamics of growth also matters - thus the idea that similar frequency growth cycles between countries in a monetary union will also ease the problems of implementing monetary policy across a collection of member states or countries, creating less "stress" within the euro area than otherwise would be the case. Higher synchronicity of growth rates within the euro area implies that cyclical features of business and growth cycles are similar between member states and so monetary policy can be more easily formulated.

c) Third, OCA theory also suggests that even without this increased synchronicity of business and growth cycles, increased mobility of factors of production can counter this and so aid implementation of monetary policy as resources can flow from one country to another to

offset the differential impact of monetary policy. With the advent of the single market in the EU after 1992, labor and capital mobility have increased, but it is still widely acknowledged that language and cultural barriers impose greater barriers to mobility of factors of production than they do in many other monetary unions (such as the US or Canada).

d) Fourth, another offset to lack of synchronisation can be found in autonomy of fiscal policy, perhaps at a national or member state level, or at the supra-national level. This has caused considerable concerns in the euro area in past years, as the Stability and Growth pact (SGP) appeared to severely limit member state fiscal policy so as to counterbalance ECB monetary policy and its differential impact on certain member states, dependent largely on debt levels and any existing structural budget deficit considerations (- for example Germany).

e) Lastly, there is also a feedback effect involved, as a single monetary policy should impact all member state growth rates across the euro area implying that an OCA might be created endogenously (- see Frankel and Rose (1997)).

Only in the last decade has the question been asked as to whether increased business cycle synchronization is driven more by global or regional factors, and whether this has changed over time. Artis and Zhang (1997) first asked whether there is a European business cycle separate from other international business cycles, while Stock and Watson (2005) first noted that cyclical convergence was much more a global rather than a regional phenomenon, but more recently, using spectral analysis Hughes Hallett and Richter (2006) showed that the convergence and lower frequencies was due to common cycles, in other words globalization. In the latter study though Hughes Hallett and Richter (2006) only used the US, UK and the euro area to assess this, so this could have been due to anomalies associated with the UK situation rather than being a general result, so .....

2.2 Data and Methodology

2.2.1 Data

To measure economic growth, in macroeconomics the Gross Domestic Product (GDP) is used, which is usually released quarterly by government statistical agencies. GDP measures the total domestic output of goods and services produced by the factors of production of a country. Countries/member states that have a reasonably long data span[3] were used, which in some cases required splicing data across different data sources. Data was sourced from a variety of sources,

[3] Most data in economics have a relatively short span compared to those in the sciences, but here with just over 500 datapoints this already considerably narrowed the number of countries/member states in our sample.

but mostly Eurostat for the European countries and from the IMF International Financial Statistics for the non-European countries. Quarterly data was collected for the period 1970Q1-2008Q4, giving 156 datapoints. In order to measure economic growth at time t, g_t, the GDP at time t, y_t, is transformed by taking natural log first differences as follows:

$$g_t = \ln(y_t) - \ln(y_{t-1}) \tag{1}$$

Due to this data transformation and also because of one missing observation for Spain at the beginning of 1970, this leaves 154 datapoints.

Three sets of countries are used in the research:

i) 9 Euro area member states: France, Germany, Spain, Ireland, Italy, Luxembourg, Portugal, Finland, Netherlands;

ii) 4 non-euro area member states/European countries: Sweden, Switzerland, UK, Denmark; and

iii) 6 international countries/entities: Euro area, US, Japan, South Africa, Canada, Australia.

The first two groups of member states/countries represent regional groupings in Europe, with the usage of the euro being the factor that distinguishes them. The third grouping represents a proxy for the international business cycle.

Next a sample of these quarterly economic growth rates are plotted. Figure 1 shows the transformed data for France, Germany and Spain. It is immediately apparent that Spain had much higher growth rates for much of the early part of the 2000s, but now has fallen into a deep recession. Figure 2 shows economic growth rates for Ireland, Italy and Luxembourg. The data for Ireland and Luxembourg appears to have become very volatile around 1997 - this is likely because of changes in the way GDP was measured rather than any sudden increase in volatility[4]. In figure 3 the prolonged downturn in Finland is readily apparent in the early 1990s, but what is most noticeable is that growth rates become much more convergent between these three euro area member states after 1993. In figure 4 there is also a decline in growth rate volatility in the early 1990s, with all three growth rates tightly bunched together for most of the period after 1993. Lastly figure 5 shows the growth rates of the US and Canada moving closely together but the Japanese rate clearly moves independently for the most part, and the "lost decade" of growth in the 1990s for Japan is clearly apparent.

[4]In what follows the volatility of the rate of growth is not a factor - solely the direction of growth is what is accounted for in the analysis, so this should not bias the results in any way.

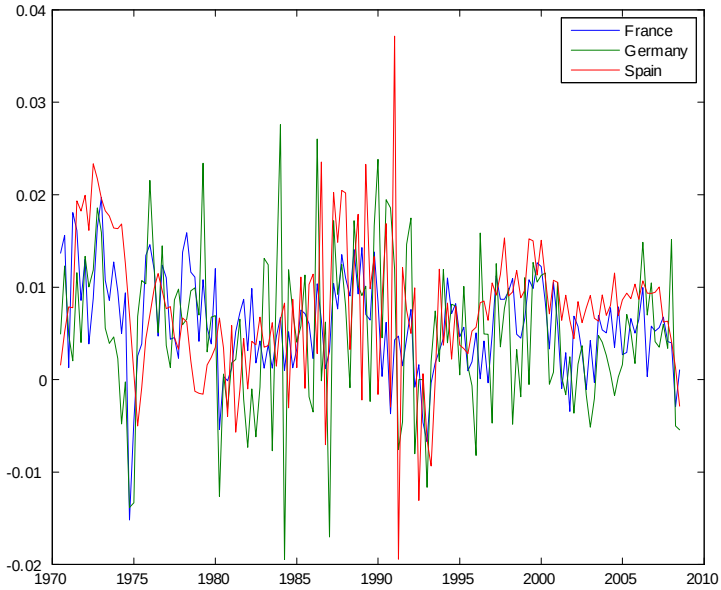

Figure 1: Quarterly log change in real GDP for France, Germany and Spain

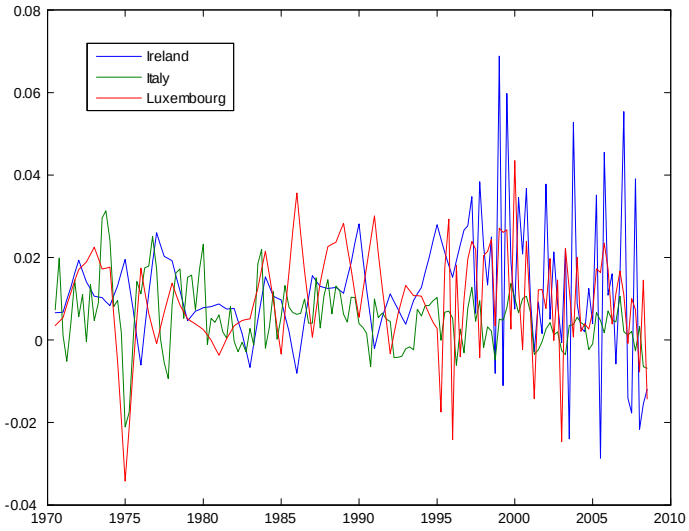

Figure 2: Quarterly log change in real GDP for Ireland, Italy and Luxembourg

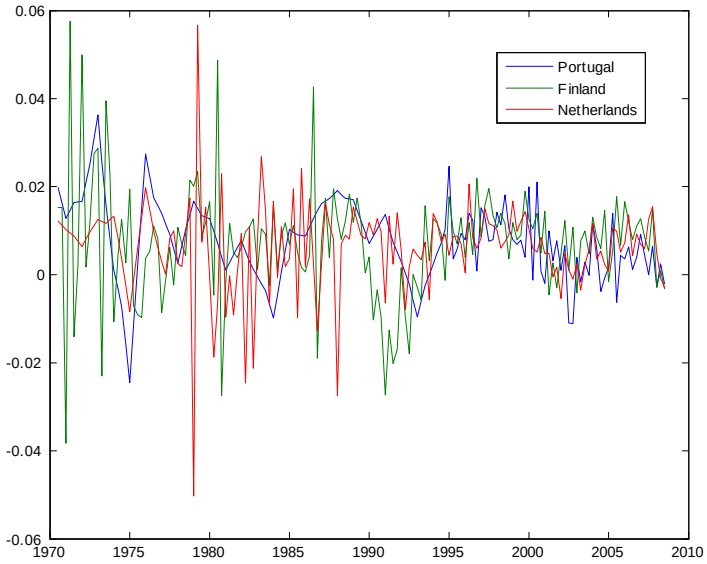

Figure 3: Quarterly log change in real GDP for Portugal, Finland, and the Netherlands

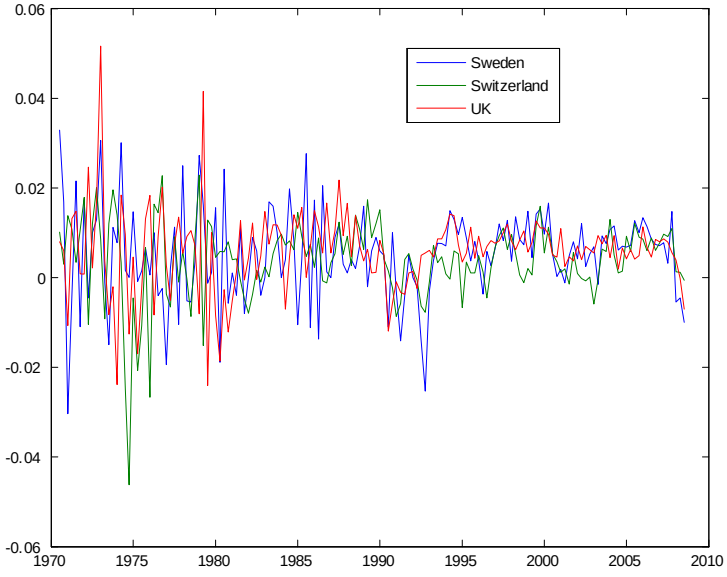

Figure 4: Quarterly log change in real GDP for Sweden, Switzerland and the UK

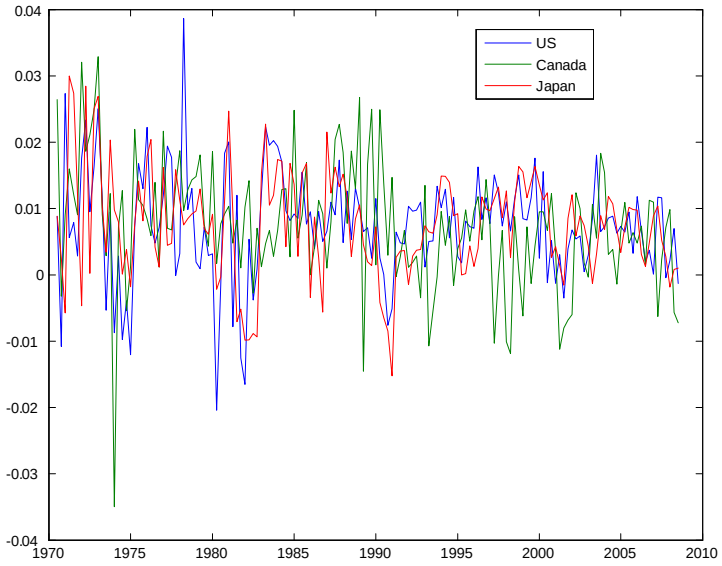

Figure 5: Quarterly log change in real GDP for the US, Canada, and Japan

2.2.2 Methodology

The research presented here is based on recurrence plots. Recurrence plot analysis is now over 20 years old (see Eckmann, Oliffson Kamphorst, and Ruelle (1987) for the first contemporary application) and the quantification of these plots is much more recent (see Zbilut and Webber Jr. (1992) and Webber and Zbilut (1994)) but the notion of recurrence has a much longer pedigree in mathematics (see Feller (1950)). Recurrence plots first originated from work done in mathematics and physics but now has a considerable following in a variety of fields[5]. There are several excellent introductions available to RQA and recurrence plots, not least those by Marwan, Romano, Thiel, and Kurths (2007) and Webber Jr. and Zbilut (2005). In this paper. There are very few papers that apply recurrence plot techniques to macroeconomic issues, the notable exceptions being Zbilut (2005), Kyrtsou and Vorlow (2005), and Crowley (2008).

In terms of the mathematical background, using Takens' embedding theorem (see Takens (1981)), the recurrence plot is a way of analysing the dynamics of phase space trajectories in deterministic systems. Takens' embedding theorem states that the dynamics can be approximated from a time series x_k sampled every t by using an embedding dimension m, and a time delay, τ, by a reconstruction of the phase-space trajectory $\overrightarrow{y}_t$, where:

[5] Norbert Marwan's website catalogues all the articles published using recurrence plots and RQA, and is a veritable mine of information on this topic. See http://www.recurrence-plot.tk

$$\overrightarrow{y}_t = (x_t, x_{t+\tau}, ..., x_{t+(m-1)\tau}) \tag{2}$$

The choice of m and τ are based on methods for approximating these parameters, such as the method of false nearest neighbors and mutual information for m and τ respectively. When using cross recurrence plots, the choice of m and τ are assumed to be the same. Every point of the phase space trajectory $\overrightarrow{y}_t$, that is,x_t is tested to see whether it is close to another point of the trajectory $x_{t+\tau}$, i.e. the distance between these two points is less than a specified threshold ε. In this case the value one (a black dot in the recurrence point) is assigned to this point in a $N \times N$-array (- the auto-recurrence plot):

$$\mathbf{R}_{i,j} = \Theta(\varepsilon - \|x_i - x_j\|)$$

Second, following Marwan, Thiel, and Nowaczyk (2002) the cross recurrence plot is definied by:

$$\mathbf{CR}_{i,j} = \Theta(\varepsilon - \|y_i - z_j\|) \tag{3}$$

where $i, j = 1, ..., N$, y_i and z_i are two embedded series, ε is the predefined "threshold", $\|\|$.is the norm (for example a Euclidean norm) and Θ is the Heaviside function. This gives a cross recurrence matrix $\mathbf{CR}_{i,j}$ which contains either 0s (the white areas in the plots) or 1s.(the black areas in the plots). To get the contoured plots shown above, ε is varied to predetermined values.

Third, in an auto-recurrence plot, the main diagonal is always present, as every point in the series is identical to the same point in the series, so there will always be a diagonal line (1's down the main diagonal of the $\mathbf{R}_{i,j}$ matrix), once all points in the series are considered (- see figure 6 for example). In the cross recurrence plot if this line is present, the two series are identical, but this is obviously a special case. A line, if it appears in the cross-recurrence plot, implies similar dynamics, but these maybe offset from the main diagonal, implying phasing of the two cycles (- see figure 11 for example)..This line, if it can be identified, is termed the "line of synchronization" or LOS.

Fourth, complexity measures can be derived to characterize the cross-dynamics of a given series. For two series these will be characterized as diagonal lines (not necessarily on the main diagonal), which demonstrate similar dynamics maybe at different points in time. Following Marwan and Kurths (2002) the distributions of the diagonal line lengths can be written as $P_t(l)$ for each diagonal parallel to the main diagonal, where $t = 0$ denotes the main diagonal, $t > 0$ denotes diagonals above the main diagonal (a lead) and $t < 0$ denotes diagonals below the main

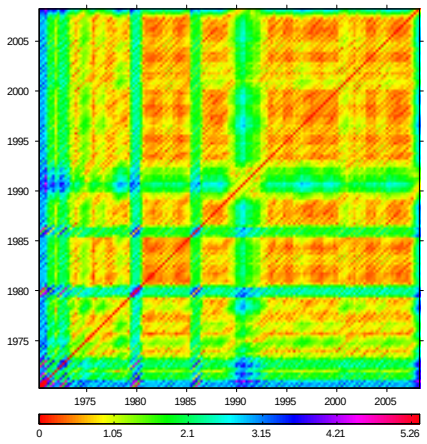

Figure 6: Auto-recurrence plot for Finnish real economic growth

diagonal (a lagged dynamic). RQA was initiated by Zbilut and Webber Jr. (1992) and has now been introduced into mainstream physics through the study of nonlinear dynamics. A good summary is available in Webber Jr. and Zbilut (2005).

The starting point for the comparison of dynamics is the auto-recurrence plot. Here we take the example of Finland, and display in figure 6 the unthresholded version (with color bar below the chart indicating distance of any point from any other point in the series. As expected the leading diagonal is red (indicating distance zero) but beyond that it is clear that the early 1990s saw growth rates that are markedly different from any other growth rates in the series (- the very deep recession that Finland experienced at this time). The squares placed on the leading diagonal indicate very similar growth rates for certain segments of the time series. Further, there are diagonal lines running up the plot off the leading diagonal indicating similar growth rates at lags or leads from current growth rates.

The next step is the analysis conducted in Crowley (2008) with cross-recurrence plots. Here we take the example of Finland again, and display in figures 7 and 8 the unthresholded and thresholded recurrence plots respectively against the euro area aggregate growth rate. In the first figure the color scale denotes the distance between the two embedded phase-space trajectories for the two series with red denoting a small distance up to blue areas which denote large distances. The diagonal lines indicate the synchronous dynamics in both series with a diagonal going up from the lower left to the upper right being the "line of identity" (LOI). In other words if there was just a red line going diagonally through the plot this would indicate identical series. It is clear that even when the values of the growth variables are far apart (as around 1980) there are some synchronous dynamics. The LOI thus indicates coincident synchronicity and it is apparent

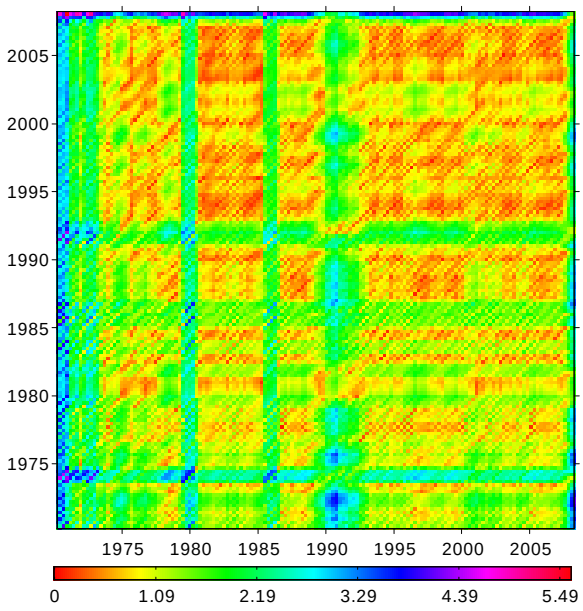

Figure 7: Unthresholded recurrence plot for Finnish vs euro area economic growth

that this is intermittent, in the sense that there are gaps (as in 1989 and 1998). The second plot considers just convergent dynamics (using a thresholded distance), and shows that indeed when growth rates are similar, there are synchronous periods (for example, 1982-84) - the vertical bands in the figure indicate that Finnish growth rates are close to euro area growth rates throughout the span of the euro area series, which in turn also signifies that Finnish growth rates departed significantly from the usual growth rate range observed for the euro area. The problem with this technique is that it does not separate convergence from synchronous dynamics, so it is difficult to isolate synchronicity measurements *per se*.

In order to remove the discrepancy between growth dynamics and convergence in growth rates, in this study each time series is transformed into signed values signifying the direction of movement in growth rates in each quarter and then a cumulative summation of the direction of growth was created from the signed values. We refer to these modified time-series as cumulative signed summation (CSS) series. Distance matrices for each un-embedded CSS series are created using the standard Euclidean distance metric as described in Marwan, Romano, Thiel, and Kurths (2007), where N is the total number of points in the phase space of variable X and k = the dimensions of X. In mathematical terms this is measured as:

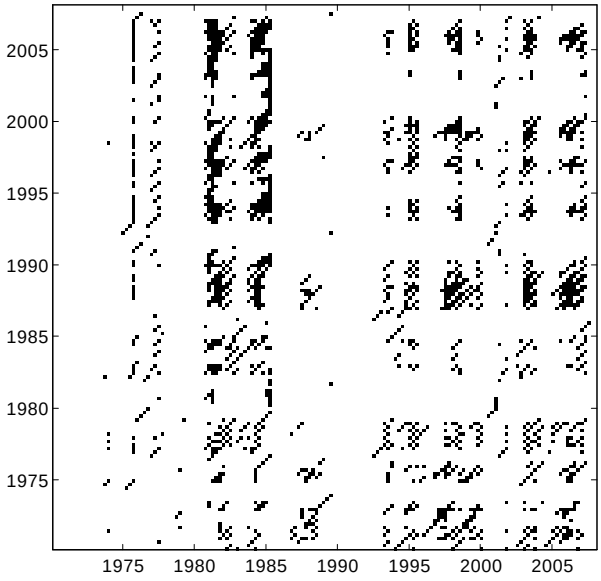

Figure 8: Thresholded recurrence plot for Finnish vs euro area economic growth

$$D_{i,j} = \sqrt{\sum_{k=1}^{n}(X_{i,k} - X_{j,k})^2} \tag{4}$$

where $i, j = 1, 2, ..., N$.To evaluate the dissimilarity between two time series, we perform an epoch (moving window) analysis with an eight sample window incremented one sample at a time. For each epoch the dissimilarity is computed by taking the absolute difference between the paired values in the epochs from each time series:

$$E = |D1_{i,j} - D2_{i,j}| \tag{5}$$

where $D1$ represents the epoch window for the first series etc, and i, j are the time points in a particular epoch. The average of this difference matrix is then the total dissimilarity between $D1$ and $D2$ for a particular epoch. This process can be done for a single member state against all other member states in a group to create a synchronicity-proxy within a set of member states or can be repeated for each pair of time series within a set so as to create a "super" dissimilarity matrix for all member states for each epoch. In the latter case, the dissimilarity matrix at each time step is then averaged to estimate the total dissimilarity between members of the set for a particular temporal window. The final product is then a one dimensional time series denoting

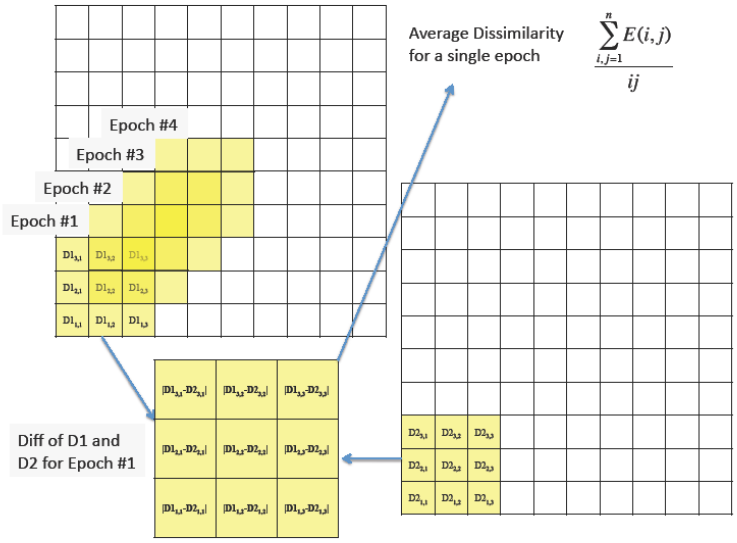

Figure 9: Dissimilarity matrix methodology

the synchronization in growth patterns between members of a set with smaller values indicating greater synchronicity. The methodology is illustrated by way of figure 9.

Note that where there is a turning point in one particular member state/country, if this does not show up in other member states countries then synchronicity will fall. Once the absolute differences have been evaluated for a set of countries they can be plotted to show the "within-group" average level of dissimilarity between all the members, and this is what is done below for the three sets of member states/countries that were specified in the section on data above.

3 Results

3.1 Euro area member states

The synchronicity of each euro area member state is first evaluated against all other member states separately. Figure 10 shows the epoch dissimilarity measure and is revealing for several reasons. First, it is apparent that France and Germany have historically been the most synchronous member states against other member states, as their dissimilarity measures usually form the lower envelope in the figure for much of the 1970s and 1980s. Second, the period of the ERM of the EMS from 1979 onwards clearly saw similar dissimilarities between member states, which then continuously fell until 1985, after which there is clearly divergence. Third, it is also readily apparent that from 1999 onwards dissimilarity measures for most member states converged, and although there is

some fluctuation, with a general increase in dissimilarity in 2000 and then a reduction in 2002-3, then increasing in 2004-5 and a large reduction for most members states by 2007. Fourth, during the post-1999 period it is also apparent that certain member states have not followed this general trend. From 2000-2003, Spain clearly had greater dissimilarity than the average euro area member state, and then in 2004-5 Portugal was non-synchronous (and to a lesser extent Italy), followed by Ireland in 2006-7.

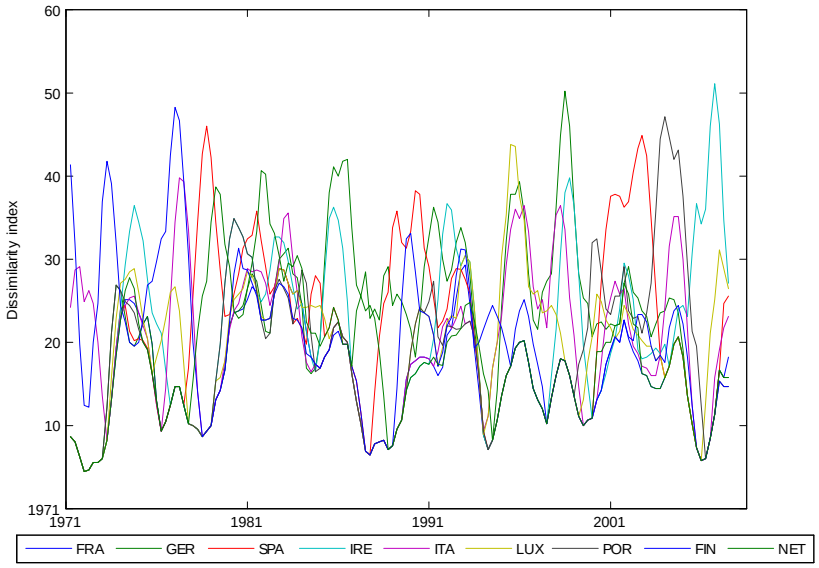

Figure 10: Within euro area dissimilarity index for individual euro area member states

Next we evaluate the simple average dissimilarity for the core member states in our sample for the euro area. Figure 11 shows the averaged dissimilarity measure in blue, together with a 4 year "moving average"[6] given by the thicker black line. The vertical pink lines indicate the "new" EMS in 1983, the signing of the Maastricht Treaty on European Union in 1991, and the inception of the euro in 1999[7]. It is not entirely clear why, but the dissimilarity measure fluctuates in roughly a two year cycle, with exceptionally synchronous periods occurring in the early 1970s, the late 1980s, around 1994, and again around 2007. Non-synchronous years include the early 1980s, which nearly saw the collapse of the EMS, 1993 - which corresponds to the collapse in the EMS, and 2002. The moving average indicates that during the period of the "snake" arrangements

[6] The "moving average" measure here is a fitted moving average. Specifically a line is first fitted to the first 16 data points (4 years worth of data). Another line is fitted to points 2:17, then 3:18 and so on. For most points in the series (except for the ends) 16 fitted values are obtained for each point. Then the average of these 16 values is taken and used as the smoothed value.

[7] These dates could be regarded as indicative of institutional structural breaks due to significant events in the timeline to European integration.

for exchange rates during the 1970s, there was an increase in dissimilarity, but then following the inception of the ERM of the EMS in 1979 this increased until the U-turn in French economic policy under Mitterand in 1983 (the "new" EMS) after which synchronicity increased until roughly 1989 when tensions between member states started to rise until the ERM crisis in 1992. What is surprising in this figure is that after the inception of the euro in 1999 synchronicity actually decreased slightly and then increased post-2005.

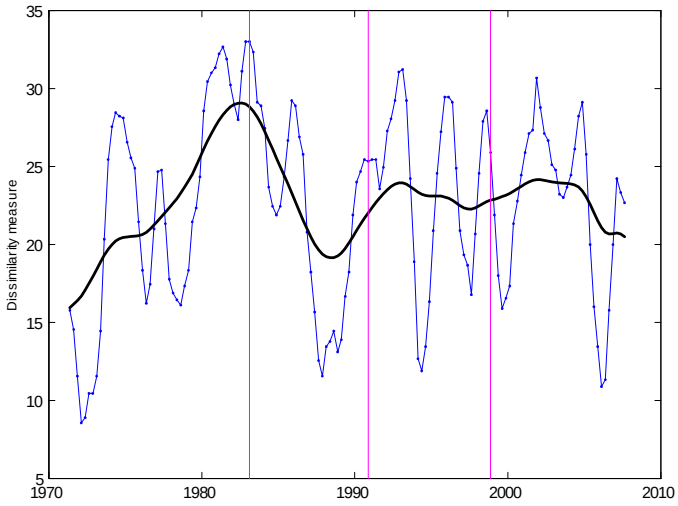

Figure 11: Averaged dissimilarity measure for euro area member states

3.2 Non-euro area European member states/countries

The four non-euro area European member states/countries are now evaluated in the same manner. Figure 12 shows the epoch dissimilarity measure for the non-euro area European member states. Once again it is apparent that certain member states/countries seem to differ from the general synchronicity observed for the others. For example, most recently Denmark has clearly had much higher dissimilarity in dynamics than the other 3 member states/countries in this sub-sample. It is also noticeable that dissimilarities for the four were very similar from 1979 to 1983 and then again from 1993 through until about 2003.

Figure 13 shows the average dissimilarity for these member states, some of which (Denmark and the UK) were members of the ERM of the EMS during the 1980s and into the early 1990s. Interestingly the trend given by the 4 year moving average is towards more synchronicity during the 1970s, and then with the advent of the "new" EMS in 1983 less synchronicity occurred, but from around 1988 until 1997 there was a trend towards increased synchronicity among these

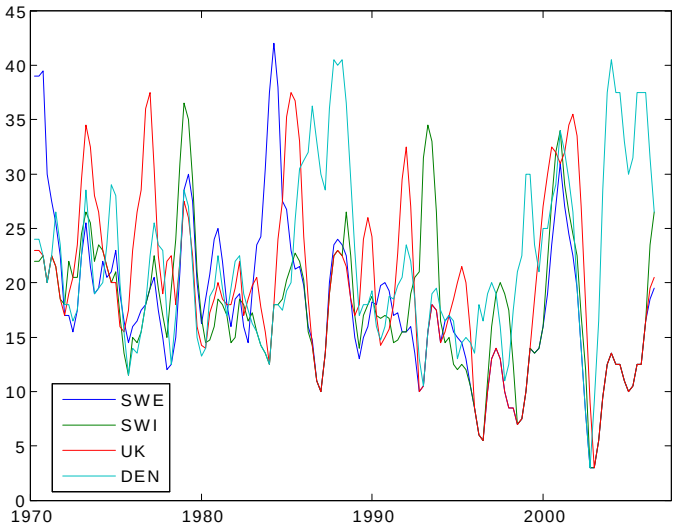

Figure 12: Within non-euro area dissimilarity index for individual member states

countries. Since 1997 synchronicity has fallen, but still not to the levels seen in the 1970s. What is interesting in this figure is that there appears to be a wild swing in synchronicity from record non-synchronicity in around 2002 almost complete synchronicity among these member states in 2004. The reasons for this large change are not clear.

3.3 International countries

Lastly, we once again compare dissimilarity measures for all the countries in this subsample. Figure 14 shows that individual international country dissimilarities vary through time, with the same intermittency that was noted for nearly all the other data, although it is noticeable that much of the data was bunched from around 1985 through until about 2002. This implies that the international business cycle not only waxes and wanes in its effect on different countries but also varies through time.in its strength.

In figure 15 representing the group of international countries, the dissimilarity metric fell in the early 1970s and then has been intermittent since this time, with a notably large fall in dissimilarity in 1997, which here we correspond to an intermittent increase in synchronicity at this time. What is striking here is that the 4 year moving average suggests that synchronicity changes through time in a cyclical manner, with roughly a ten year cycle.

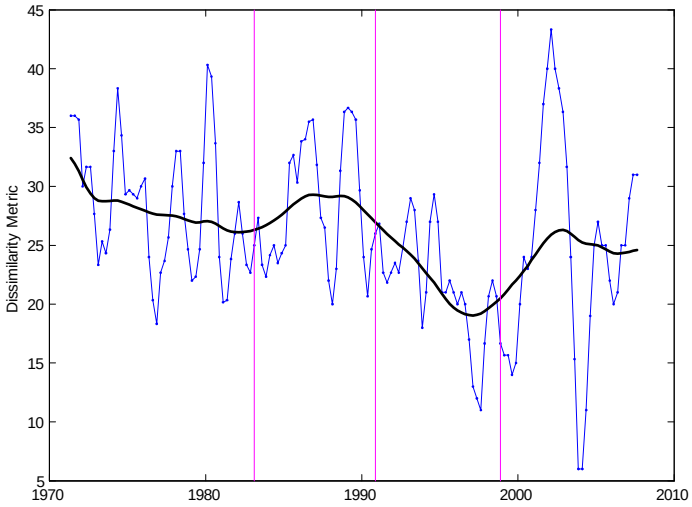

Figure 13: Averaged dissimilarity measure for non-euro area European member states

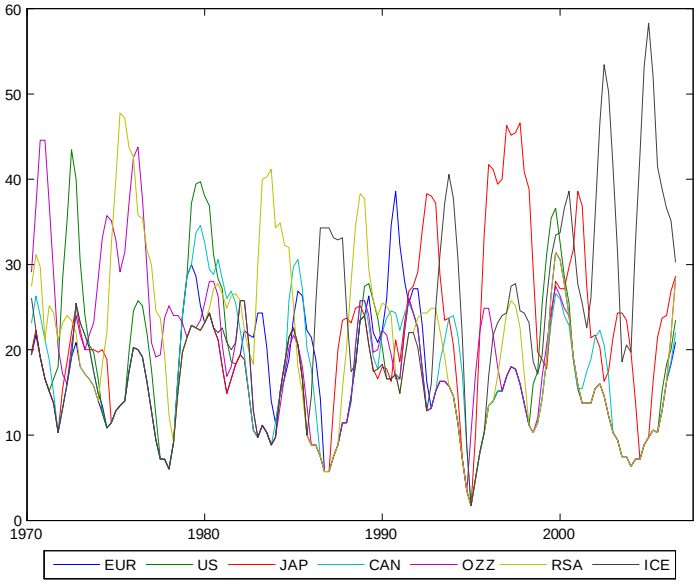

Figure 14: Within-international group dissimilarity index for individual countries

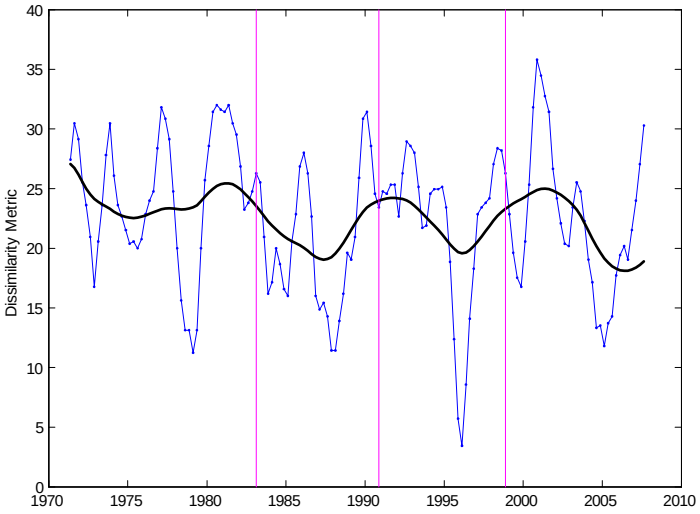

Figure 15: Averaged dissimilarity measure for International countries/entities

3.4 Monetary vs Regional vs International synchronization

Given that we have obtained average dissimilarity measures for three different groups of member states/countries, it is now possible to compare these measures and thereby infer which groups have had higher levels of synchronicity over given time periods. The first exercise evaluates whether monetary union in the form of the inception of the euro has caused greater synchronization among its members compared with the rest of Europe.

3.4.1 Euro area member state synchronization with euro area aggregate

First it is instructive to look at the difference in synchronization for each euro area member state's growth rate and compare with the synchronization for the euro area aggregate growth rate. If a member state has greater dissimilarity than the euro area then this clearly indicates that it was partially the cause of the euro area dissimilarity becoming greater. This therefore measures the degree to which a euro area member state was more or less dissimilar to the euro area average. Figures 16 to 24 show the dissimilarities for the individual euro area member state growth rates in our sample compared with the euro area aggregate growth rate. Only France has had dissimilarities with other euro area member state growth rates that consistently lie at or below those of the euro area aggregate, although the Netherlands has consistently been at or under the euro area aggregate dissimilarity level since 1988 and Finland since 1995. In terms of syncrhonicity this implies that both the latter member states have clearly become more syncrhonous than the

euro area weighted average. Germany was less synchrronous than the average from 1986 to 1993 and then again from 1995 to 2000. Particularly notable is the large departures from synchronous growth that can be observed in certain periods in Italy, Spain and Ireland.

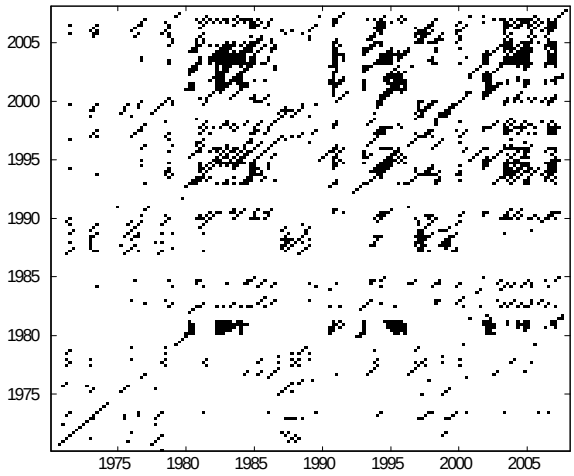

Figure 16: French growth synchronicity compared with euro area growth synchronicity

3.4.2 Euro area vs non-euro area European member states

Figure 25 shows the difference between the dissimilarity metrics for the euro area and the non-euro area European member states. The black line plots the dissimmilarity metric for the euro area and the blue line is that of the non-euro area member states, while green areas represents periods when euro area synchronicity is greater than non-euro area member state synchronicity, while red areas signify greater synchronicity for non-euro area member states. Clearly efforts in the 1970s to coordinate exchange rates and other European economic initiatives led to higher levels of synchronicity for euro area member states. This reversed in the early 1980s but then from the advent of the "new" EMS in 1983 the euro area member states had greater synchronicity. The period from 1990 to 1993 saw slightly less synchronization in the euro area, and then there is a short period of greater synchronicity in 1994. What is somewhat surprising here is that from 1995 to 2000 there is clearly greater synchronicity in the non-euro area member states. This might be due to the efforts that all member states made to economically converge once it was clear that EMU would occur. Apart from a short period from around 2003-2005, euro area member states appear to have been more synchronous in the post-1999 era.

Figure 26 which just looks at the moving average measures mostly reflects the patterns noted

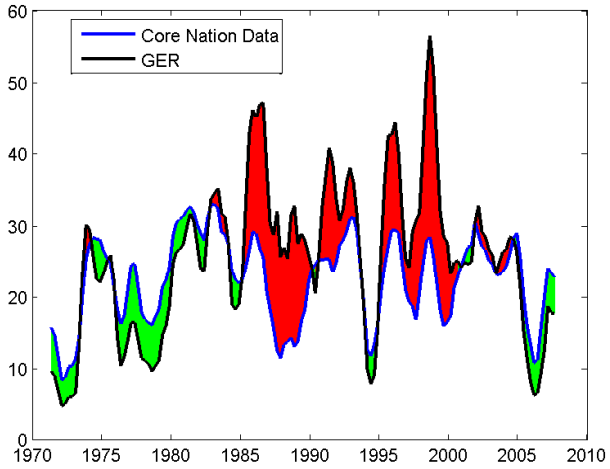

Figure 17: German growth synchronicity compared with euro area growth synchronicity

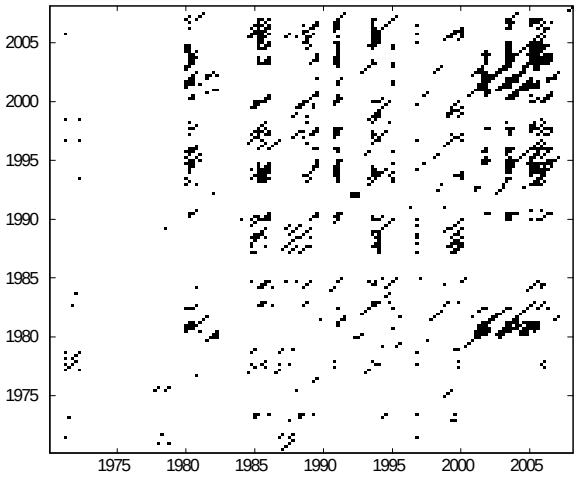

Figure 18: Italian growth synchronicity compared with euro area growth synchronicity

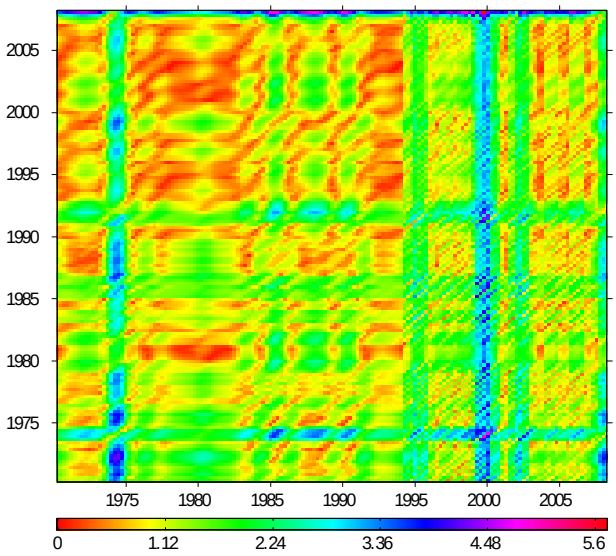

Figure 19: Luxembourg growth synchronicity compared with euro area growth synchronicity

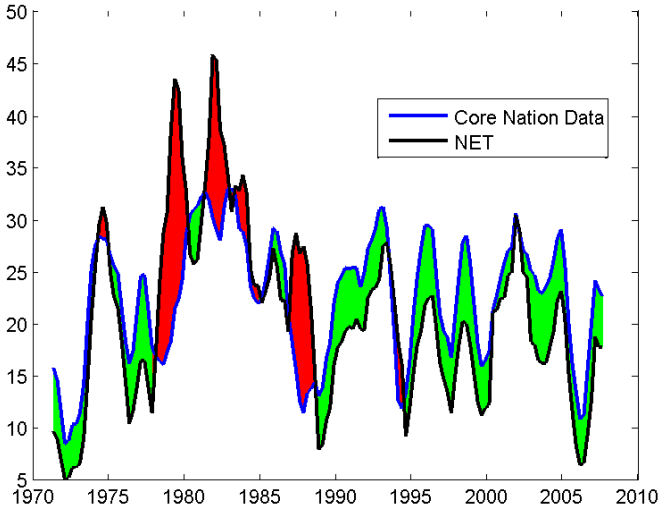

Figure 20: Netherlands growth synchronicity compared with euro area growth synchronicity

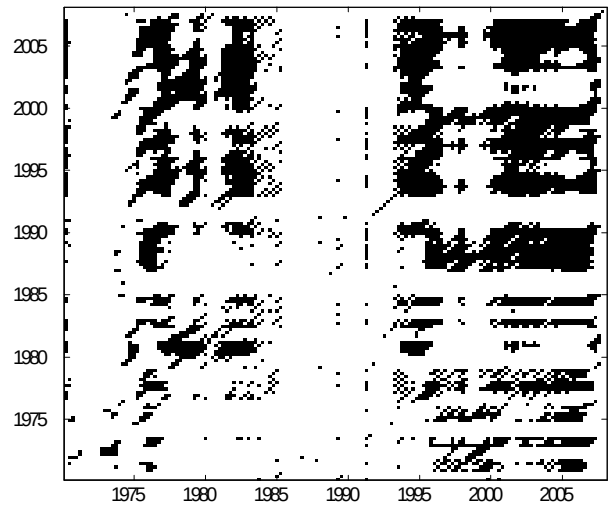

Figure 21: Spanish growth synchronicity compared with euro area growth synchronicity

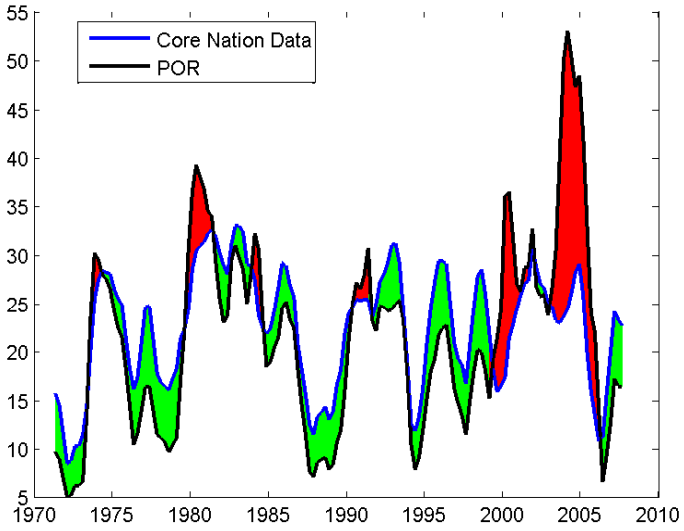

Figure 22: Portuguese growth synchronicity compared with euro area growth synchronicity

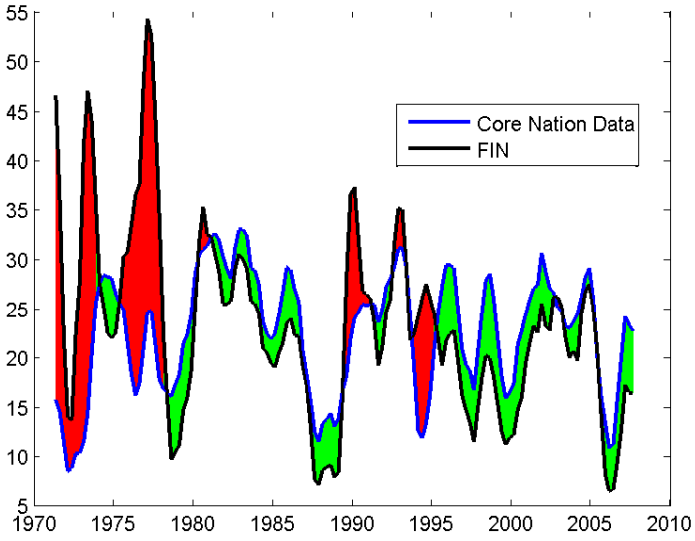

Figure 23: Finnish growth synchronicity compared with euro area growth synchronicity

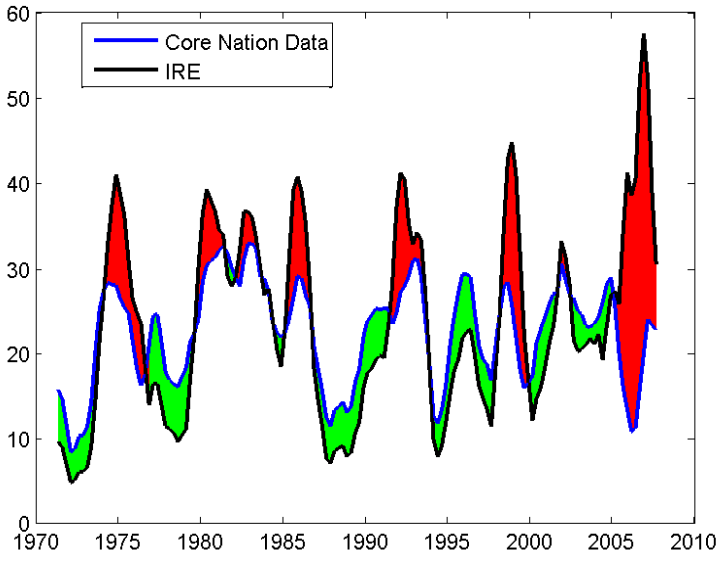

Figure 24: Irish growth synchronicity compared with euro area growth synchronicity

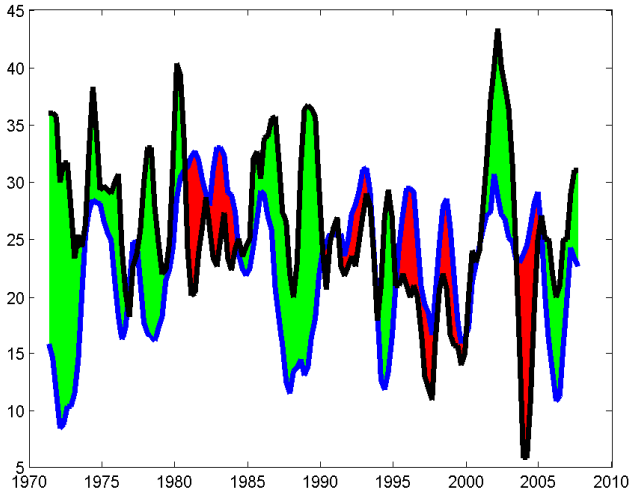

Figure 25: Comparison of dissimilarity measure for the euro area and other non-euro area European member states

above. In the 1970s and early 1980s it is clear that euro area member states were more synchronous than non-euro area member states, but the advent of the early years of the ERM of the EMS clearly reversed this leading to a period up until roughly 1985 when non-euro area member states were more synchronous, but then from about 1983 (the "new" EMS) there was a downward trend in synchronicity for the euro area member states leading to a period following 1985 when euro area member states were once again more synchronous than non-euro area member states. This began to reverse again in 1990 leading to the ERM crisis in 1993 when once again the non-euro member states became more synchronous, but then another turning point can be detected in 1997 after which euro area member states started becoming rapidly more synchronous, and then from the end of 2000 euro area member states became more synchronous and this trend has continued through until the mid-point of the moving average in 2006.

3.4.3 Euro area vs international

In figure 27 the patterns are much more complex than for the simple comparison of the euro area and the other member states. It is interesting that for much of the 1980s the patterns of growth for the international grouping and the euro area member states were remarkably similar.

Here the 4 year moving average clearly helps in understanding the trends at work in synchronicity. Figure 28 shows the overall trends at work and it is clear that in the 1970s the euro area member states were more synchronous than the international grouping, but that from 1979

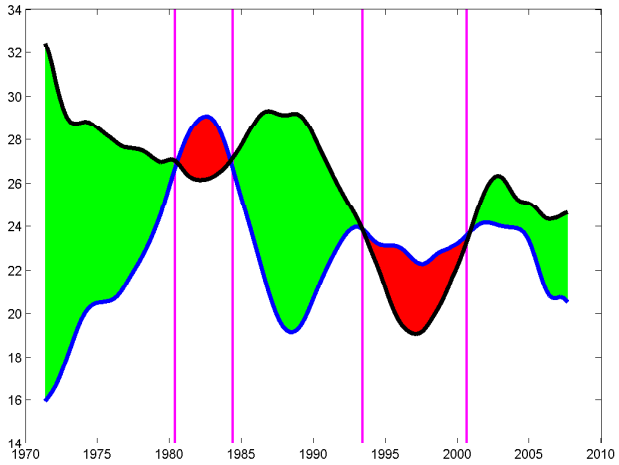

Figure 26: Comparison of dissimilarity measure moving average for the euro area and non-euro area member states

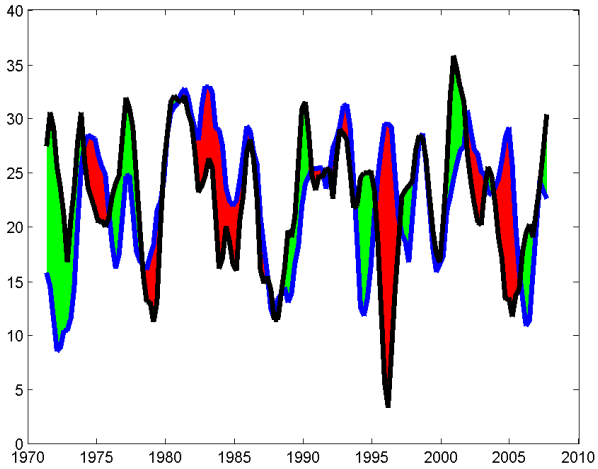

Figure 27: Comparison of dissimilarity measure for the euro area and international countries/entities

through 1987 the international grouping was more synchronous. From around 1998 through 1993 the European grouping is slightly more synchronous but then this again reverses for the run up to the launch of the euro in 1999. What is interesting here is that in the early years of the euro clearly there were more synchronous dynamics in euro area member states than there were internationally, but that from around mid-2003 this trend has reversed, with the international grouping more synchronous than the euro area grouping.

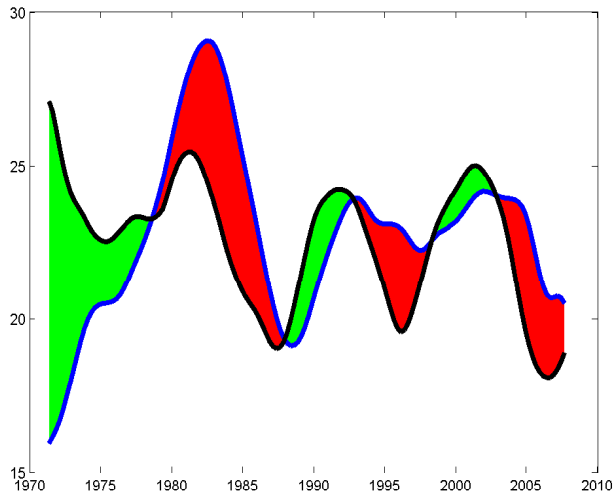

Figure 28: Comparison of dissimilarity measure moving average for the euro area and international countries/entities

3.4.4 Non-euro area Europe vs international

In figure 29 the comparison is made between the non-euro area member states and the international grouping. It is clear once again that the international grouping appears to be more synchronous throughout most of the data span which tends to suggest that the non-euro area member states are no more synchronous than any random grouping of international countries.

In figure 30 the moving average version of the difference between the non-euro area member states and the international grouping gives a little more insight into the trends at work in the data. There is only one sustained period when synchronicity was either at the same level or higher in non-euro area member states, and this was from 1992 through until around 2002. In all other periods the international grouping had lower average synchronicity than the European grouping.

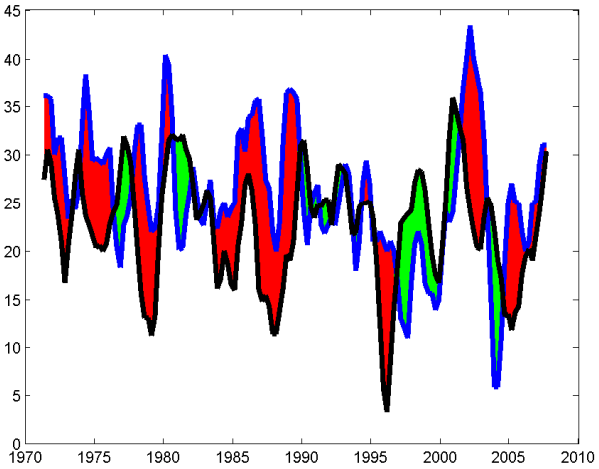

Figure 29: Comparison of dissimilarity measure for the outlying Europe and international countries/entities

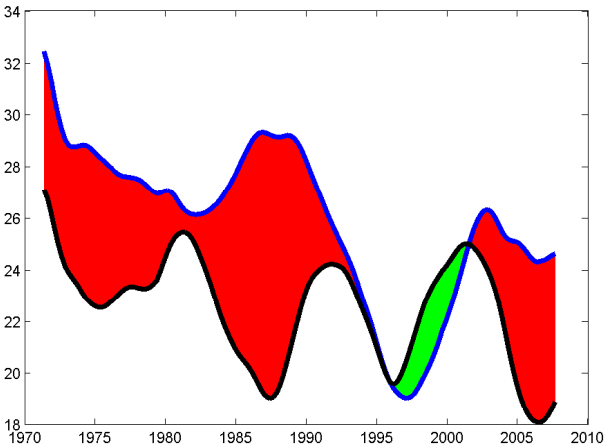

Figure 30: Comparison of dissimilarity measure moving average for outlying Europe and international countries/entities

4 Conclusions

The usual interpretation given by economists to the concept of "synchronization" between growth and business cycles.relates to the pattern of growth between these countries rather than the magnitude of growth rates or the amplitude of the growth or business cycles. In this paper a dissimilarity measure was constructed to account for differences in the patterns of quarterly growth rates between three different groups of member states/countries so as to proxy the dynamic of these growth and business cycles. The expectation was that there would be more similarity between growth and business cycles for euro area member states, particularly after the launch of the euro and establishment of the ECB in 1999.

The main empirical result is that there are certain periods of time when growth rate synchronicity increased and these appear to be during the "new" EMS period after 1983 up until roughly 1990, and then again from 1997 through until 2002. After 2002 synchronicity is only higher against the non-euro area European member states, and does not appear to be more synchronous than the international grouping of countries/entities. The corollary of this is that international business cycles, due to globalization, had a bigger impact than regional factors such as monetary union for most of the period, with only these two exceptions.

A secondary and important result of this paper relates to a new stylized fact relating to the phenomenon of synchronization. There appears to be "intermittency" in synchronization of business and growth cycles between member states and countries. This intermittency does not appear to have any fixed cyclical properties, but varies according to the group of different member states/countries considered. This is shown by the wave-like fluctuations observed in synchronization of growth rates between countries, and in the averages of these measures as well.

There is clearly a considerable amount of future research which is prompted by this research. First, the groups of member states/countries are relatively small, so perhaps shortening the data set so as to include more member states/countries would lead to more generally robusts results (- and this is particularly the case for the non-euro area groupings). Second it would be informative in the case of the euro area itself to construct a real GDP weighted average so that smaller member states such as Luxembourg, which are clearly relatvely unimportant in determining overall euro area synchronicity, do not possess the same relative importance as a country such as Germany, whose GDP makes up just less than a fifth of total GDP. Third, more research is clearly needed to understand the nature of the "intermittency" in synchronization of business and growth cycles and it's causes.

References

Altavilla, C. (2004). Do EMU members share the same business cycle? *Journal of Common Market Studies 42*(5), 869–896.

Artis, M. and W. Zhang (1997). International business cycle and the ERM: Is there a european business cycle? *International Journal of Finance and Economics 2*, 1–16.

Artis, M. and W. Zhang (1999). Further evidence on the international business cycle and the ERM: Is there a european business cycle? *Oxford Economic Papers 51*, 120–132.

Backus, D. and P. Kehoe (1992). International evidence on the historical properties of business cycles. *American Economic Review 82*, 864–888.

Backus, D., P. Kehoe, and F. Kydland (1995). International business cycles: Theory and evidence. In F. Cooley (Ed.), *Frontiers of Businss Cycle Research*, pp. 331–356. Princeton, NJ, USA: Princeton University Press.

Böwer, U. and C. Guillemineau (2006). Determinants of business cycle synchronisation across euro area countries. ECB, Frankfurt, Germany. ECB Working Paper 587, February.

Crivellini, M., M. Gallegati, M. Gallegati, and A. Palestrini (2004). Industrial output fluctuations in developed countries: A time-scale decomposition analysis. Working Papers and Studies: Papers from the 4th Eurostat and DGFin Colloquium "Modern Tools for Business Cycle Analysis", European Commission, Brussels, Belgium.

Crowley, P. (2008). Analyzing convergence and synchronicity of business and growth cycles in the euro area using cross recurrence plots. *European Physical Journal: Special Topics 164*, 67–84.

Crowley, P. and J. Lee (2005). Decomposing the co-movement of the business cycle: A time-frequency analysis of growth rates in the euro area. Bank of Finland, Helsinki, Finland. Discussion paper 12/2005.

de Haan, J., R. Inklaar, and R. Jong-a Pin (2008a). Trade and business cycle synchronization. *European Economic Review 52*(4), 646–666.

de Haan, J., R. Inklaar, and R. Jong-a Pin (2008b). Will business cycles in the euro area converge? a critical survey of empirical research. *Journal of Economic Surveys 22*(2), 234–273.

De Haan, J., R. Inklaar, and O. Sleijpen (2002). Have business cycles become more synchronized? *Journal of Common Market Studies 40*(1), 23–42.

Eckmann, J.-P., S. Oliffson Kamphorst, and D. Ruelle (1987). Recurrence plots of dynamical systems. *Europhysics Letters 4*(9), 973–977.

Feller, W. (1950). *An Introduction to Probability Theory and its Applications, Vol.* New York, NY, USA: John Wiley Sons.

Frankel, J. and A. Rose (1997). Is EMU more justifiable ex-post than ex-ante? *European Economic Review 41*(3), 753–760.

Gallegati, M. and M. Gallegati (2007). Wavelet variance analysis of output in g-7 countries. *Studies in Nonlinear Dynamics Econometrics 11*(3), 1435–1455.

Giannone, D. and L. Reichlin (2006). Trends and cycles in the euro area: How much heterogeneity and should we worry about it? ECB, Frankfurt, Germany. ECB Working Paper 595.

Hughes Hallett, A. and C. Richter (2006). Is the convergence of business cycles a global or regional issue? the UK, US and euroland. *International Journal of Finance and Economics 11*, 177–194.

Kontolemis, Z. (1997). Does growth vary over the business cycle? Some evidence from the G7 countries. *Economica 64*(255), 441–460.

Kyrtsou, C. and C. Vorlow (2005). *Complex Dynamics in Macroeconomics: A Novel Approach*, Chapter 11, pp. 223–238. Springer, NY, USA.

Marwan, N. and J. Kurths (2002). Nonlinear analysis of bivariate data with cross recurrence plots. *Physics Letters A 302*, 299–307.

Marwan, N., C. Romano, M. Thiel, and J. Kurths (2007). Recurrence plots for the analysis of complex systems. *Physics Reports 438*, 237–329.

Marwan, N., M. Thiel, and N. Nowaczyk (2002). Cross recurrence plot based synchronization of time series. *Nonlinear Processes in Geophysics 9*, 325–331.

Mundell, R. (1961). A theory of optimum currency areas. *American Economic Review 51*, 509–17.

Sensier, M., M. Artis, D. Osborn, and C. Birchenhall (2004). Domestic and international influences on business cycle regimes in europe. *International Journal of Forecasting 20*, 343–357.

Stock, J. and M. Watson (2005). Understanding changes in international business cycle dynamics. *Journal of the European Economic Association 3*(5), 968–1006.

Süssmuth, B. (2002, January). National and supranational business cycles (1960-2000): A multivariate description of central g7 and euro15 NIPA aggregates. CESifo Working Paper 658(5).

Takens, F. (1981). *Detecting Strange Attractors in Turbulence*, Volume 898 of *Lecture Notes in Mathematics: Dynamical Systems and Turbulence, Warwick 1980*, pp. 366–381. Springer-Verlag, Berlin, Germany. D. Rand L.-S. Young (eds).

Valle e Azevedo, J. (2002, April). Business cycles: Cyclical comovement within the european union in the period 1960-1999. a frequency domain approach. WP 5-02, Banco do Portugal, Lisbon, Portugal.

Webber, C. J. and J. Zbilut (1994). Dynamical assessment of physiological systems and states using recurrence plot strategies. *Journal of Applied Physiology 76*, 965–973.

Webber Jr., C. and J. Zbilut (2005). Recurrence quantification analysis of nonlinear dynamical systems. National Science Foundation, Washington DC, USA. Chapter 2, Methods for the Behavioral Sciences, eds. M. Riley and G. Van Orden, available at www.nsf.gov/sbe/bcs/pac/nmbs/nmbs.jsp.

Zarnowitz, V. and A. Ozyildirim (2002, January). Time series decomposition and measurement of business cycles, trends and growth cycles. Working Paper 8736, NBER, Cambridge, MA, USA.

Zbilut, J. (2005). Use of recurrence quantification analysis in economic time series. In M. Salzano and A. Kirman (Eds.), *Economics: Complex Windows*, pp. 91–104. Milan, Italy: Springer-Verlag Italia.

Zbilut, J. and C. Webber Jr. (1992). Embeddings and delays as derived from quantification of recurrence plots. *Physics Letters A 171*, 199–203.