BREXIT AND MACROECONOMIC SYNCHRONIZATION IN THE EU

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Abstract

The departure of the UK from the EU (commonly known as Brexit) leads to some fundamental questions about the future economic relationship with the EU and whether the UK might consider joining the EFTA countries as an alternative. This paper uses a recently developed measure of synchronicity to assess i) the degree of macroeconomic synchronicity that the UK has historically had with the EU as a whole, and ii) the degree of macroeconomic synchronicity with other individual EU member states; and iii) the degree of synchronicity that the UK has historically had with the EFTA countries. The findings are that while the UK has not been an outlier within the EU, it would also fit quite comfortably within the EFTA grouping. This may be due to the emergence of a European business cycle that affects both EU and EFTA member business cycles.

1.Introduction

The UK's decision in 2016 to leave the European Union (EU) by referendum has initiated a debate in economics about whether the effects of leaving the EU will be significant, and whether it might be advantageous for the UK to join the European Free Trade Area (EFTA) instead[1], or to just trade under World Trade Organization (WTO) rules. Recent events, most notably the election of Boris Johnson as Prime Minister of the UK and the departure of the UK from the EU on January 31st, 2020 now makes the question addressed in this paper even more prescient.

One economic perspective on this issue is purely in terms of synchronicity of cycles, given the existence of a distinct European business cycle. The argument here is that if there is a common EU business cycle, then the UK economy, largely through existing trade linkages, should continue to grow on a similar trajectory to the rest of the EU, and therefore should experience a similar level of synchronization either in or out of the EU. This can be partially tested by looking at the EFTA member states and seeing whether their level of synchronization with the EU is similar to that of other non-euro area member states. Of course this does presume that the trade negotiations between the UK and the EU lead to a similar arrangement to that of the EU with the individual EFTA countries, which at the time of writing, is still not assured.

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[1] EFTA consists of Iceland, Liechtenstein, Norway, and Switzerland. Here we just consider Iceland, Norway and Switzerland as EFTA countries given lack of data availability for Liechtenstein.

This research presented here is essentially statistical in nature, and first takes a backward look solely at the macroeconomic synchronization in the European Union and in the EFTA, and then second postulates whether the macroeconomic synchronization will change, and if so, whether the UK might be more suited to joining the EFTA or not. This short paper is organized into 4 sections, with the next section focused on measuring macroeconomic synchronization, then section 3 detailing the statistical technique used in this paper, section 4 showing the results and then section 5 concludes.

2. Macroeconomic Synchronization

2.1 Background

In most economics papers that deal with Europe and in particular the euro area[2], it is assumed that synchronization of macroeconomic variables will lead to a more sustainable and successful monetary union. The reason for this expectation is that policies enacted at the supranational, federal, or confederate level, most notably fiscal and monetary policy, should provide a common dynamic component which will be found across the constituent members of the union[3].

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[2] Perlikis Gogas, "Business Cycle Synchronisation in the European Union: The Effect of the Common Currency," *OECD Journal: Journal of Business Cycle Measurement and Analysis* 2013, no. 1 (2013), 1-14. For example the abstract to this paper states that "In this paper, I analyze the synchronization of business cycles within the European Union (EU), as this is an important ingredient for the implementation of a successful monetary policy".

[3] Of course fiscal policy enacted by for example the US Congress can be aimed at a particular set of States (- for example disaster relief after a hurricane), or its impact might incidentally give greater benefits to a specific state (- for example defense spending in relation to the Californian economy). Similarly, monetary policy that benefits financial institutions might have a greater impact on those regions of the country that have a concentration of financial services (such as New York in the

But taking this logic one step further, any economic union or group of countries that has a considerable amount of supranational policy competencies should also prompt a weaker common dynamic component than between a monetary union to exist between those countries. To date, though, there has only been limited inquiry presented in the economics literature to provide any firm empirical evidence for this assertion, with the exception of Karras, who applies a simple synchronization analysis to the US and finds that there is no firm evidence to support this assertion, and Antonakakis and Tondl, who does find that market integration within the EU fosters greater synchronization through trade and Foreign Direct Investment (FDI) channels[4].

The EU though is much more complicated than a simple monetary union, as it encompasses concentric policy competencies in different areas, making any statistical generalization much harder than for a simple federally or confederally constituted (monetary) union. Indeed, being part of an economic and monetary union within some larger governance structure could also generate industry dynamics which give rise to agglomeration effects, and hence idiosyncratic (and often faster) growth dynamics in a specific location (for example

US context).

[4] Georgios Karras, "How Homogenizing are Monetary Unions?: Evidence from the US States," *The North American Journal of Economics and Finance* 14, no. 3 (2003), 381-397; Nikolaos Antonakakis and Gabriele Tondl, "Does Integration and Economic Policy Coordination Promote Business Cycle Synchronization in the EU?," *Empirica* 41, no. 3 (2014), 541-575.

technology in relation to Silicon Valley in California in the US and Berlin in Europe, or banking and securities in relation to Frankfurt and Luxembourg in Europe or Toronto in Canada). But if location effects are spread fairly evenly across the union or common market or trading area, then these effects will likely not overpower the impact of supranational, federal or confederal policies at the national, state or provincial level. At the same time, similar idiosyncratic regional characteristics might come into play as certain industries (such as agricultural or resource extraction industries) might dominate regionally, giving a higher degree of regional co-movement. In the context of the EU, Antonakakis and Tondl[5] finds that greater specialization does not appear to hinder the trend towards increased synchronization.

This also fits in with Optimal Currency Area (OCA) theory, as Mundell argues that monetary unions with more redistributive fiscal policies enacted at a federal level should be able to withstand less synchronization of business cycles if there is a high degree of labour mobility between the constituent parts of a monetary union[6]. In this regard, monetary unions vary significantly in their degree of labour

[5] Ibid.
[6] Robert A. Mundell, "A Theory of Optimum Currency Areas." *The American Economic Review* 51, no. 4 (1961): 657-665. See also Ronald I. McKinnon, "Optimum Currency Areas," *The American Economic Review* 53, no. 4 (1963), 717-725; Peter Kenen, "The Theory of Optimum Currency Areas: An Eclectic View. In Mundell R. and A. Swoboda, eds,"Monetary Problems in the International Economy" (Chocago" University of Chicago Press, 1969): 41-54; and Paul Krugman, *Geography and Trade* (Cambridge: MIT Press, 1991).

mobility, with the US and Australia having the highest degree of mobility, closely followed by Canada, but the European Union is noted for its general lack of labour mobility due to linguistic and cultural barriers to migration. This logic also carries through to common markets and customs unions, where comparative advantage would suggest that labour should move to where it can be most effectively employed, hence labour mobility once again becomes pertinent.

Of course, there is also the issue of longevity, where it is notable that the member states that joined the euro in the first wave were, for the most part, member states that were founding members of the EU. This fact could also give rise to greater synchronicity given that common stocks are likely to be symmetric in their impact and therefore induce greater synchronicity over time, as greater harmonization gives rise to so-called "endogenous" effects[7]. Naturally it is difficult to account for this fact within any statistical framework, given the fact that path dependencies and other idiosyncratic factors are likely to impinge upon any transition to more common macroeconomic dynamics for the particular issue of the EU accession countries)[8].

Lastly, another complication concerns the business cycle itself.

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[7] See Jeffrey A. Frankel and Andrew K. Rose, "Is EMU More Justifiable ex post than ex ante?," *European Economic Review* 41, no. 3-5 (1997), 753-760.

[8] For example, see Bas van Aarle, Harry Garretsen and Cindy Moons, "Accession to the Euro-area: A Stylized Analysis Using a NK Model," *International Economics and Economic Policy* 5, no. 1-2 (2008), 5-24.

Growth convergence is usually assessed in terms of the distribution of economic growth rates, as measured by the growth in real Gross Domestic Product (GDP) over time[9], and in particular over the span of the business cycle. In Crowley (2008) and in Crowley and Schultz (2011) synchronicity was measured in terms of measures derived from recurrence plot analysis methodology[10]. This approach is refined and repeated here. The complication concerning the business cycle is that indeed these episodes of growth usually are extremely synchronized during the contractionary phase of the business cycle, but during the expansionary phase of the cycle, which usually includes growth cycles, there are signs of only "intermittent synchronicity"[11]. This "intermittency" is perhaps due to the way that policy measures filter through the macroeconomy, with other factors sometimes overwhelming any policy initiatives.

2.2 The Macroeconomics of EU Business Cycle Synchronization

Assessment of the synchronicity in movement of economic growth rates is important for two underlying reasons:

a) The more globalized the world becomes, the more likely that

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[9]An alternative is to use output gaps as Mink, Jacobs, and de Haan do: Mark Mink, Jan PAM Jacobs and Jakob de Haan, "Measuring Coherence of Output Gaps with an Application to the Euro Area," *Oxford Economic Papers* 64, no. 2 (2012), 217-236.

[10] Patrick Crowley, "Analyzing Convergence and Synchronicity of Business and Growth Cycles in the Euro Area using Cross Recurrence Plots," *European Physical Journal: Special Topics 164 (2008)*, 67-84; Patrick Crowley and Aaron Schultz, "Measuring the Intermittent Synchronicity of Macroeconomic Growth in Europe," *International Journal of Bifurcation and Chaos* 21, no. 4 (2011), 1215-1231.

[11] See Crowley, "Analyzing Convergence and Synchronicity of Business and Growth Cycles," 67-84.

trade and financial flows will cause greater "synchronization" in macroeconomic variables between countries; and

b) For regional agreements from free trade agreements onwards, similar movements in macroeconomic variables due to common policies are likely to foster similarities in macroeconomic dynamics.

There has long been recognition of the propagation phenomenon of business cycles between countries (the main mechanisms being trade and capital flows). The main indicator of this propagation is the synchronicity of turning points in business cycles (noted Backus and Kehoe (1992) and Backus, Kehoe, and Kydland (1995) in the real business cycle literature) between countries[12], but what is not recognized here is that the economic growth dynamic between these turning points (usually the recessions or peaks of business cycles) can be radically different. 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[13]. From an empirical perspective there have been some efforts to extract cycles for measurement and

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[12] David K. Backus and Patrick J. Kehoe, "International Evidence on the Historical Properties of Business Cycles," *The American Economic Review* (1992), 864-888; David K. Backus, Patrick Kehoe and Finn Kydland, "International Business Cycles: Theory and Evidence," In F. Cooley (Ed.), *Frontiers of Business Cycle Research* (Princeton: Princeton University Press, 1995), 331-356.

[13] See Zenon G. Kontolemis, "Does Growth Vary Over the Business Cycle? Some Evidence from the G7 Countries," *Economica* 64, no. 255 (1997), 441-460 and V. Zarnowitz and A. Ozyildirim, "Time Series Decomposition and Measurement of Business Cycles, Trends and Growth Cycles [Електронний ресурс]," *NBER Working Paper–January* (2002).

comparison across countries using time-frequency domain techniques[14].

This is in contrast with the euro area context, for example, where there is a recognition that it cannot be characterized as an OCA and that the shift to the adoption of the euro within the Economic and Monetary Union (EMU) process using specified economic convergence criteria has only partially fostered greater synchronization of euro area growth rates, at best[15]. As this is an important issue for the cohesion of the euro area, there has been a considerable empirical research done on this topic, with a good summary of the literature in de Haan, Inklaar, and Jong-a Pin[16]. This was followed by Artis and Zhang (1997) who first recognized the

[14] See Patrick M. Crowley and Andrew Hughes Hallett, "Correlations Between Macroeconomic Cycles in the US and UK: What Can A Frequency Domain Analysis Tell Us?," *Italian Economic Journal* 2, no. 1 (2016), 5-29; Marco Gallegati and Mauro Gallegati, "Wavelet Variance Analysis of Output in G-7 Countries," *Studies in Nonlinear Dynamics & Econometrics* 11, no. 3 (2007); Patrick M. Crowley and Jim Lee, "Decomposing The Co-movement of the Business Cycle: A Time-frequency Analysis of Growth Cycles in the Euro Area, "*Bank of Finland Research Discussion Paper* 12 (2005); M. Crivellini, M. Gallegati, M. Gallegati, and A. Palestrini, "Industrial Output Fluctuations in Developed Countries: A Time-scale Decomposition Analysis," In *Working Papers and Studies: papers from the 4th Eurostat and DGFin Colloquium 'Modern Tools for Business Cycle Analysis'* (2004).

[15] See Maximo, Camacho, Gabriel Perez-Quiros, and Lorena Saiz, "Are European Business Cycles Close Enough To Be Just One?," *Journal of Economic Dynamics and Control* 30, no. 9-10 (2006), 1687-1706; and Sébastien Wälti, "Business Cycle Synchronicity, Amplitude and the Euro: One Size Does Not Yet Fit All" (2009).

[16] Jakob, De Haan, Robert Inklaar, and Richard Jong-A-Pin, "Will Business Cycles in the Euro Area Converge? A critical Survey of Empirical Research," *Journal of Economic Surveys* 22, no. 2 (2008), 234-273.

existence of a separately identifiable European business cycle[17], and then this was followed by Artis and Zhang (1999)[18], 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[19]. Apart from a comparison between the euro area and the US done by Wynne and Koo (2000) and usage of the technique used in this paper in Crowley and Trombley (2015), little has been done though to compare macroeconomic synchronization of regional integration projects[20].

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[17] Michael J. Artis and Wenda Zhang, "International Business Cycles and the ERM: Is There A European Business Cycle?," *International Journal of Finance & Economics* 2, no. 1 (1997), 1-16.

[18] Michael J. Artis and Wenda Zhang, "Further Evidence on the International Business Cycle and the ERM: Is there a European Business Cycle?," *Oxford Economic Papers* 51, no. 1 (1999), 120-132.

[19] See Carlo Altavilla, "Do EMU Members Share the Same Business Cycle?," *JCMS: Journal of Common Market Studies* 42, no. 5 (2004), 869-896; Marianne Sensier, Michael Artis, Denise R. Osborn, and Chris Birchenhall, "Domestic and international Influences on Business Cycle Regimes in Europe," *International Journal of Forecasting* 20, no. 2 (2004), 343-357; João Valle e Azevedo, *"Business Cycles: Cyclical Comovement within the European Union in the Period 1960-1999. A Frequency Domain Approach. No. w200205* (2002); Jakob De Haan, Robert Inklaar, and Olaf Sleijpen, "Have Business Cycles Become More Synchronized?," *JCMS: Journal of Common Market Studies* 40, no. 1 (2002), 23-42; Bernd Süssmuth, "National and Supranational Business Cycles (1960-2000): A Multivariate Description of Central g7 and euro15 NIPA Aggregates" (2002); Uwe Böwer, Uwe Catherine Guillemineau, "Determinants of Business Cycle Synchronisation Across Euro Area Countries" (2006); Domenico Giannone and Lucrezia Reichlin, *Trends and Cycles in the Euro Area: How Much Heterogeneity and Should We Worry about It?. No. 595.* ECB working paper (2006); and Robert Inklaar, Richard Jong-A-Pin, and Jakob De Haan, "Trade and Business Cycle Synchronization in OECD Countries—A Re-examination," *European Economic Review* 52, no. 4 (2008), 646-666.

[20] Mark A. Wynne and Jahyeong Koo, "Business Cycles under Monetary Union: A Comparison of the EU and US," *Economica* 67, no. 267 (2000), 347-374; Patrick M. Crowley and Christopher Trombley, "Are Monetary Unions More Synchronous Than Non-monetary Unions?," *Bank of Finland Research Discussion Paper* 11 (2015).

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 first noted that cyclical convergence was much more a global rather than a regional phenomenon, with Hughes Hallett and Richter showing that the convergence at lower frequencies was due to common cycles, in other words globalization[21]. In the latter study though, Hughes Hallett and Richter only used the US, UK and the euro area to assess this, so this was not confirmed as a general result. Another strand of literature has used factor analysis to attempt to identify global, regional and idiosyncratic business cycles, and a key paper in this strand is Kose, Otrok, and C., with a more recent discussion of the issues connected with distinguishing between regional and global cycles found in Cooke, Kose, Otrok, and Owyang[22].

Despite the result from Hughes Hallett and Piscitelli (2002) that

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[21] James H. Stock and Mark W. Watson, "Understanding Changes in International Business Cycle Dynamics," *Journal of the European Economic Association* 3, no. 5 (2005), 968-1006; Andrew Hughes Hallett and Christian Richter, "Is the Convergence of Business Cycles A Global or Regional Issue? The UK, US and Euroland," *International Journal of Finance & Economics* 11, no. 3 (2006), 177-194.

[22] M. Ayhan Kose, Christopher Otrok, and Charles H. Whiteman, "International Business Cycles: World, Region, and Country-specific Factors," A*merican Economic Review* 93, no. 4 (2003), 1216-1239; Christopher, Otrok, Diana A. Cooke, Michael T. Owyang, and M. Ayhan Kose, "Regional vs. Global: How Are Countries' Business Cycles Moving Together These Days?," *The Regional Economist* April (2015).

trade integration does not necessarily lead to greater synchronization, Lee (2010) provides strong evidence in sup-port of the conventional wisdom that rising global integration over time, through either trade or foreign direct investment flows, raises a US State economy's business cycle correlation with the world economy. Interestingly, openness to trade and investment promotes greater business cycle synchronization within regional US economies than with the rest of the world. Of course the results of Hughes Hallett and Piscitelli are now somewhat dated, and the results of Lee relate to an entity that is already a monetary union[23].

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[23] A. Hughes Hallett and Laura Piscitelli, "Does Trade Integration Cause Convergence?," *Economics Letters* 75, no. 2 (2002), 165-170; Jim Lee, "Globalization and Business Cycle Synchronization: Evidence from the United States," *Journal of International and Global Economic Studies* 3, no. 1 (2010), 41-59.

Figure 1: EU Member State Business Cycle Synchronization
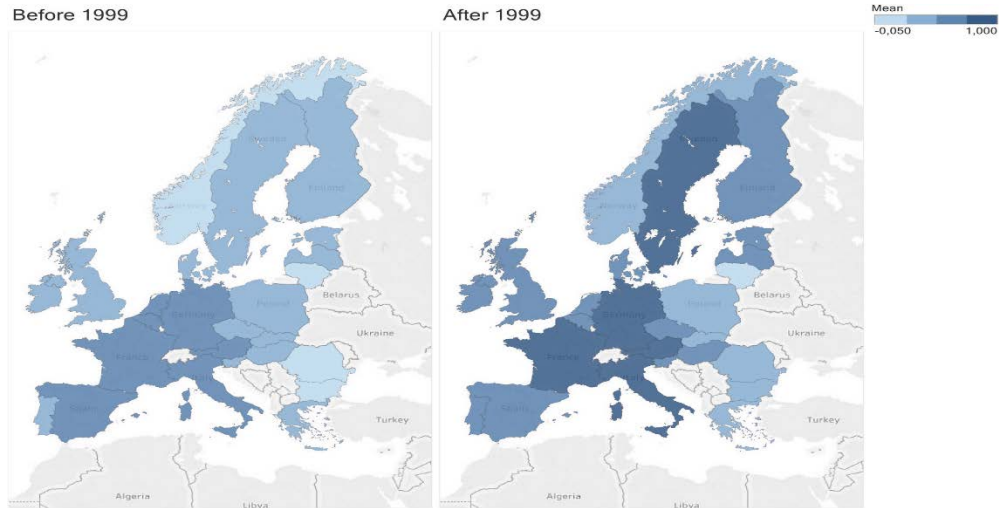
(Source: Campos, Fidrmuc, and Korhonen (2019)

3. Methodology and Data

3.1 Measuring Synchronicity as Dynamic Dissimilarity

The technique used to derive a measure of synchronicity presented here which we label a Dynamic Dissimilarity Measure (DDM), is based on recurrence plots[24] and is described in detail in Crowley and Trombley (2014) (with an application to US States)[25]. The DDM focuses on the similarity of the dynamics by taking the distance measure between the cumulative sum of any two series, and seeing

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[24] Recurrence plot analysis is now over 20 years old (see J-P Kamphorst, S. Eckmann, S. Oliffson, and D. Ruelle, "Recurrence Plots of Dynamical Systems," *Europhysics Letters* 4, no. 9 (1987) for the first contemporary application) and the quantification of these plots is much more recent (see Joseph P. Zbilut and Charles L. Webber Jr., "Embeddings and Delays as Derived from Quantification of Recurrence Plots," *Physics Letters A* 171, no. 3-4 (1992), 199-203 and Charles L. Webber Jr. and Joseph P. Zbilut, "Dynamical Assessment of Physiological Systems and States Using Recurrence Plot Strategies," *Journal of Applied Physiology* 76, no. 2 (1994), 965-973) but the notion of recurrence has a much longer pedigree in mathematics (see W. Feller, *An Introduction to Probability Theory and its Applications* (New York, John Wiley & Sons, 1950)) and now has a considerable following in a variety of fields particularly in the physical sciences. There are several excellent introductions available to recurrence plots, not least those by Norbert M. Marwan, Carmen Romano, Marco Thiel, and Jürgen Kurths, "Recurrence Plots for the Analysis of Complex Systems," *Physics Reports* 438, no. 5-6 (2007), 237-329 and Charles L. Webber Jr. and Joseph P. Zbilut, "Recurrence Quantification Analysis of Nonlinear Dynamical Systems," Chapter 2, Methods for the Behavioral Sciences, eds. M. Riley and G. Van Orden (Washington D.C.: National Science Foundation, 2005. Available at www.nsf.gov/sbe/bcs/pac/nmbs/nmbs.jsp. Other economic applications to macroeconomic issues using recurrence plot techniques can be found in Joseph P. Zbilut, "Use of Recurrence Quantification Analysis in Economic Time Series", In M. Salzano and A. Kirman (Eds.), *Economics: Complex Windows*, pp. 91-104 (Milan: Springer-Verlag Italia, 2005); Catherine Kyrtsou and Constantinos E. Vorlow, "Complex Dynamics in Macroeconomics: A Novel Approach," In *New Trends in Macroeconomics*, pp. 223-238 (Berlin; Heidelberg: Springer, 2005), Crowley (2008) and Crowley (2010).

[25] Patrick Crowley and Christopher Trombley, "Synchronicity Assessment Using a Non-parametric Dynamic Dissimilarity Measure," In *Translational Recurrences*, pp. 187-210. Springer, Cham, 2014.

how this varies through time within an epoch (windowed) analysis framework. The advantage of this approach is that it is solely based on the dynamics of the series not on degree of movement (as correlations are), so it separates the idea of similarity of direction of movement (synchronization) from the degree of movement (convergence). In terms of actually calculating the measure, it is dependent on the length of span that is used, so there is some interpretation required, which there is not for a correlation measure.

We begin the analysis with a dataset consisting of a panel of time series. As a preliminary step, we first convert each data point, $Z_{i,j}$ where j is the series label and i is the time point into a stationary series (if necessary, otherwise we treat $X_{i,j} = Z_{i,j}$) by log first differencing, so that:

$$X_{i,j} = \sum_{i=1}^{n} \ln Z_{i,j} - \ln Z_{i-1,j}$$

where $i = 1$ is the first quarter on record.

The series is first converted into a cumulative unsigned series (CUS) by the standard method:

$$X_{i,j} = \sum_{n=1}^{i} X_{n,j}$$

Around each datapoint, a Euclidean distance matrix is formed in the manner of [Marwan07]. In other words, we form a window or

epoch, and then wish to know the relative distance of datapoints from each other within the specified window or epoch. This means that at each datapoint we form a matrix in the following manner:

$$\mathcal{D}_{i,j} = \sqrt{\sum_{\ell=i}^{n} (\mathcal{X}_{\ell,j} - \mathcal{X}_{i,j})^2}$$

Where $\mathcal{N}$ is the desired number of datapoints in the epoch or window. The matrix $\mathcal{D}_{i,j}$ therefore contains the dynamics of series j over time. This matrix is then normalized. We choose to normalize the distance matrix by the maximum entry $\max_{i,j} \mathcal{D}_{i,j}$. In order to compare dynamics between two variables, for example, component wise absolute differences are taken

$$E_{i,k,m} = \frac{\mathcal{D}_{i,k} - \mathcal{D}_{i,m}}{2}$$

These results are placed in an ordered list of matrices, which in mathematical terms is defined as a tensor. For a given year i, the tensor reduces to a matrix given by the absolute difference between countries i and j in Euclidean distance travelled by the cumulative sum of the measured rate over a window starting on that year. For a given j, the tensor reduces to a matrix given by a running tally of such differences between series j and each series m over time. The

DDM itself is found by averaging all of these latter component matrices for a given time over all locations. In essence, this is given as:

$$\mathcal{DDM}_{i,k} = \frac{\sum_{m=1}^{\mathcal{M}} E_{i,k,m}}{\mathcal{M}}$$

where $\mathcal{M}$ is the number of series. Note that for example in the case where $\mathcal{N} = 3$: i) the dynamics included in the comparison range over 5 periods, as each point in itself represents a change in the distance matrix; ii) the $E_{i,k,m}$ matrix incorporates both lead and lag dynamics as it includes off-diagonal elements as well; and iii) A value of $E_{i,k,m} = 0$ clearly denotes complete synchronization between the two series.

This process can be done for a single variable against another variable by setting $\mathcal{M} = 2$ in equation Eq6 to create a synchronicity-proxy, or can be repeated for each possible combination pair of time series so as to create a "super" dissimilarity matrix for all variables. In the latter case, the dissimilarity matrix at each time step is then averaged to estimate the total dissimilarity between members of the group for a particular temporal window - this is the version of the dynamic dissimilarity measure (DDM) used in the analysis here. The final product is then a one-dimensional time series representing the synchronization in dynamics between members of a set with smaller values indicating greater synchronicity, and vice versa. The methodology is summarised in terms of a flow diagram in figure 2.

Figure 2: Flow diagram representation of DDM calculation
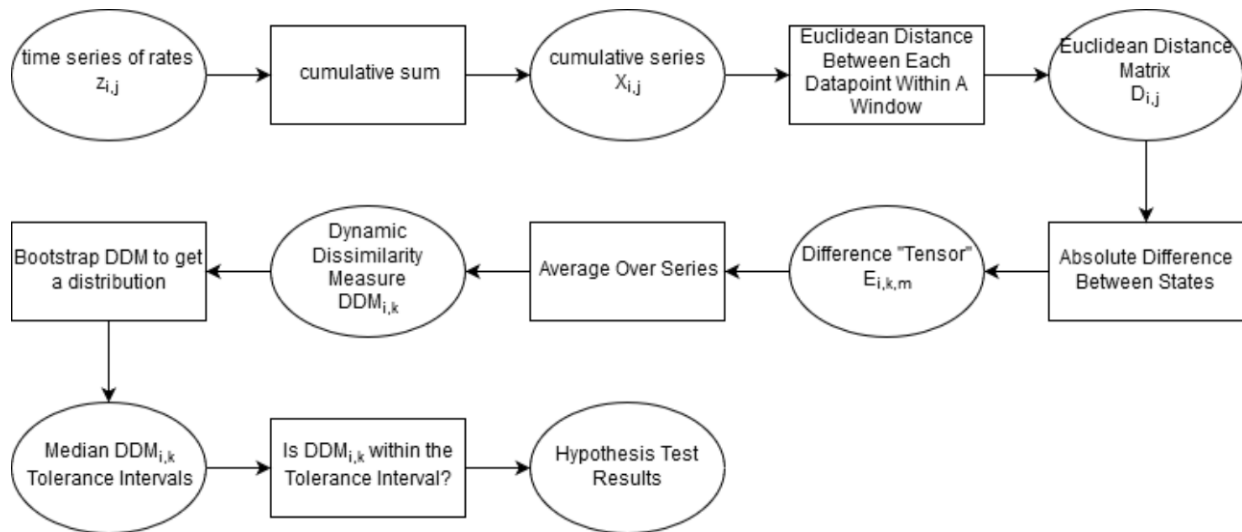
Figure 3: Real GDP growth for EU member states
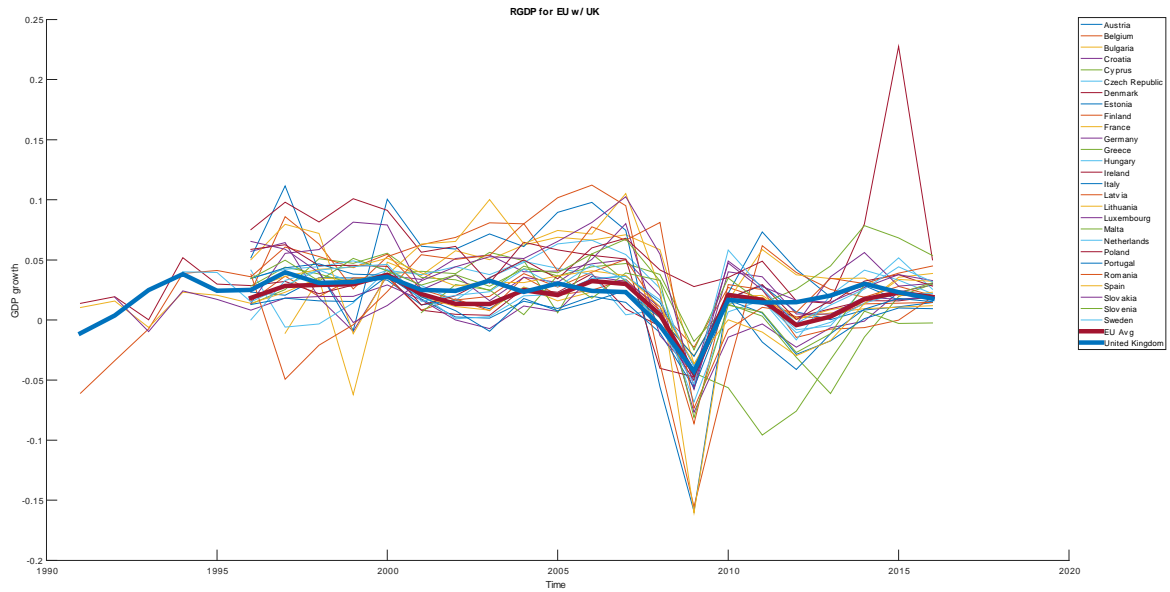
Although the method described above is similar to the approach described in Sornette and Zhou[26] for finding optimal lag or lead structures, the present method is not concerned with lead or lag structures but is solely concerned with using a general approach to construct a non-parametric dynamic measure of synchronicity. The DDM described here was first applied by Crowley and Schultz (2011) to EU data to show how signed macroeconomic synchronicity between European Union member states is intermittent, and in this paper we use an unsigned (Euclidean distance) measure as a means of assessing synchronicity in small samples identical to that used in Crowley and Trombley (2014).

3.2   Data

The macroeconomic data available for EU member states is sourced from Eurostat and the IMF IFS, as well as the OECD:

a)   Economic growth - here we measure economic growth at time t, as g_t , by taking the real Gross Domestic Product (GDP) at time t, y_t , and transforming it by taking natural log first differences. For the EU, this dataset is only available from 1998 on an annual basis for all member states, so once log first differences are taken the data span is from 1999 to 2017, giving 18 datapoints. The data is plotted in Figure 3, which shows that the international business cycle is clearly at play for all countries, as the downturn in economic growth

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[26] Didier Sornette and Wei-Xing Zhou, "Non-parametric Determination of Real-time Lag Structure Between Two Time Series: The 'Optimal Thermal Causal Path' Method," *Quantitative Finance* 5, no. 6 (2005). 577-591.

in the early 1990s occurs in a staggered fashion, and then a synchronized downturn follows in both the 2001 recession, and with the great recession in 2008-09.

Now a similar exercise can be done for the EFTA countries, and this appears in Figure 4. Clearly, Iceland has been rather an outlier from the EFTA countries, not only in its rapid growth before the great recession, but also in the downturn it experienced during the great recession and its phenomenal bounce afterwards.

b)   Inflation - here this is proxied by the GDP deflator, otherwise known as the GDP Price Index (GDPPI). Once again, the natural log first difference is taken. Figure 5 shows the inflation measures. For all the EU member states, and it is immediately apparent that since the great recession there has been convergence in inflation rates, with perhaps the exception of the UK. Certainly in 2015, although inflation rates were low in the EU on average, the UK appears to have experienced a bout of deflation. In figure 6 we show the UK inflation rate against that of the EFTA countries. Interestingly Norway and Switzerland also experienced bouts of deflation around 2015.

c)   Unemployment - this is taken as the usual definition of the unemployment rate, i.e. the number of unemployed as a percentage of the labour force. Figure 7 shows that from the early 2000s unemployment rates fell through until the great recession, after which there was a sharp move upwards as the great recession hit. In the aftermath of the great recession rates have largely been convergent

from around 2013 onwards, with a couple of member states - Greece and Spain experiencing extremely high unemployment rates in around 2013. This can be contrasted with figure 8, which shows that EFTA unemployment bifurcated between Norway and Switzerland, whose labour markets only had minor responses to the great recession in terms of unemployment, and this is contrast with both Iceland and the UK, which had a much greater increase in unemployment during the great recession.

4. Brexit and Macroeconomic Synchronization

The research strategy in this paper is to use the dynamic dissimilarity method described above to analyze the synchronization of:

i) EU member states with the EU aggregates for a) GDP growth, b) inflation and c) unemployment over time with particular emphasis on the UK;

ii) EU member states with each other for a) GDP growth, b) inflation and c) unemployment over time with particular emphasis on the UK; and

   d) EFTA member states + UK with each other for a) GDP growth, b) inflation and c) unemployment.

Figure 4: Real GDP growth for EFTA countries and the UK

RGDP for EFTA w/ UK
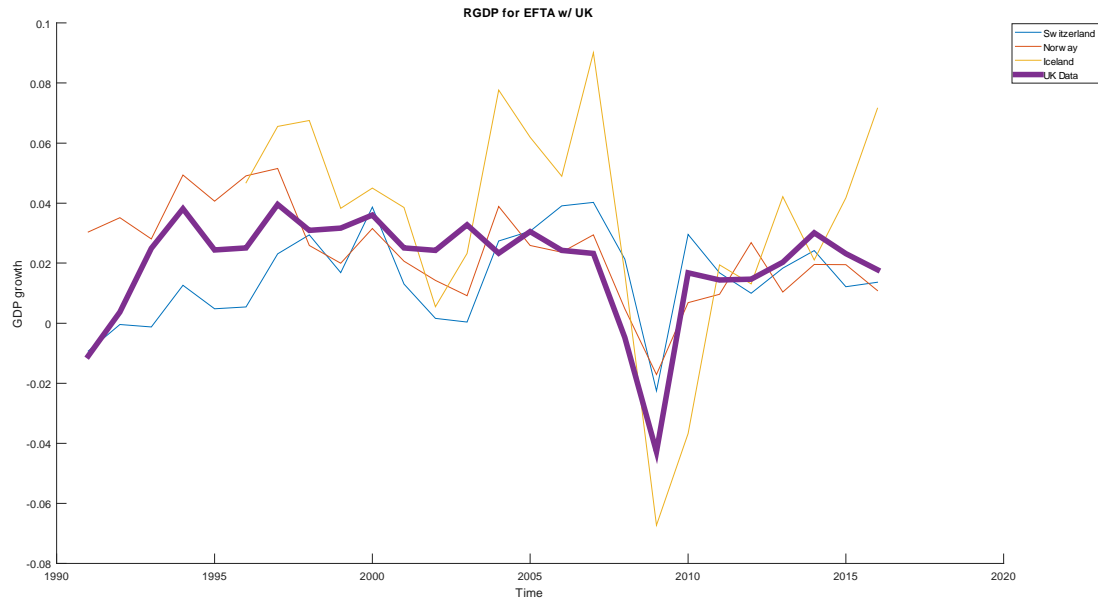
Figure 5: GDPPI inflation for EU member states
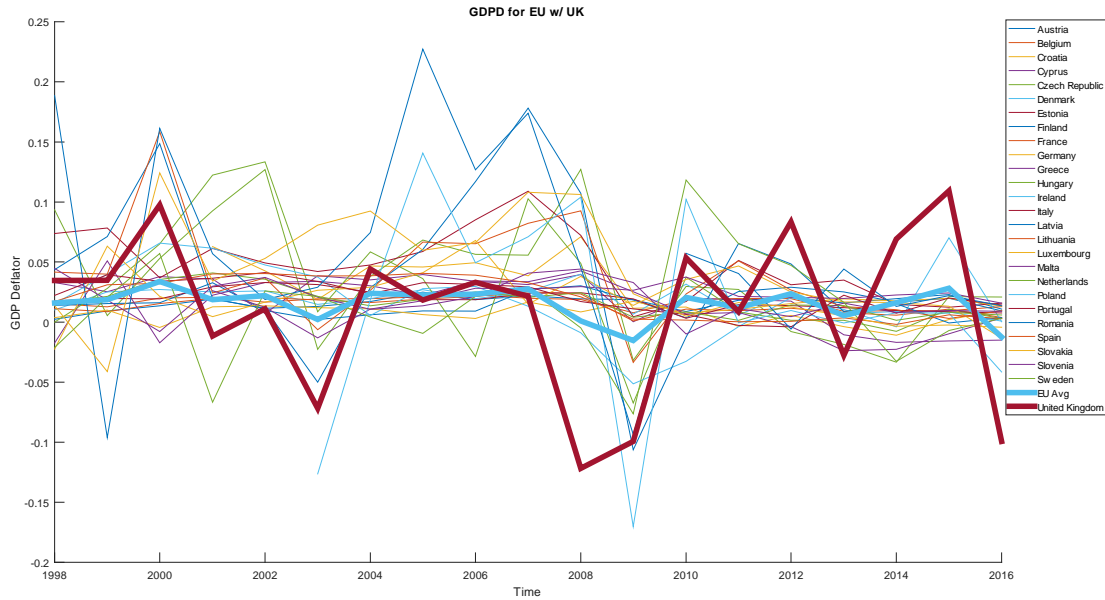
Figure 6: GDPPI inflation for EFTA countries and the UK
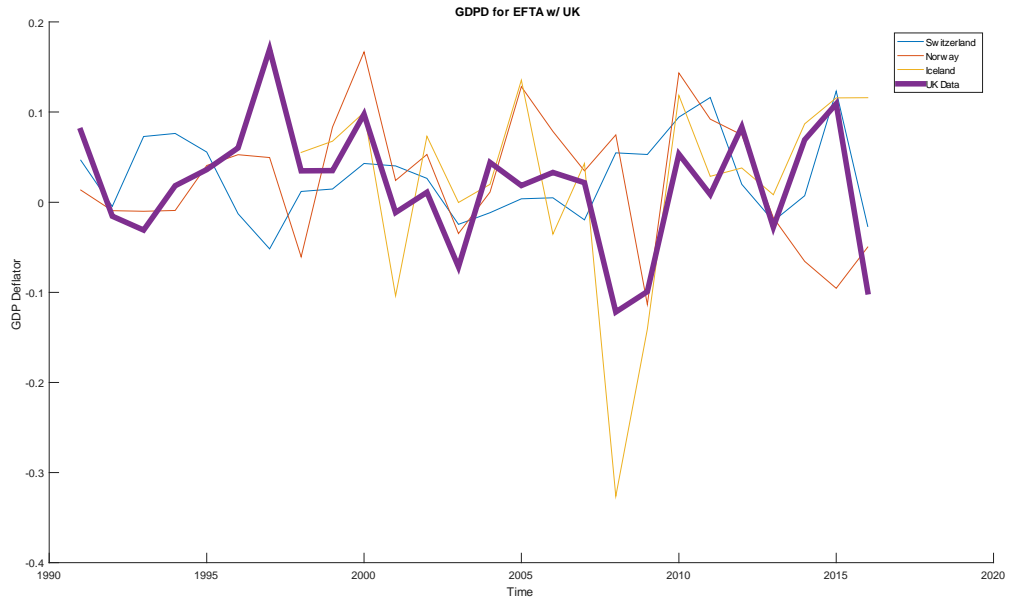
Figure 7: Unemployment rates for EU member states

UNEMP for EU w/ UK

Legend:
Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Spain, Slovakia, Slovenia, Sweden, EU Avg, United Kingdom

X-axis: Time (2000–2016)
Y-axis: GDP Deflator (0–30)
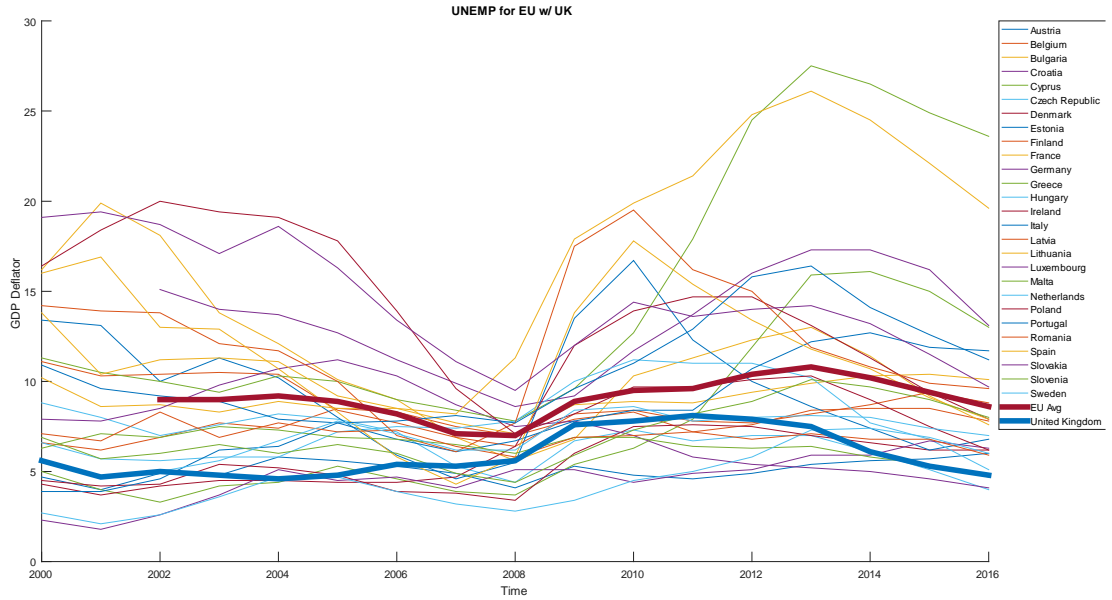
Figure 8: Unemployment rates in EFTA countries and the UK
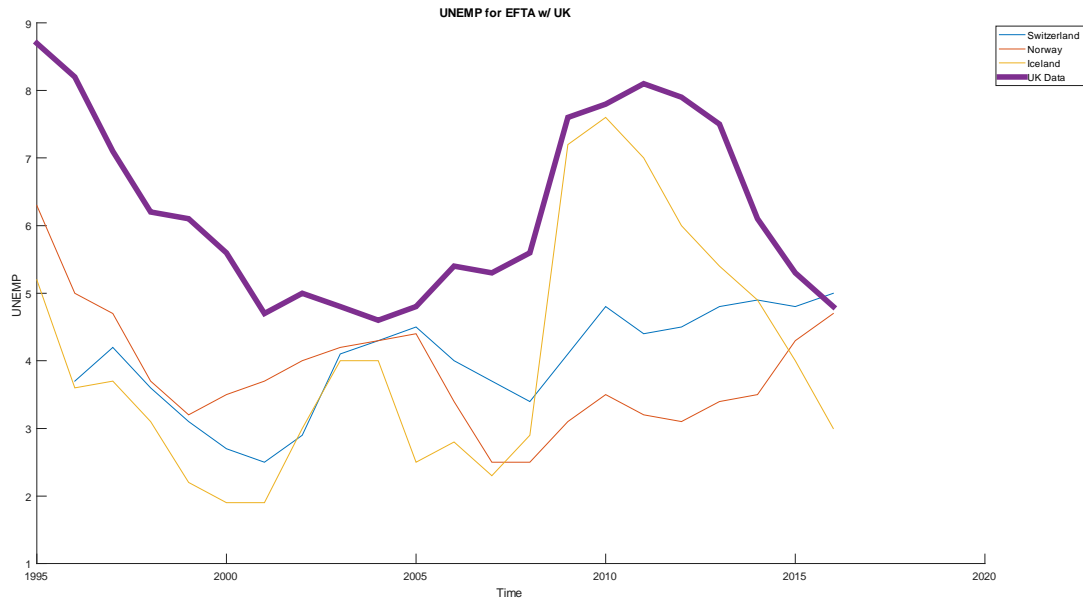
4.1 UK Macroeconomic Synchronization with the EU Aggregates

4.1.1 GDP

In figure 9, the dissimilarity is plotted for all EU member states vs the EU aggregate. A value of 0.0 would represent complete similarity in dynamics, so it is clear that at any point in time no particular member state has identical economic growth dynamics to the EU aggregate, but nonetheless there are episodes when particular member states experience quite dissimilar macroeconomic dynamics to the aggregate. So, for example during the great recession Latvia in particular had quite dissimilar dynamics and lately Italy appears to have experienced somewhat dissimilar dynamics to the rest of the EU.

For purposes of comparison, we also plot a mean dissimilarity for the EU as a whole, plus a 95% confidence interval. In figure 10 we isolate the UK's growth dynamics to show if the UK was outside the 95% confidence interval (thick yellow line), and also we can see the synchronicity of the UK in relative terms compared to the average level for all member states. It is clear that apart form a brief period between 2005 and 2007, UK economic growth was synchronized with the EU aggregate. Also, after 2008 economic growth rates for the UK have been not that far from the average for the EU.

Figure 9: EU member state economic growth synchronization
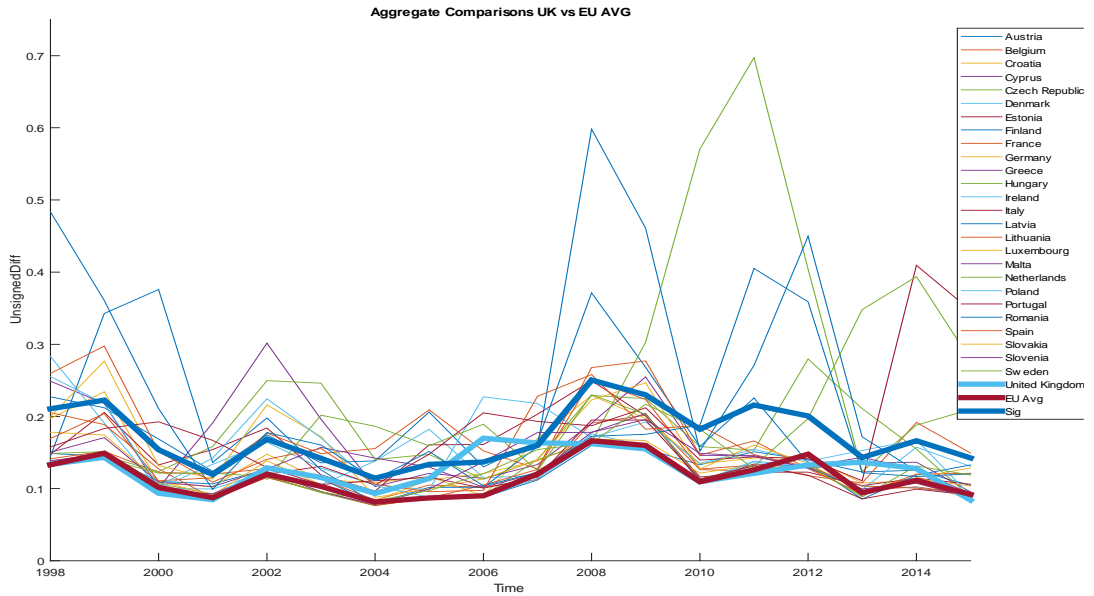
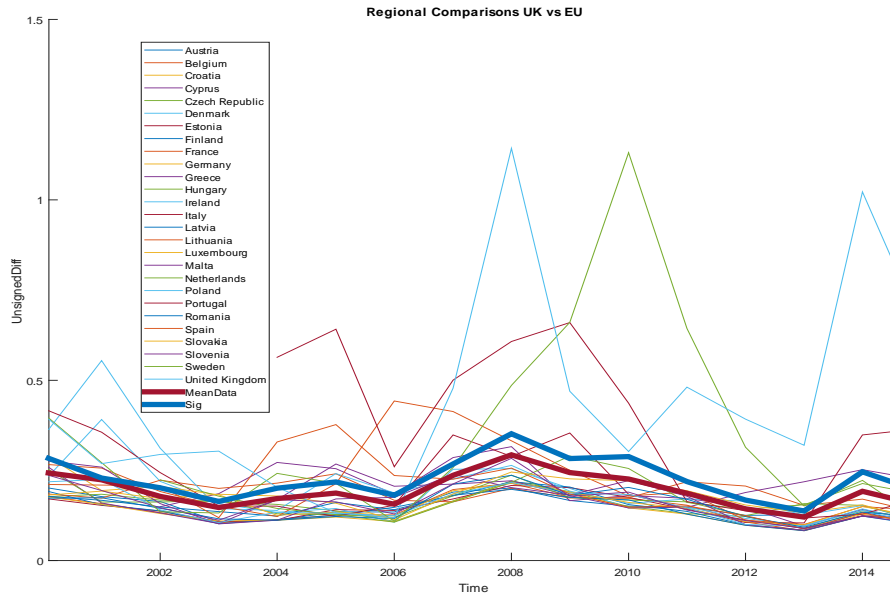Figure 10: UK economic growth significance test

Aggregate Comparisons UK vs EU AVG
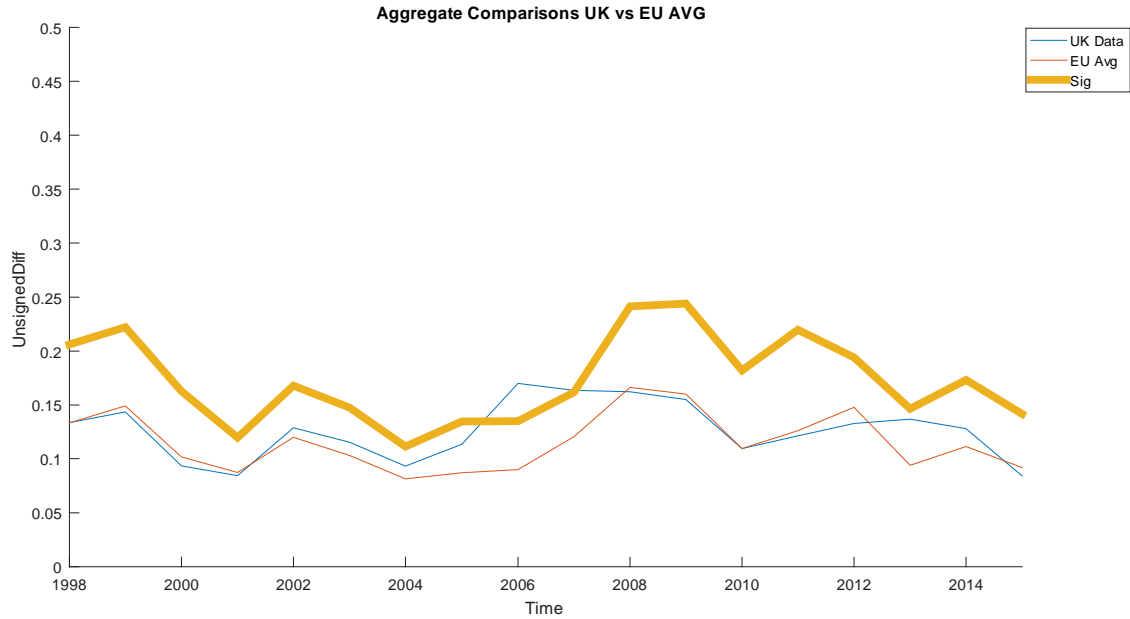
Figure 11: Synchronization of EU member state inflation vs EU aggregate

4.1.2 GDPPI

For GDPPI (GDP price index or deflator), in figure 11 it is clear that both the UK and Greece have been regularly experiencing quite dissimilar inflation dynamics to that of the EU. In figure 12 we focus exclusively on the UK and note that only in and around 2005 was UK inflation close to the average in terms of EU synchronization levels. From 2006 onwards there has been effectively dissimilar inflation dynamics between the UK and the EU.

4.1.3 Unemployment

In figure 13 unemployment synchronization for the EU member states against an EU aggregate are plotted As might be expected, there is a high degree of synchronization in unemployment rate dynamics in 2008, as the recession got underway, but after that the level of synchronization diverges as certain member states experience persistently high rates of unemployment. Figure 14 shows that the UK is for the most part not too far away from the EU mean level of synchronization, and only rarely has the UK dynamic strayed too far away from the average, but noticeably it did in 2008, when of course the great recession hit harder in the UK due to its higher level of exposure to US business cycles.

Figure 12: UK inflation synchronization vs EU aggregate

Aggregate Comparisons UK vs EU AVG
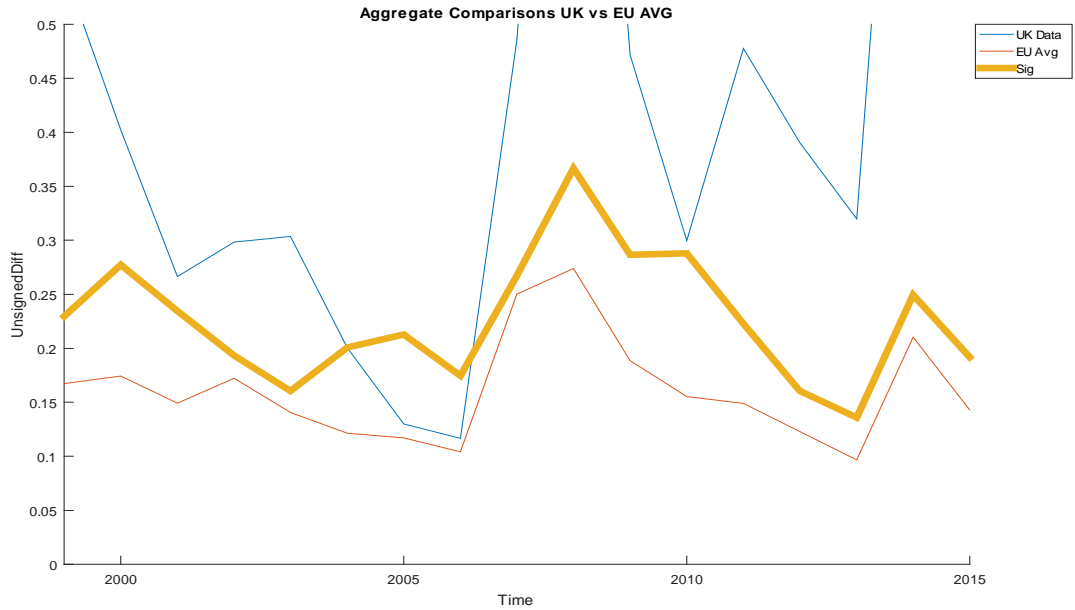
Figure 13: Synchronization of EU member state unemployment rates vs EU aggregate
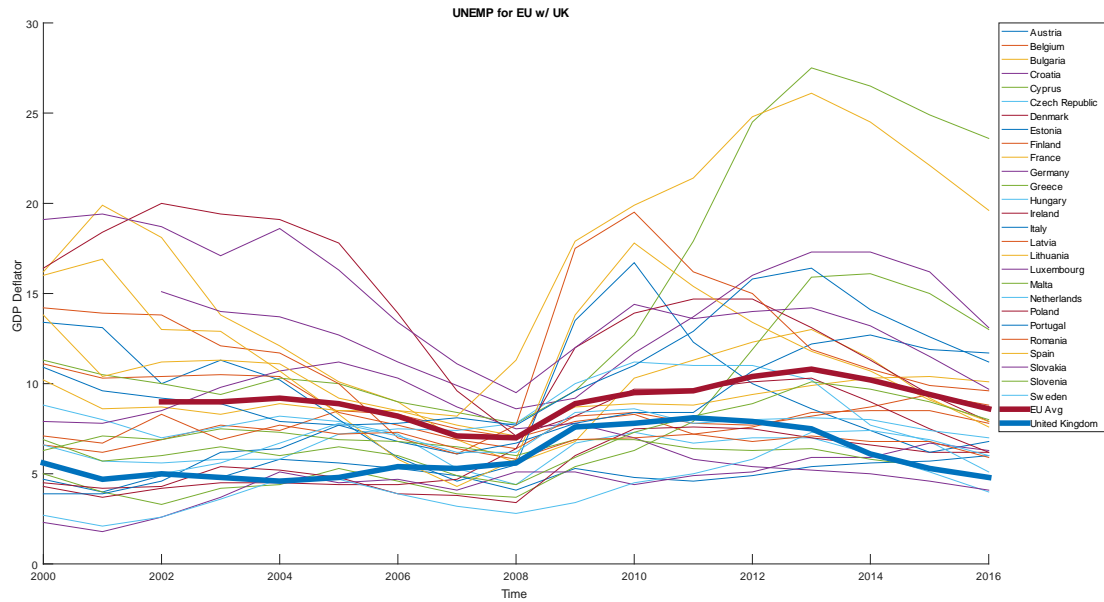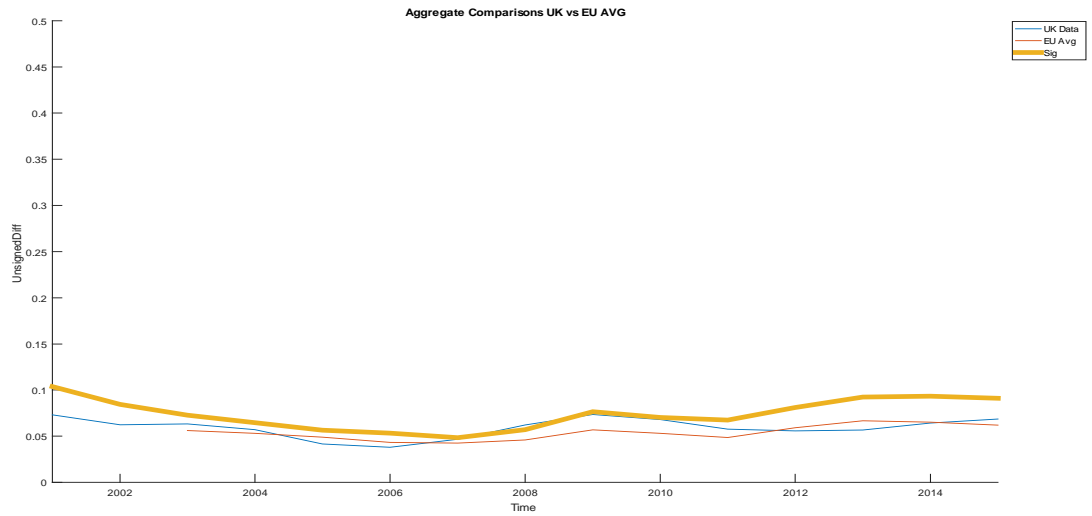

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Figure 14: UK unemployment rate synchronization vs EU aggregate

4.2 UK Macroeconomic Intra-Synchronization with EU member states

Here we look at each member state's synchronization with every other member state, rather than using an EU aggregate. This can be seen as an alternative way of viewing synchronization within a grouping of countries.

4.2.1   GDP growth

Figure 15 shows the average synchronization of each EU member state to all other member states. For the period going into the great recession synchronicity between member states increased with the mean dissimilarity falling from around 0.2 to 0,1, but once synchronicity fell again coming out of the great recession in 2009, the average dissimilarity of all the EU member states has successively fallen (signifying an increase in synchronization), with some undulations evident, perhaps signaling growth cycles in the data. Figure 16 also shows a similar pattern for the UK level of synchronization with the EU aggregate when using the intra-synchronization measure, with only the window around 2005 being a period where the UK appears to have a divergent dynamic from the rest of the EU.

4.2.2   GDPPI

Figure 17 shows the synchronization of inflation with other member states, and once again this is quite similar to the EU aggregate chart shown earlier. Most of the member states are bunched close to one another, with a trend of higher synchronization occurring

after the great recession but to a lesser extent than with economic growth. Figure 18 isolates out the UK and shows that for much of the time under consideration the UK has been significantly less synchronized with other member states inflation rates compared to the level of intra-synchronization of other EU member states.

4.2.3 Unemployment

In figure 19 the synchronization of unemployment rate movements with other member states shows that synchronization was at its highest in the downturn that marked the start of the great recession (2007), but that after the downturn the dynamics of unemployment then diverged for member states with progressively less similarity through until the present day. In figure 20 the unemployment dynamic for the UK has been fairly similar to other EU member states, and post-2011 the UK has actually had more synchronized unemployment dynamics with other EU member states compared with the average EU member state.

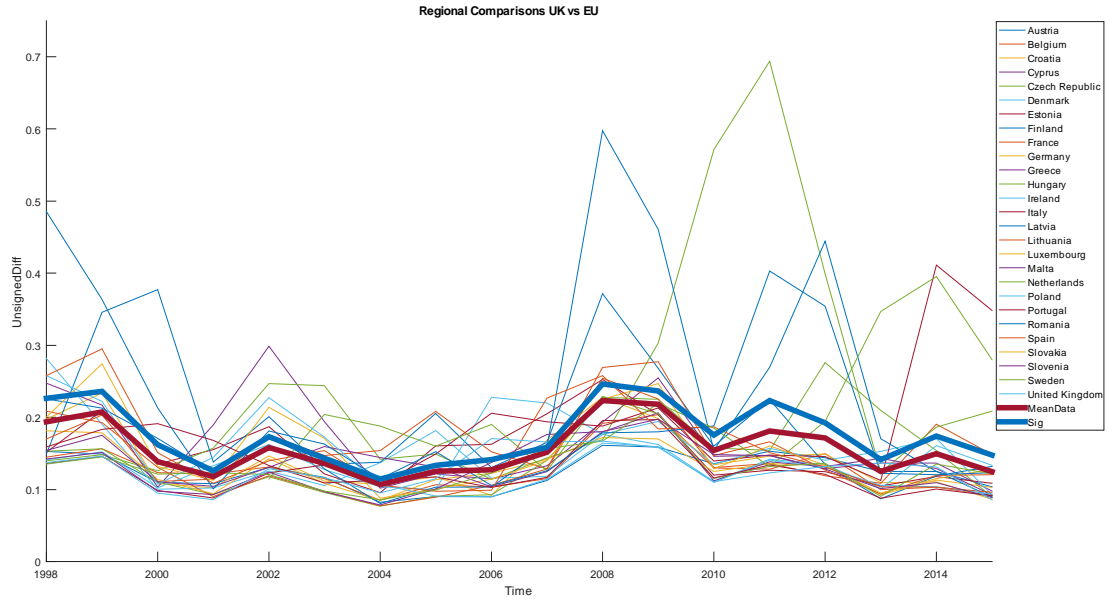Figure 15: Economic growth intra-synchronization for EU member states

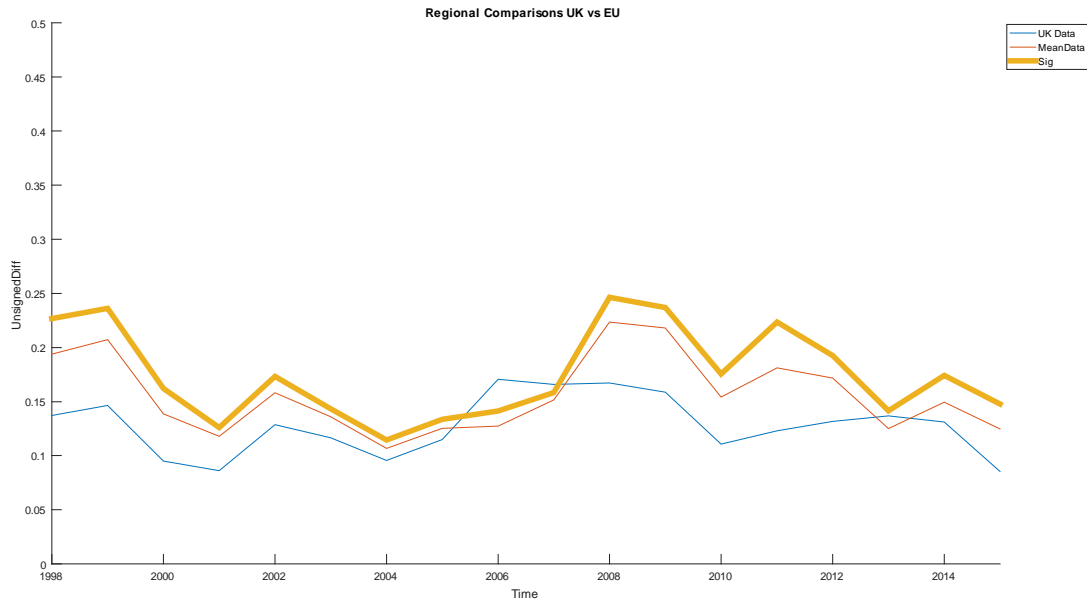Figure 16: UK growth synchronization vs EU intra-synchronization

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Figure 17: Inflation intra-synchronization for EU member states
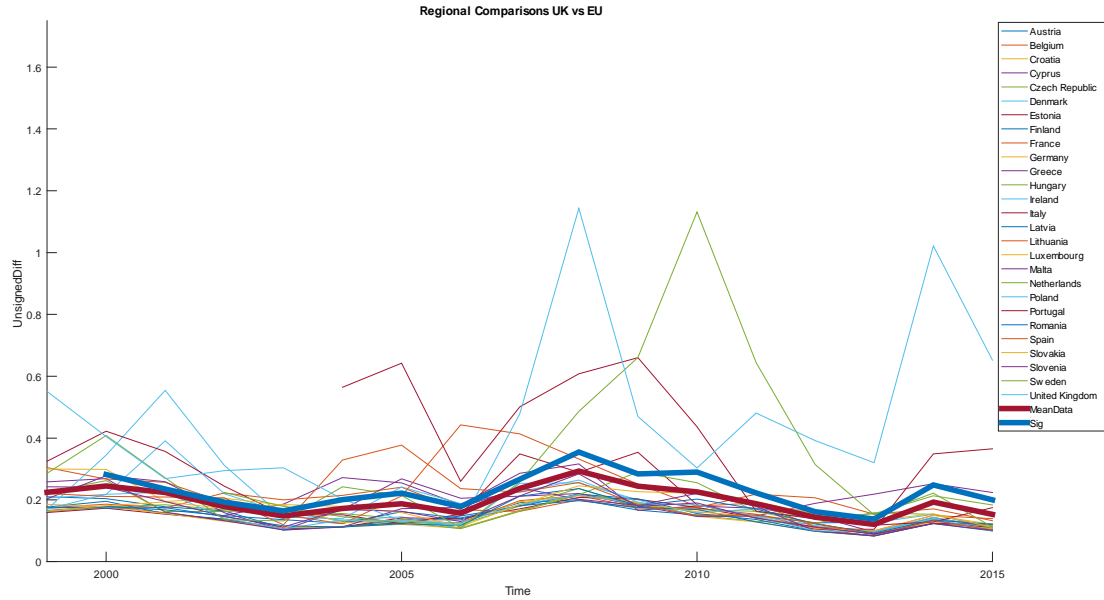

Regional Comparisons UK vs EU

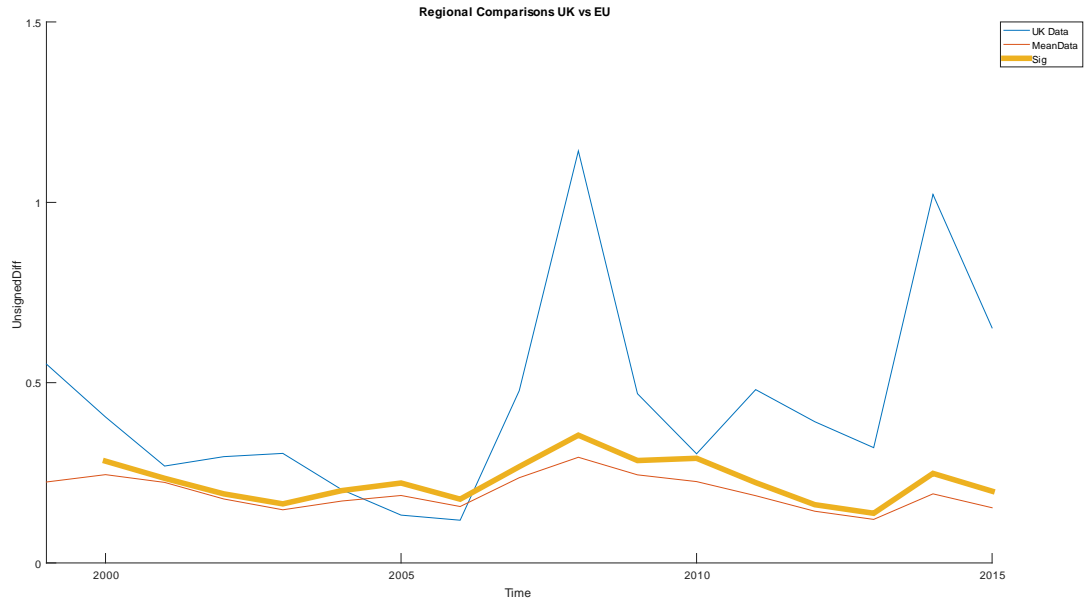Figure 18: UK inflation synchronization vs EU intra-synchronization

Figure 19: Unemployment intra-synchronization for EU member states

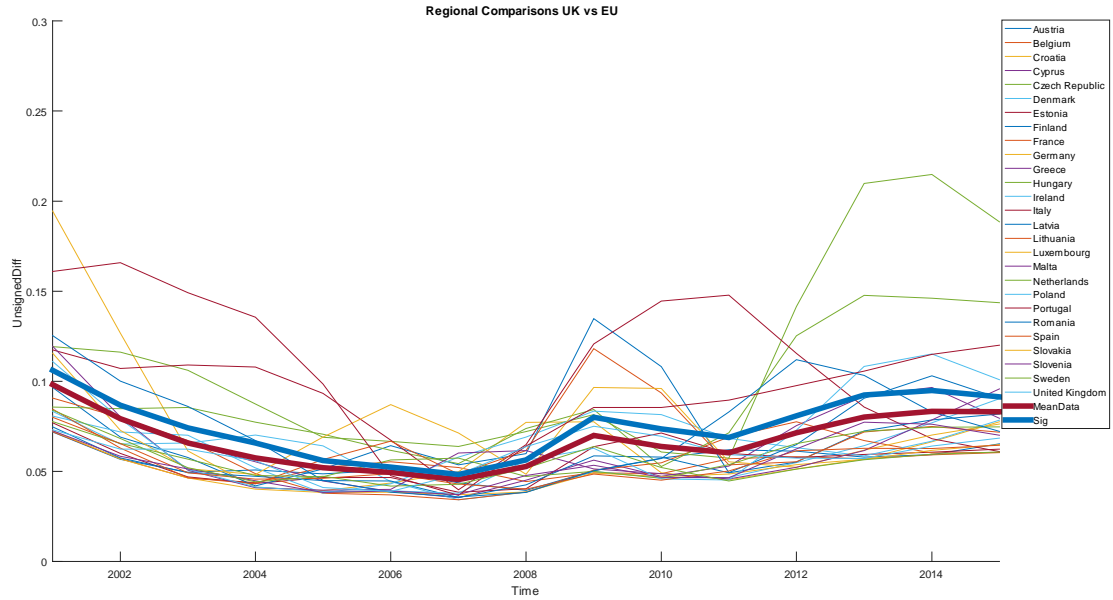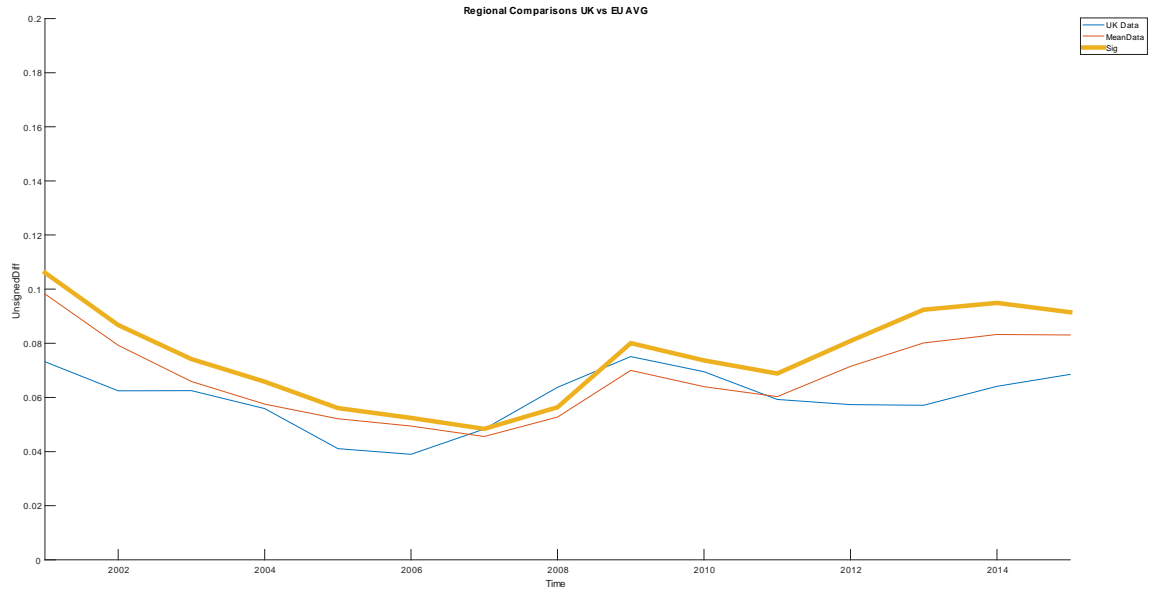Figure 20: UK unemployment synchronization vs EU intra-synchronization

4.3 UK Macroeconomic Intra-Synchronization with EFTA countries

Here we evaluate the synchronicity of the UK with EFTA countries (Iceland, Norway and Switzerland). To evaluate synchronization for the members we take each country and evaluate the intra-synchronicity, and then to evaluate hypothetical synchronization for the UK, we then add the UK to this group and calculate the synchronization against the 3 EFTA members separately.

4.3.1 GDP growth

In Figure 21 we show the synchronization of the UK with the EFTA members for economic growth, and compare it with the intra-group synchronization for each EFTA country with only other EFTA countries. The results are quite surprising for the UK, as for much of the recent past, the UK has been highly synchronized with the EFTA countries, and since roughly 2002 the UK has been the most synchronized country with other EFTA members.

4.3.2 GDPPI

In figure 22 we evaluate the synchronization of the UK with EFTA members for inflation. In this instance, synchronization of inflation varies, with the UK being highly synchronous with EFTA countries before 1995, and around 2005 and 2010, but at other times, not synchronous, and in fact significantly so, for example from 1995-8 and during the great recession where clearly the UK seemed to have a different trajectory than most other European countries.

4.3.3　Unemployment

For unemployment, figure 23 shows synchronization in unemployment rate dynamics for the EFTA countries and for the UK. Apart for the period from 2001 to 2004, the synchronization of the UK with EFTA countries was high.

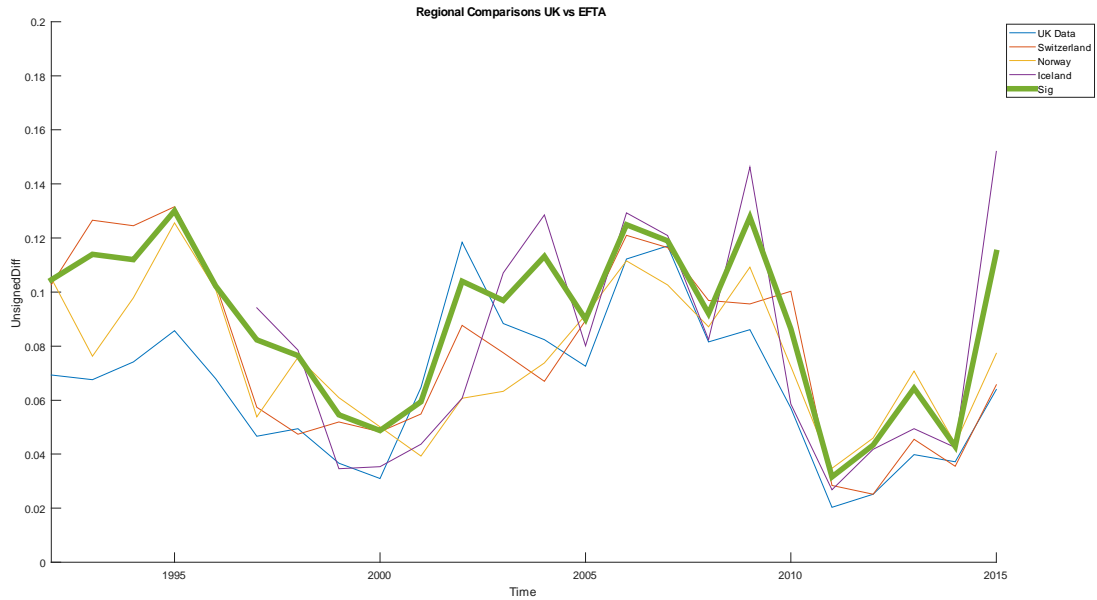Figure 21: UK growth synchronization with EFTA countries

Regional Comparisons UK vs EFTA

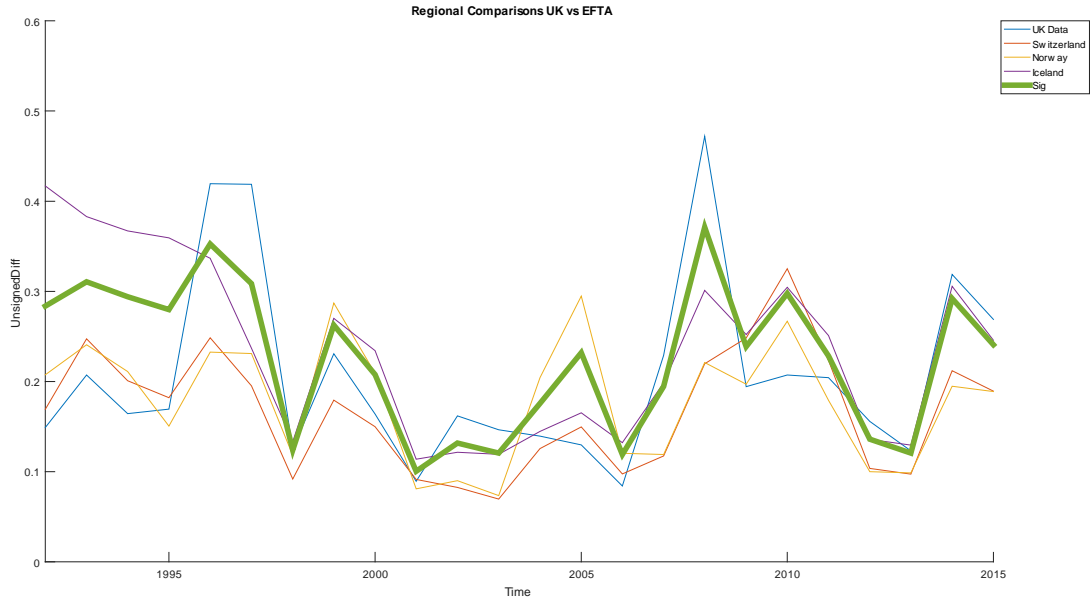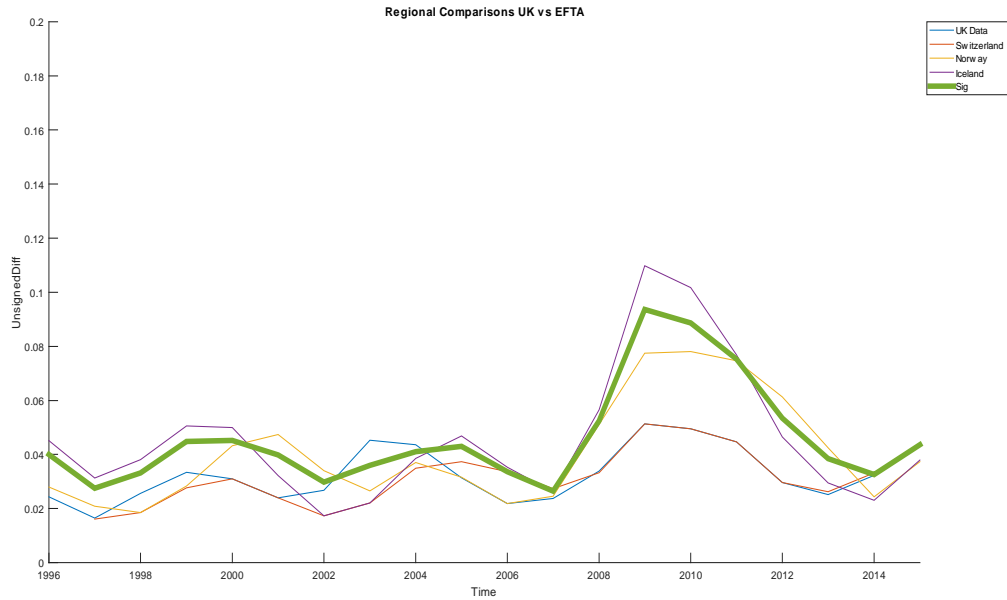Figure 22: UK inflation synchronization vs EFTA countries

Figure 23: UK Unemployment synchronization with EFTA countries

4.4 Post-Factual Brexit Exercise

One question that likely arises from the above analysis is whether the UK better fits with the EU or the EFTA countries from the viewpoint of macroeconomic synchronization. In figure 24 we assume that the UK joins EFTA and compare the intra-group synchronization for the EU member states with those of EFTA. Rather surprisingly, synchronization between EFTA countries was until 2015, higher for EFTA countries than for EU member states, although synchronization in growth appears to be increasing among EU member states, and declining among EFTA countries.

When we do the same for inflation in figure 25, we find that there is essentially no difference between the EU and EFTA for much of the period under consideration in terms of inflation dynamics, although the UK still has significantly different dynamics from all other European countries in the last few years of the dataset. This is also surprising, as with the euro area and its European Central Bank (ECB) monetary policy, one might have expected significantly greater inflation synchronization within the EU than for EFTA.

Lastly, we turn to unemployment in figure 26. Here the picture is a little different as there are times, particularly during the period going into the great recession (2007/08) and coming out of it (2011), when intra-group synchronization for both the EU and EFTA are similar, which tends to suggest that international business cycle considerations dominate, but outside of that period, it is noteworthy that in the early 2000s there was a higher degree of synchronization

in EFTA than in the EU and that also has been the case from around 2012 onwards.

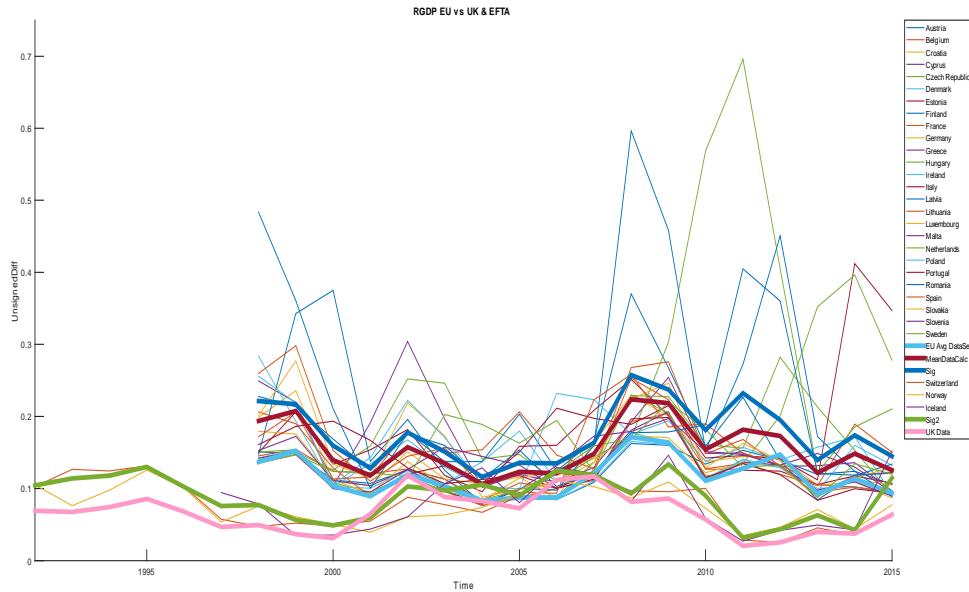Figure 24: Economic growth intra-group synchronization under Brexit for EU and EFTA

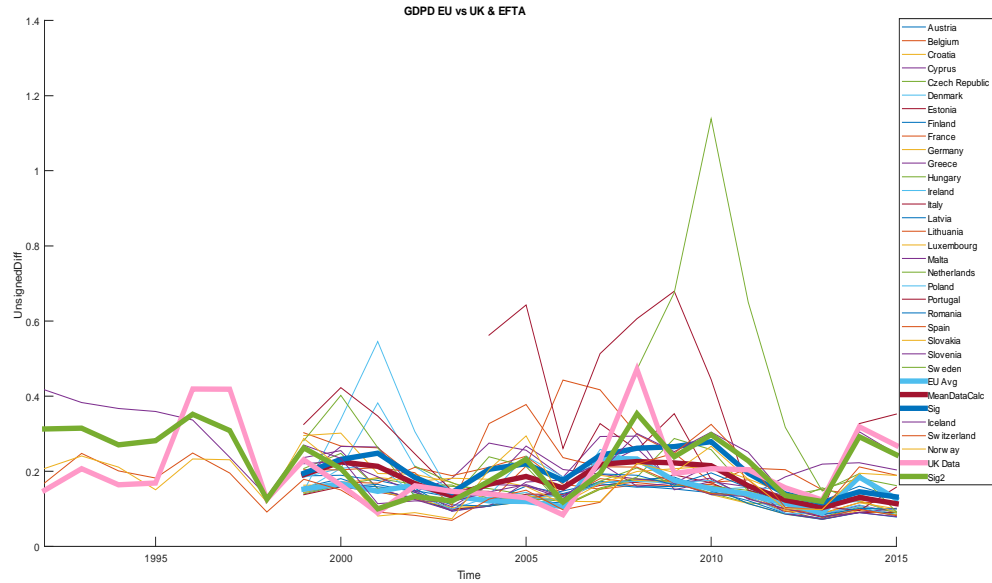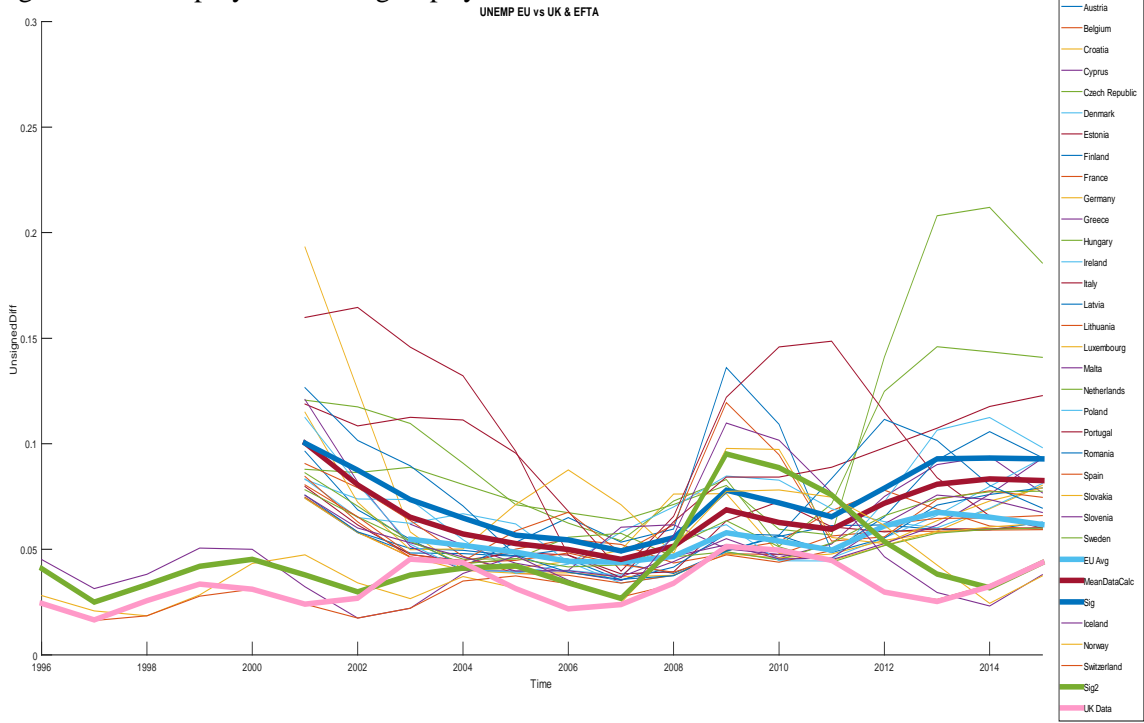Figure 25: Inflation intra-group synchronization under Brexit for EU and EFTA

GDPD EU vs UK & EFTA

Figure 26: Unemployment intra-group synchronization under Brexit for EU and EFTA

UNEMP EU vs UK & EFTA

4.5   Discussion

The general result found above is that clearly macroeconomic synchronization varies over time, with higher degrees of synchronization within the EU occurring at the peak and the trough of the "great recession", and that the synchronization within the EU and within EFTA for the most part is not that different, although there are periods when EFTA has greater macroeconomic synchronization than the EU.   Although our results are limited to just 3 economic variables, [Campos19] showed that business cycle synchronization increased in both euro and non-euro countries of the EU according to meta-analysis of about 3000 business cycle synchronization coefficients, which implies that synchronization has increased on a European wide level, so that if the UK cides to just change group membership, this might not lead to significantly less synchronization for the UK or for the EU as a whole.

This might not be so surprising considering that all members of EFTA are either members of the European Economic Area (EEA), or like Switzerland have a separate side agreement, so are all participants in the single market. Given that a European business cycle clearly exists, it will impact countries that are not even members of the EU through the EEA.

Perhaps the most surprising result obtained from this research though is that the UK would fit quite well from a macroeconomic synchronization perspective with the existing EFTA trading bloc, and apparently, this would on average be a better fit than the

macroeconomic synchronization with the EU. But given recent events, membership of the EEA does not seem to be something that any new trade agreement between the UK and the EU will include. The UK is a member of the EEA until 2021, but given disagreements overfishing and other issues, it is unlikely to continue as a member of the EEA. So, the main concern might be whether even the EFTA countries would contemplate having the UK as a member. It is our understanding that this is now a major concern of the EU right now - the fact that the UK wants rights to continue to access the single market but is unwilling to bind itself to the EEA membership requirements.

The likelihood that the UK completely decouples from the influence of the European business cycle is extremely low, given the location of the UK and the importance of trade in both goods and services between the UK and the EU.

5.   Conclusions

In this paper, a non-parametric dissimilarity measure was used to proxy synchronicity - the measure is based on the comparison of topological features of series based on recurrence plots. This synchronicity measure is then used to assess synchronicity of 3 key macroeconomic variables between EU members and EFTA members, with a particular focus on the UK and its synchronization relative to both groupings. There are limitations to the study - one relates to the fact that the sustainability of any country grouping is also likely to be dependent on the number of countries within that grouping, and

another relates to the fact that the dissimilarity measure that we use is dependent on annual data, so misses any synchronized movements on a quarterly or monthly basis.

The results vary by variable and approach, although synchronization vs the EU aggregate and the intra-group synchronization measures yielded quite similar results. For economic growth, apart from the run up and entry to the "great recession" (2008-09), synchronization between member states was fairly high, with the UK also highly synchronized and only in 2005 is the UK significantly unsynchronized with other EU members. Against the EFTA countries, the UK is even more highly synchronized, and in this instance only in 2001-02 was the UK significantly differently synchronized compared to the EFTA countries. On the whole, growth in EFTA countries is on average more synchronized than for EU countries, although not always so. For inflation, synchronization for inflation in the EU countries is not volatile, and only in 2008 (as the "great recession" took hold) did dissimilarity of synchronization peak. Nevertheless, certain countries, including the UK are consistently significantly dissimilar in their synchronization of inflation dynamics with both the EU aggregate and also on a within-group basis. Compared with the EFTA countries, the UK was frequently significantly dissimilar, but so were other EFTA countries as well. In terms of inflation dynamics, the EFTA group had a very similar level of similarity, and this was relatively constant throughout the time period in question. Lastly, for unemployment synchronization, the EU member states had quite similar levels of

dissimilarity throughout the period in question, with some countries (notably Greece) having somewhat different dynamics in the recovery since the "great recession". The UK's level of dissimilarity was only significantly different during the 2009-11 period, which coincides with the exit from the "great recession". These results were very similar for the intra-group synchronization measure as well, but the bunching entering the "great recession" was much less pronounced. For EFTA countries, there was a spike in dissimilarity from 2008 to 2013, showing that different dynamics persisted for 5 years after the "great recession" started. Compared to EFTA countries, the UK was very synchronous, and only became significantly dissimilar in the 2002-04 period. Comparing the 2 groups, the EFTA countries were significantly more similar than EU member states in the early 2000s and then after 2012.

In general, in terms of macroeconomic synchronization, the results point to possible UK membership of the EFTA group of countries, but this is a group of geographically dispersed countries whose members all have ties to the EU which are stronger than the UK currently envisages. There is also the issue of the US-UK trade agreement, currently being negotiated at the time of writing. If this is a trade agreement of greater significance than the final UK-EU agreement, then this might cause the UK to be an outlier in terms of its synchronization with other European countries. And lastly one must remember that Brexit comprises many facets: political, judicial, economic, social and others too - and these may impact the eventual economic relationship that the UK decides it wants with the EU.

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David Anderson graduated with a major in Computer Science and a minor in Economics from Texas A&M University – Corpus Christi in the spring of 2019 and worked as a research assistant to Patrick Crowley during the 2018/19 academic year. David now lives in the Dallas/Fort Worth area for Interconnect Wiring as an Analyst.