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Are Monetary Unions more Synchronous than non-Monetary Unions?

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Abstract

Within currency unions, the conventional wisdom is that there should be a high degree of macroeconomic synchronicity between the constituent parts of the union. But this conjecture has never been formally tested by comparing sample of monetary unions with a control sample of countries that do not belong to a monetary union. In this paper we take euro area data, US State macro data, Canadian provincial data and Australian state data – namely real Gross Domestic Product (GDP) growth, the GDP deflator growth and unemployment rate data – and use techniques relating to recurrence plots to measure the degree of synchronicity in dynamics over time using a dissimilarity measure. The results show that for the most part monetary unions are more synchronous than non-monetary unions, but that this is not always the case and particularly in the case of real GDP growth. Furthermore, Australia is by far the most synchronous monetary union in our sample.

Keywords: Business cycles, growth cycles, frequency domain, optimal currency area, macroeconomic synchronization, monetary policy, single currency.

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JEL Classification: C49, E32, F44, F45, F62

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1 Introduction

Synchronization occurs regularly in nature, usually because of some external driving force (such as the time of day, month or year, or because of social interactions)[1] Given that synchronization is also an integral part of human behavior, it would seem logical to expect synchronization to occur in economic growth when entities are subject to the similar exogenous forces. In the particular circumstance of a monetary union between countries, the common external force in the form of a single monetary policy might be expected to coerce a greater degree of synchronization in macroeconomic variables between the members of the monetary union over the business cycle. Indeed, economists widely adopt this assumption when analyzing monetary unions, as the common characteristics of a monetary union would suggest greater synchronization of macroeconomic variables than for a collection of countries that do not form a monetary union, and therefore are not subject to the same common external force. Testing this conjecture is the basis of this paper.

Economists have difficulty defining synchronization, partly because nearly all economic time series are stochastic in nature, and so a variety of different measures have been proposed to measure synchronicity. We economists often refer to time series as being "synchronized" if they exhibit co-movement, as measured, for example, by a simple measure of correlation. But generally co-movement in economics is measured from a long term perspective, using large datasets, and employing simple measures such as maximal windowed correlations to indicate synchronization, or more complex techniques such as cointegration and concordance measures from factor models (see Moneta and Ruffer (2006) and Gogas and Kothroulas (2009)), if data permits. This is an important issue though for policy purposes, as most policy decisions are taken on the basis of short term (real-time) data, so that much shorter horizon synchronization measures are most useful - hence most of the co-movement measures mentioned above are unsuited to capturing any meaningful assessment of short-term dynamic similarity. To address this shortcoming, a recently developed measure of dynamic synchronicity is used in this paper which is based on recurrence plots (see Crowley and Hughes Hallett (2014)).

From a theoretical perpective, macroeconomic synchronicity is often related to the optimal currency area (OCA) literature, in that the costs of joining a monetary union can be minimized if the synchronization of certain macroeconomic variables is high between the constituent members. These variables that require a high degree of synchronization are

[1] The topic of synchronization is vast, with probably the best reference on the subject being Pikovsky, Rosenblum, and Kurths (2001), which details the myriad forms of synchronization in nonlinear science.

economic growth, inflation, and similarity in unemployment rates if there is a low level of labor mobility, or a high degree of dissimilarity would be permissable if there were a high degree of labor mobility. Although the research presented here is clearly related to the OCA literature, testing for sychronization in variable dynamics is only one factor in the assessment of whether a monetary union can be classified as an OCA.

The paper is organized as follows: section 2 discusses some of the issues involved in assessing the degree of conformity in levels and movements in macroeconomic data, while section 3 summarizes the methodology and presents the data employed in this study. Section 4 then presents results, while section 5 concludes.

2 Macroeconomic Synchronization in Monetary Unions

2.1 Background

In most economics papers that deal with monetary unions, and for the euro area in particular (see, for example, Gogas (2013)[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 confederal 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]. To date though, there has not been any systematic inquiry that has been presented in the economics literature to provide any firm empirical evidence for this assertion, with the exception of Karras (2004), who applies a simple synchronization analysis to the US, and finds that there is no firm evidence to support this assertion.

The more centralized policymaking is in a given monetary union, the more likely it is that a common set of economic policies will generate common cycles within the monetary union and therefore lead to greater synchronicity between the members of the monetary union. But monetary unions are never solely monetary unions, as monetary policy is one of many economic policy functions within federations, confederations, or in the case of the

[2]For example the abstract to this paper states that "In this paper, I analyse the synchronisation 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 US context).

euro area, within a completely unique political and economic system of governance.

Of course 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 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, 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 regional characteristics might come into play here as certain industries (such as agricultural or natural resource industries) might dominate regionally, giving a higher degree of regional co-movement.

Fiscal policy can also have an impact, particularly when enacted at a federal, confederal or supranational level, but of course the effects of national, state or provincial government policies vary widely between monetary unions, with most US states having balanced budget amendments, little restriction on debt issue in Canada or Australia, and no sizeable supranational fiscal policy in the euro area.

This also fits in with the OCA theory, as Mundell (1961) (see also McKinnon (1963), Kenen (1969) and Krugman (1991)) 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. In this regard, monetary unions vary significantly in their degree of labor 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 labor mobility due to linguistic and cultural barriers to migration.

Of course there are other major differences between monetary unions in terms of longevity, with the US being the longest standing large monetary union, and the euro area only having been in existence for just over 15 years. This fact could also give rise to greater synchronicity in the US if monetary unions do indeed coerce greater synchronicity, as so-called endogenous OCAs could be generated once the single monetary policy is allowed to endogenously cause greater commonality in business cycle features (see Frankel and Rose (1997)). Of course it is difficult to account for this fact within any statistical framework, given the fact that path dependencies are likely to impinge on any transition to new macroeconomic dynamics.

Lastly, another complication concerns the business cycle. 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, and in particular over the span of the business cycle[4]. In Crowley (2008) and in Crowley and Schultz (2011) synchronicity was measured in terms of measures derived from recurrence plot analysis methodology. 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 sub-cycles, the cycles in growth show signs of only "intermittent synchronicity" (see Crowley (2008)). This "intermittancy" is perhaps due to the way that policy measures filter through the macroeconomy, with other factors sometimes overwhelming any policy initiatives.

2.2 The Economics of Business Cycle Synchronization

Assessment of the synchronicity in movement of economic growth rates is 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 monetary unions, similar movements in growth rates due to a common monetary policy are likely to foster similarities in economic growth dynamics.

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 here 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 cycles for measurement

[4] The business cycle is defined as the phases of economic expansion ("boom" periods), and economic contraction or recessionary ("bust") periods that typically characterise the path of real GDP through time.

and comparison across countries using time-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 US, as the US dollar has been the adopted currency of the US for so long (despite the private printing of notes in the 19th century), according to the theory it should clearly be an OCA *ex-post*, and indeed many studies have shown that the majority of US States do exhibit high correlations in growth dynamics, but some research has indicated that the geographic extremes of the country (Hawaii, Alaska and Florida in particular) exhibit some idiosyncratic growth dynamics. Several papers have also asserted that the US should be regarded as an OCA because of the perceived synchronization between most US States and macroeconomic measures for the country as a whole (see Lee (2010) for an example in relation to globalization, and in particular an unpublished paper by Leiva-Leon (2012)), due to the impact of federal fiscal policy, which is partially designed to offset any asymmetric shocks in specific US States.

This must be set in contrast with the euro area context, for example, where there is a recognition that the euro area cannot be characterised 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 synchronisation of euro area growth rates, at best. As this is an important issue for the cohesion of the euro area, there has been a considerable amount 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)). Apart from a comparison between the euro are and the US done by Wynne and Koo (2000), little has been done to compare macroeconomic synchronization in terms of different monetary unions.

In terms of economic policy, fiscal policy, as enacted by a federal or confederal government, often takes into account regional disparities in terms of the distribution of the allocations for various projects (- for example the number of military bases or the granting of Federal contracts in the US), so that the fiscal "unevenness" can compensate for (and can encourage) greater convergence and synchronicity between the constituent members of the monetary union. However monetary policy, by its nature, obviously does not directly involve any automatic redistribution between constituent members to encourage or maintain an OCA[5]. Indeed, for monetary policy, as it varies over the business cycle, convergence in macroeconomic variables is likely to be less important than synchronicity of these variables between the consituent members of the monetary union.

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. Lee (2010) provides strong evidence in support of the conventional wisdom that rising global integration over time, through either trade or foreign direct investment flows, raises a 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.

To summarize, in this paper we are not assessing whether any specific monetary union is an OCA, but rather, we are assessing whether the synchronization in business cycle variables (economic growth, inflation and unemployment) has changed over time within monetary unions, and whether this is significantly different from a control group of countries that are not part of a monetary union.

[5] An exception to this is the euro area QE, currently being initiated by the ECB, where the ECB has specifically designated certain bonds as targets for purchase, thereby likely having the effect of easing rates for issuance of debt for these member states going forward. Also, it could be the case that deposits at depository institutions in a monetary union might be transferred to member states where returns are higher, although in the euro area this is unlikely to be a large scale effect, given that the European financial sector is not well integrated yet.

3 Methodology and Data

3.1 A Dynamic Dissimilarity Measure of Synchronicity

The technique used to derive a measure of synchronicity presented here is based on recurrence plots, and is described in detail in Crowley and Trombley (2014) (with an application to US States). 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. 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). Other economic applications to macroeconomic issues using recurrence plot techniques can be found in Zbilut (2005), Kyrtsou and Vorlow (2005), Crowley (2008) and Crowley (2010).

The measure of synchronization used here is a dynamic dissimilarity measure (DDM). It focuses on the similarity of the dynamics by taking the distance measure between the cumulative sum of any two series, and seeing how this varies through time within an epoch (windowed) analysis framework.

We begin the analysis with a dataset consisting of a collection of time series. We can therefore denote each data point as $z_{i,j}$ where j is the series label and i is the time point. If the variable is given in absolute terms it is converted into a stationary growth rate by log first differencing so that:

$$x_{i,j} = \sum_{i=1}^{n} \ln z_{i,j} - \ln z_{i-1,j} \tag{1}$$

where $i = 1$ is the first quarter on record. If the data is already in terms of a stationary rate (such as unemployment), this step is skipped and we treat $x_{i,j} = z_{i,j}$. The series is converted in to a cumulutive unsigned series (CUS) by the standard method:

$$X_{i,j} = \sum_{n=1}^{i} x_{n,j} \tag{2}$$

Around each datapoint, a Euclidean distance matrix is formed in the manner of Marwan, Romano, Thiel, and Kurths (2007). We want to know the relative distance of timepoints within a specified window or epoch. This means that at each timepoint and each location a matrix is formed in the following manner:

$$D_{i,k} = \sqrt{\sum_{l=1}^{N} (X_{l,k} - X_{i,k})^2} \tag{3}$$

where N is the desired number of time points in the comparison window. This matrix can also be normalized. The matrix $D_{i,k}$ contains the dynamics of series k over time. In order to compare dynamics between two variables, for example, componentwise absolute differences are taken

$$E_{i,k,m} = |D_{i,k} - D_{i,m}| \tag{4}$$

These results are placed in an ordered list of matricies, which in mathematical terms is described as a "tensor". The dynamical distance matrix is found by averaging all of these component matrices for a given time and location. In essence, this is given as:

$$DDM_{i,k} = \frac{\sum_{m=1}^{M} E_{i,k,m}}{M} \tag{5}$$

where M is the number of series. Note that for example in the case where $N = 3$: 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 $M = 2$ in equation 5 to create a synchronicity-proxy or can be repeated for each possible pair of time series so as to create a "super" dissimilarity matrix for all variables by 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 or epoch - this is the version of the dynamic dissimilarity measure (DDM) used in the analysis below. 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.

Although the method described above is similar to the approach described in Sornette and Zhou (2005) for finding optimal lag or lead structures, the present method is not concerned with lead or lag structures but is solely concerned with using the 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

There is very little macroeconomic data available by State or Province in terms of time span, but we select three variables directly related to the business cycle, namely:

a) Economic growth - here we measure economic growth at time t, as g_t, by taking the real Gross State Product (GSP) or GDP at time t, y_t, and transforming it by taking natural log first differences as follows:

$$g_t = \ln(y_t) - \ln(y_{t-1}) \tag{6}$$

Unfortunately for the US, this dataset is only available from 1987 on an annual basis, so once log first differences are taken, the data runs from 1988 to 2013, giving 25 datapoints. For the US, the data is sourced from the Bureau of Economic Analysis (BEA), for Canada from StatCan, for the euro area, from Eurostat, for Australia, from the Australian Bureau of Statistics, and for the non-monetary union countries, from the IMF International Financial Statistics (IFS) database.

The aggregates for the US, Canada, Australia, the euro area and for the group of non-monetary union countries are plotted in Figure 1.

Figure 1 shows that the international business cycle is clearly at play for all countries, as the downturn in economic growth 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. Interestingly Australia and the non-monetary union countries appear to be less affected by the great recession than the US, Canada and the euro area.

b) Inflation - here this is proxied by the GSP or GDP deflator, as a Consumer Price Index (CPI) is only available for urban areas in the US, and so does not cover all US States Once again the natural log first difference is taken. The data is sourced from the BEA[6] for the US, from Eurostat for the euro area, from Statcan for Canada, from the

[6] Two series had to be spliced together to create this series. Details are available from the author on request.

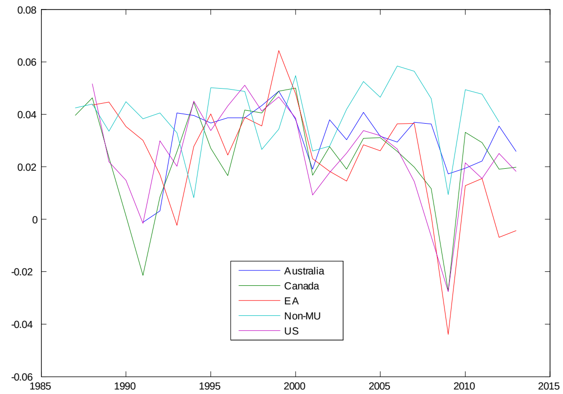

Figure 1: Mean of Aggregate Economic Growth by MU

Figure 2: GDP/GSP Deflator Inflation Aggregate

Australian Bureau of Statistics and from the IMF IFS for the non-monetary union countries. For the US, this dataset was derived from BEA data on real GSP and nominal GSP;

Figure 2 shows the inflation measures for the US, Canada, Australia, the euro area and the group of non-monetary union countries.

Figure 2 shows that the average level of inflaton was considerably higher in the non-monetary union countries, but also that the great recession caused deflationary pressure with inflation turning negative for Canada and skirting close to zero for the euro area and for the US.

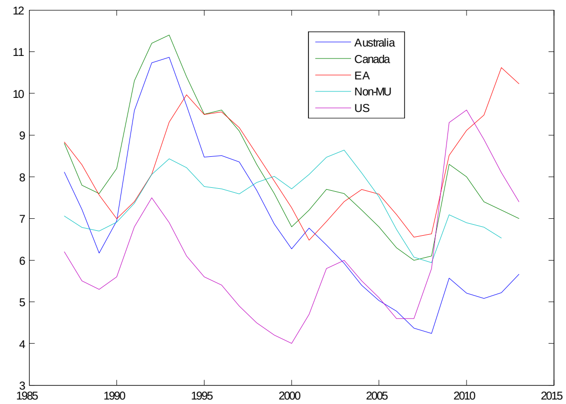

Figure 3: Unemployment Rate Aggregates

c) Unemployment - this is taken as the usual definition of the unemployment rate, i.e. the number of unemployed as a percentage of the labor force. In the US this was sourced from the Bureau of Labor Statistics. In the euro area the unemployment rate was sourced from Eurostat, in Canada from StatCan, in Australia from the Australian Bureau of Statistics and for the rest of the non-monetary union countries, from the IMF IFS.

Unemployment is usually viewed as a lagging indicator when referencing the business cycle, and in figure 3 it is presented for the monetary unions and non-monetary union included in this study.

Figure 3 shows that unemployment rates fell from the high levels of the early 1990s through until the early 2000s recession, bouncing upwards before continuing their downward trend until the great recession. And then in the aftermath of the great recession rates have largely been convergent, with the exception of the euro area, where rates have only recently begun to fall.

4 Empirical Results I - Individual Comparisons

4.1 Non-Monetary Union Control Group

Our strategy here is to first analyse the behavior of a control group of non-monetary unions in order to then secondly construct a one sided hypothesis test of similar synchronicity. A surrogate is used to construct a lower confidence interval as a one-sided test at a 5% level

Figure 4: Mean and 90% confidence interval for Real GDP growth for non-MU Countries

of significance for monetary unions having a greater degree of synchronicity (and therefore lower dissimilarity). In order to do this, we use a sample of countries, solely dependent on data availability in the IMF IFS database for each variable, and use the intra-group dissimilarity measure to analyse synchronicity of each variable over time. There are 61 countries in the control group and the list of countries is located in the appendix. The cross sectional mean and standard deviation of the within-group dynamic dissimilarity measure for the non-monetary union control is displayed in figure 4.

The figure shows that as might be expected synchronization in real GDP growth has increased since the mid-1980s, but what is interesting is that the synchronization dynamic appears to have fallen during the late stages of the last cycle, but on emergence from the great recession, synchronicity once again appears to be increasing again. Overall, there appears to have been an increase in synchronicity in growth (as measured by the fall in dissimilarity), which mirrors the results of Lee (2010).

In figure 5, both the mean dissimilarity and the 90% confidence limits for the GSP/GDP deflator measure of inflation are plotted for the within-group dissimilarity measure for the non-monetary union control sample. There are 63 countries included in this control group. The results clearly confirm the increase in synchronicity documented earlier, likely due to globalization, but here the increase in synchronicity is largely achieved by the early 2000s, after which divergence appears to be cyclical, but not entirely connected to business cycles.

Lastly, figure 6 shows the dynamic nature of synchronization when looking at the within-group dissimilarity measure for unemployment rates for the non-monetary union control

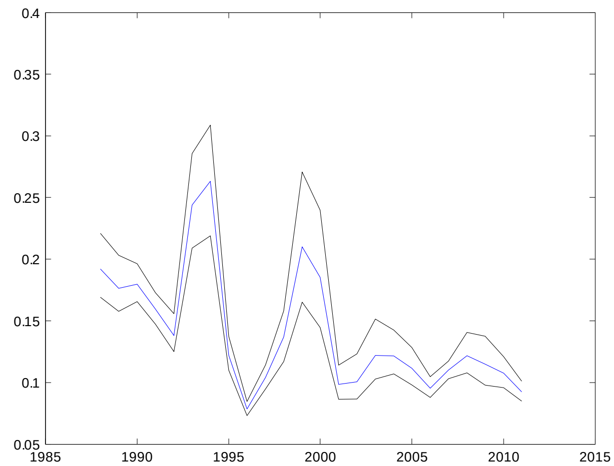

Figure 5: Mean and 90% confidence interval for GDP deflator growth for non-MU Countries

sample. There are 24 countries that are members of this control group. As might be expected, it is immediately apparent that synchronization within this group decreases on entering a recession (- here notably for the South East Asian crisis in 1997 and the great recession in 2007), until the recovery mode is underway. What is also interesting is that the synchronization within this group has increased over the span of the period.

4.2 Real GDP growth

In this section we show the within-group dissimilarity measures by monetary union for real GDP growth, and compare them with the baseline established by the 90% confidence level for the non-monetary union control sample.

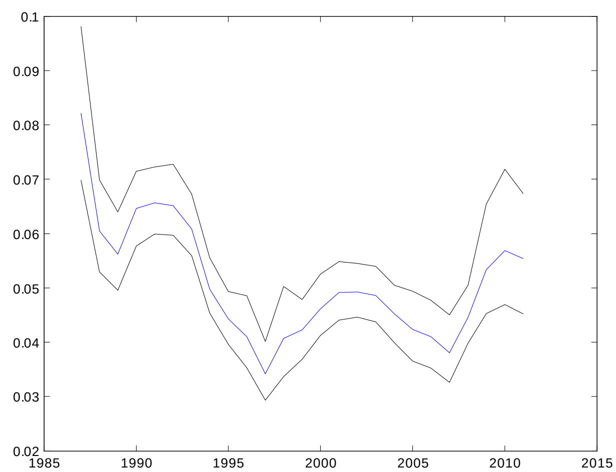

Figure 6: Mean and 90% confidence interval for Unemployment rate for non-MU Countries

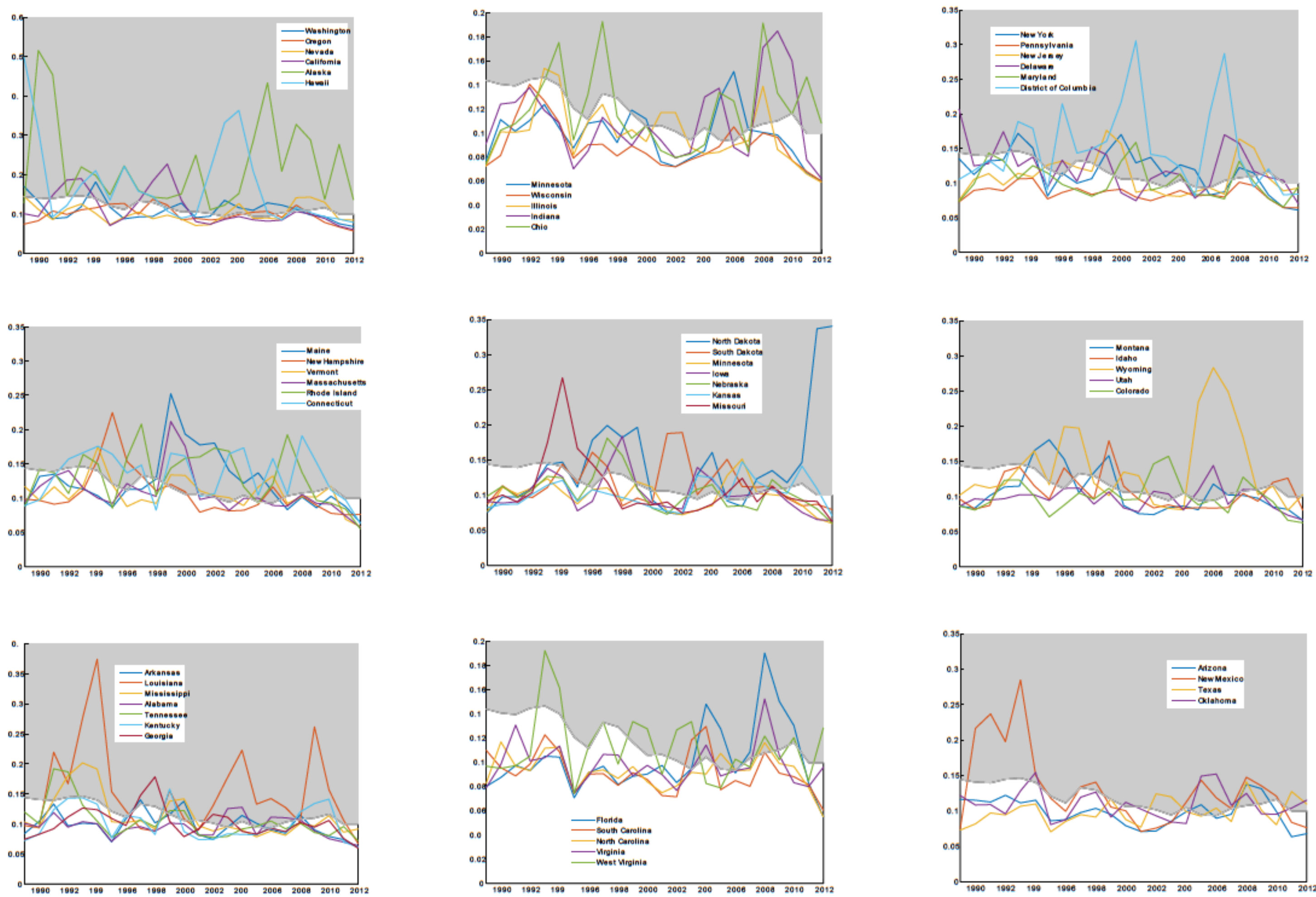

Figure 7: Dissimilarity measure for US Real GDP

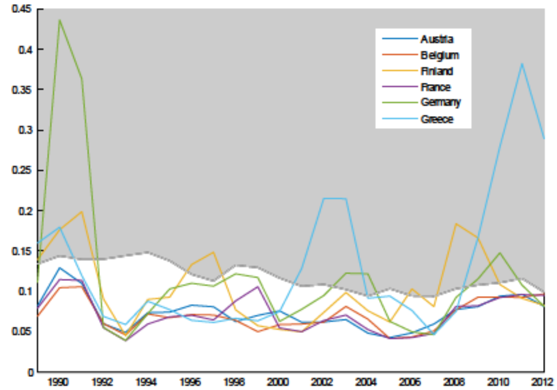

Figure 8: Dissimilarity Measure for euro area real GDP growth

4.2.1 US

In figure 7 the dissimilarity measure is shown for each US state by BEA region. It is clear that many of the US states are not significantly different from the control sample in terms of their growth dynamics, and that this varies to a certain degree by region. It is also noteworthy that those US states that have had shale oil discoveries in the last decade are all not significantly different from the control group in recent years, but this is obviously not due to the fact that they necessarily had the same dynamics as the control group - their dynamics are likely to have been outliers compared with the rest of the US, and therefore the measure of dissimilarity captures the dissimilarity as compared to other States within the US, as the test only captures the within-group dissimilarity significance.

4.2.2 Euro area

In figures 8 and 9, the dissimilarity measure is shown for the euro area. It is clear that Greece's growth dynamic has been unsynchronized with the rest of the euro area in recent years, and also that Italy has also not been synchronous in growth with the rest of the euro area through the great recession. It is also interesting to note that Germany was not synchronous with the rest of the euro area in the early 1990s, which is to be expected given the fact that German reunification occurred at this time. It is interesting to note that from around 1992 onwards, Germany became very synchronous, which is possibly due to the fact that other member states had growth dynamics that were coerced into greater synchronicity with that of a united Germany.

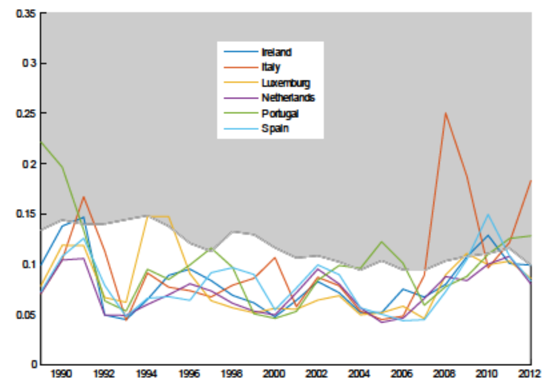

Figure 9: Dissimilarity measure for euro area real GDP growth

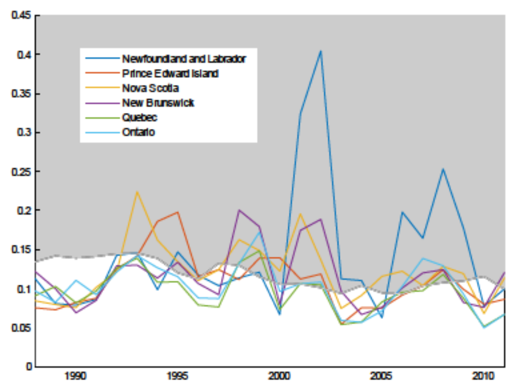

Figure 10: Dissimilarity measure for Eastern Canada real GDP growth

4.2.3 Canada

In figure 10 and 11 we plot the dissimilarity measure for real GDP growth for Canada. In this case Newfoundland and Labrador and Alberta are clearly ouliers in the 2000s and beyond. Once again this is likely due to the oil industry, as large amounts of oil were discovered and began to be extracted in both of these two provinces. Also noticable is that synchronicity doesn't seem to have fallen or increased in absolute terms over the period as a whole.

4.2.4 Australia

Lastly, in figures 12 and 13 we plot the dissimilarity measure for Australian states. Here the results are quite different from other monetary unions. Apart from Tasmania in the early

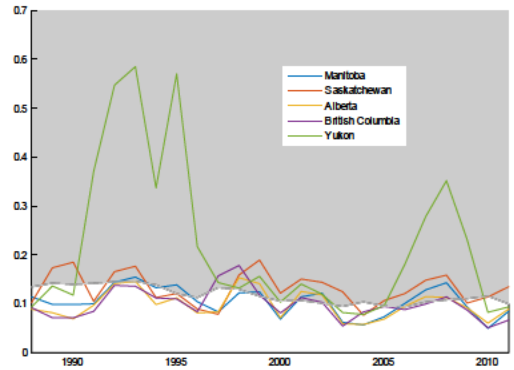

Figure 11: Dissimilarity measure for Western Canada real GDP growth

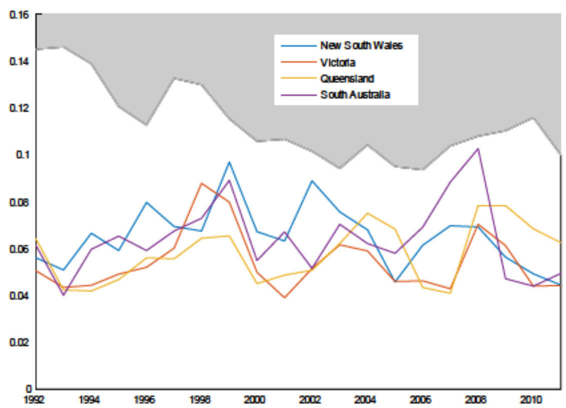

Figure 12: Dissimilarity measure for Eastern Australia real GDP growth

2000s, Australian states appear to collectively have a different economic growth dynamic from the non-monetary union countries. Certainly nearly all levels of synchronization in any given year are significantly different from the control group, signifying greater synchronization in economic growth for all the members of this particular monetary union.

4.3 GDP deflator inflation

4.3.1 US

In figure 14 the dissimilarity measure is shown for each US state by BEA region. It is clear that most US states are significantly different from the control group in terms of their growth dynamics, signifying that the monetary union has coerced a greater degree of synchronicity

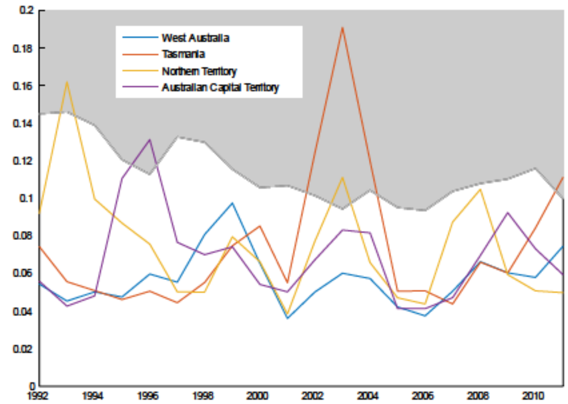

Figure 13: Dissimilarity measure for Western Australia real GDP growth

in inflation than for non-monetary unions. There are certain states that appear to frequently stray into the insignificant area, those being Alaska, Wyoming, Louisiana, New Mexico and lately South Dakota and Texas. Once again, it is likely that shale oilfields in all of these states prompted this, with the exception of Wyoming.

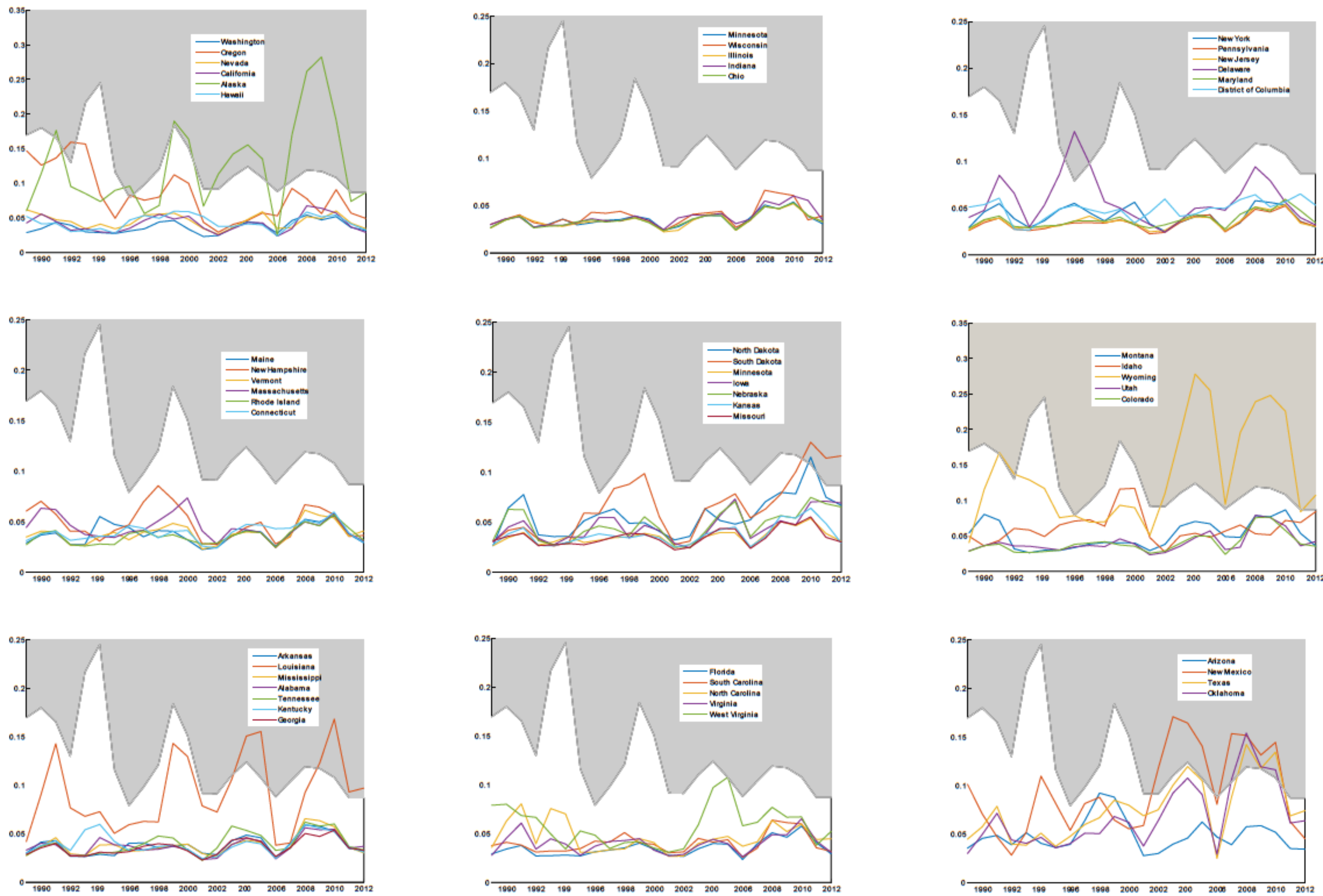

Figure 14: Dissimilarity measure for US GSP deflator inflation

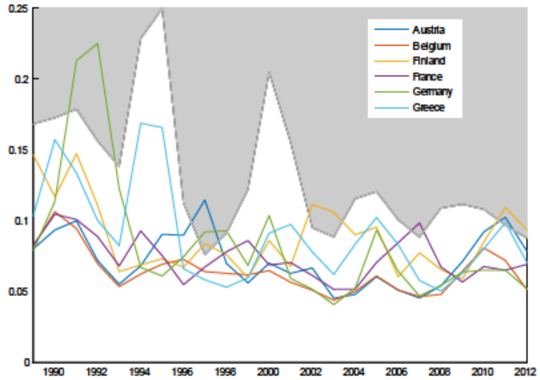

Figure 15: Dissimilarity measure for Euro area GDP deflator inflation

4.3.2 Euro area

In figures 15 and 16, the dissimilarity measure for GDP deflator inflation is plotted for the euro area member states. Most of the time all member states have a significant level of synchronicity with each other, but occasionally Luxembourg, Ireland and Finland stray into the insignificant area, and it is noteworthy once again that Germany was not synchronous with other euro area members in the early 1990s.

4.3.3 Canada

Here, in figures 17 and 18, the dissimilarity measure for GDP deflator inflation is shown for Canadian provinces. For the most part in Eastern Canada, dynamics in inflation were synchronous, but then by the mid 2000s Newfoundland and Labrador had significantly different inflation dynamics. In Western Canada, the picture is less clear, but both Alberta and lately Saskatchewan, have had significantly different inflation dynamics. In all 3 cases, this is likely caused by the large amount of oil related activity in these provinces, with Saskatchewan experiencing a boom in oil production in recent years.

4.3.4 Australia

Figures 19 and 20 show the dissimilarity measure for the Australian GDP deflator inflation for eastern and western states respectively. Both figures show an extremely high degree of dynamic similarity between inflation rates in different parts of Australia.

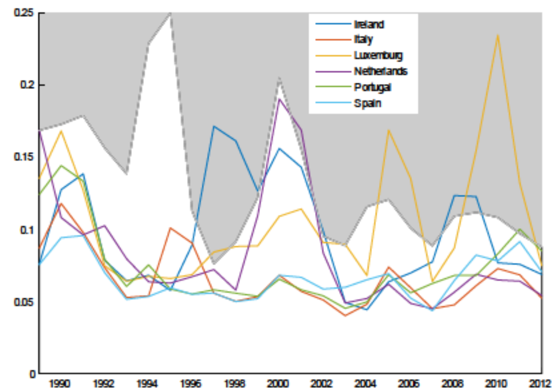

Figure 16: Dissimilarity measure for Euro area GDP deflator inflation

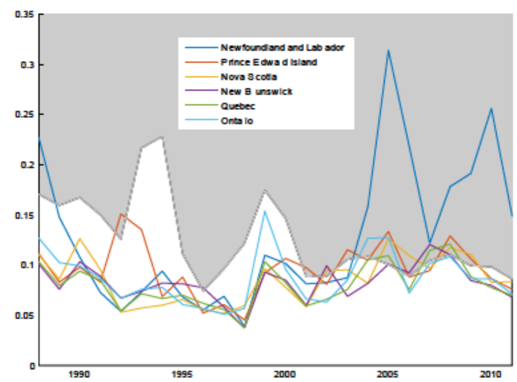

Figure 17: Dissimilarity for Eastern Canada GDP deflator inflation

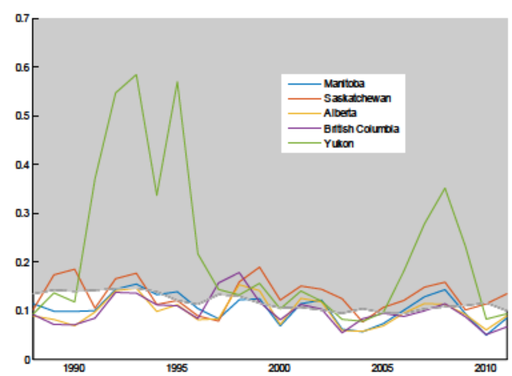

Figure 18: Dissimilarity for Western Canada GDP deflator inflation

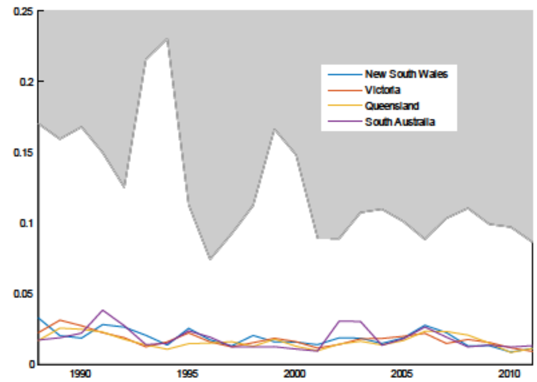

Figure 19: Dissimilarity measure for Eastern Australia GDP deflator inflation

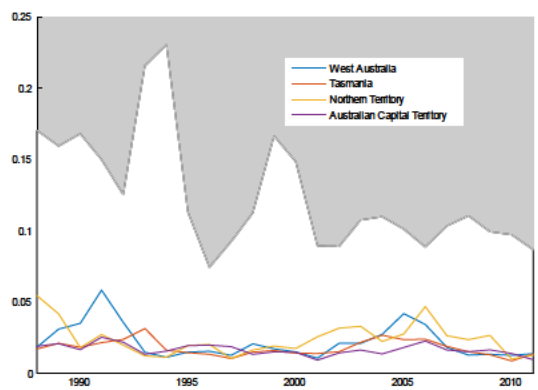

Figure 20: Dissimilarity measure for Western Australia GDP deflator inflation

4.4 Unemployment

4.4.1 US

Figure 21 shows the dissimilarity measure for unemployment for the US states. Hawaii, Nevada, and more recently North Dakota have clear dissimilarity measures which are significantly different from the rest of the US at certain times. Part of the reason for this is likely to be once again related to the oil and gas sector for North Dakota, but Hawaii and Nevada have different dynamics for reasons perhaps due to the prominence of the tourist industry in both these States.

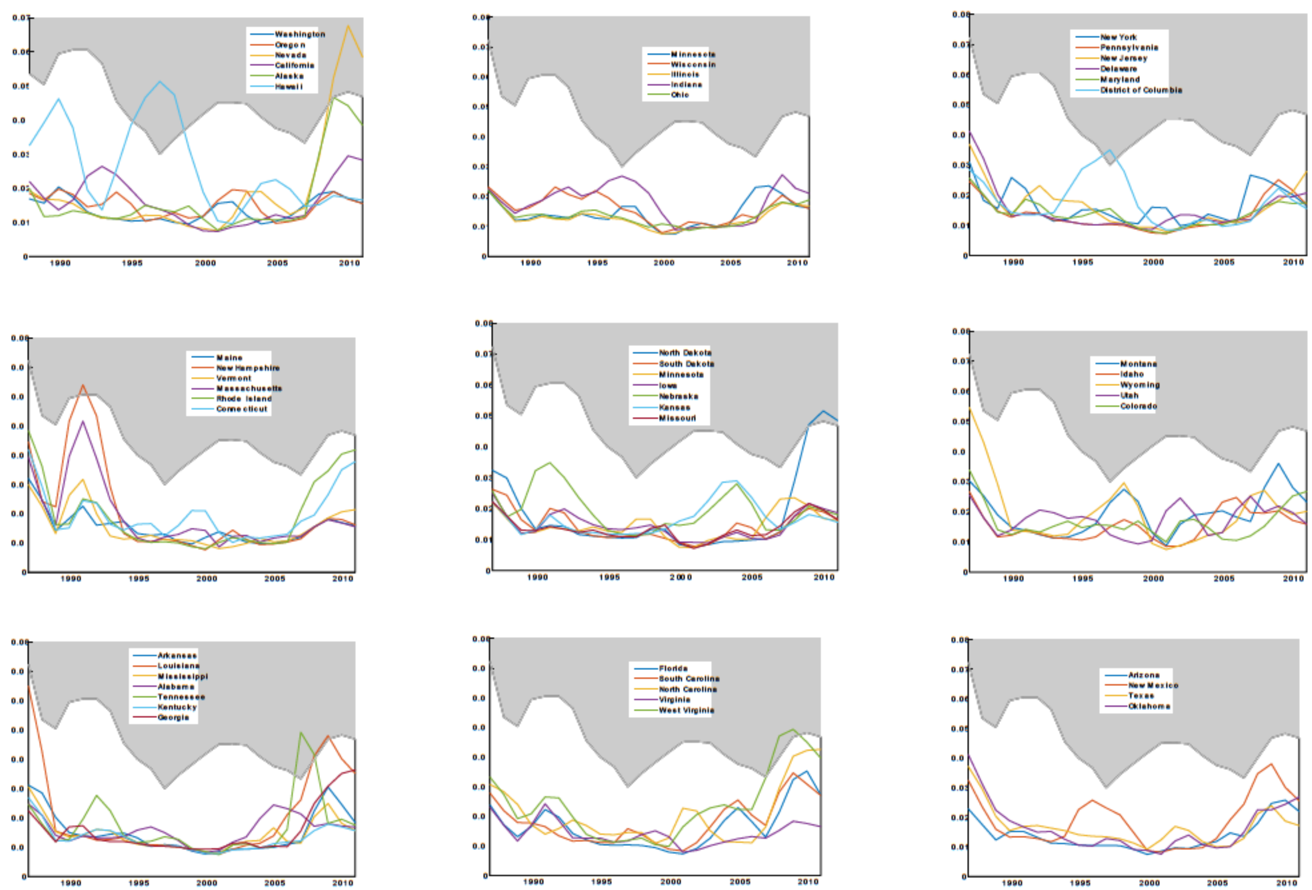

Figure 21: Dissimilarity measure for US Unemployment rate

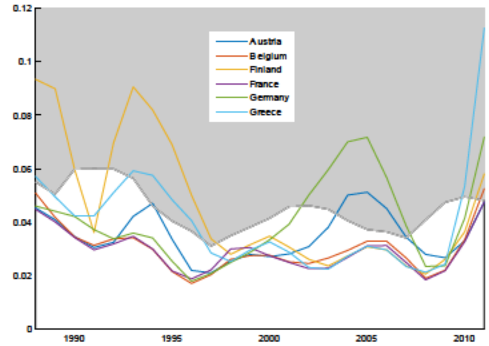

Figure 22: Dissimilarity measure for Euro Area Unemployment rate

4.4.2 Euro area

In figures 22 and 23, the dissimilarity measures for euro area unemployment rates are shown. It is clear that Finland was not synchronous with the rest of the euro area during the early 1990s as the dislocation from the reorientation of trade with the former Soviet Union and a banking crisis caused a deep recession there. In the late 1990s and 2000s Ireland and Spain in particular also had quite different dynamics to the rest of the euro area, which show up in the measure, and since 2005 Portugal has also been notably significantly different. Greece, as might be expected, shows that it is not significantly different from the control group from 1992-96 and then again in 2010, and rather unexpectedly, Germany had dynamics that were not significantly different from the control group from 2001 to 2007.

4.4.3 Canada

In figures 24 and 25, the unemployment dissimilarity measure is plotted for eastern and western Canadian provinces, respectively. Apart from a small period during the late 1980s, when Ontario did not have significantly different synchronicity to the control group, all provinces had unemployment dynamics that were significantly different from the control group.

4.4.4 Australia

Finally, we plot the dissimilarity measure for the Australian unemployment rate in figures 26 and 27. Apart from a short period in the mid to late 1990s when the Northern Territories and the Capital Territory were not significant, Australian states have all had unemployment

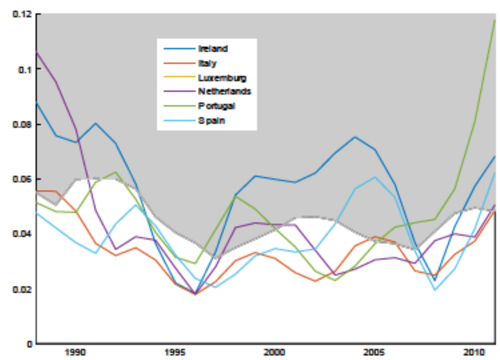

Figure 23: Dissimilarity measure for Euro Area Unemployment rate

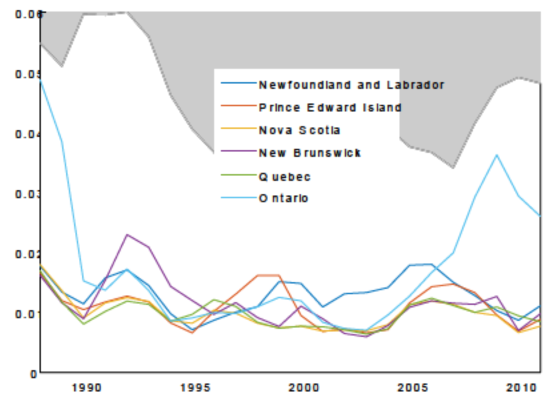

Figure 24: Dissimilarity measure for eastern Canada Unemployment rate

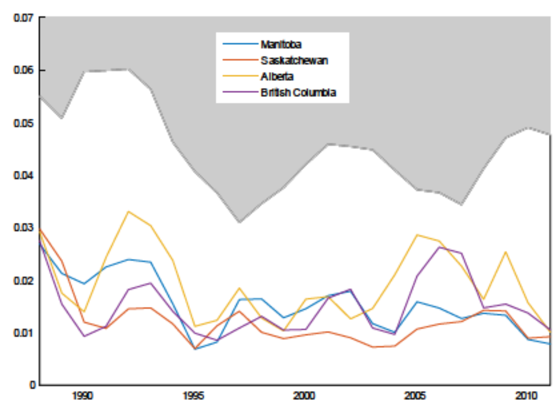

Figure 25: Dissimilarity measure for western Canada Unemployment rate

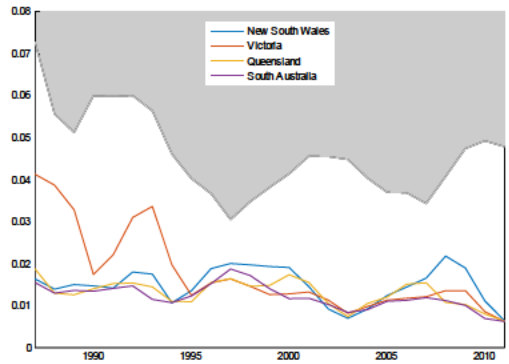

Figure 26: Dissimilarity measure for eastern Australia Unemployment rate

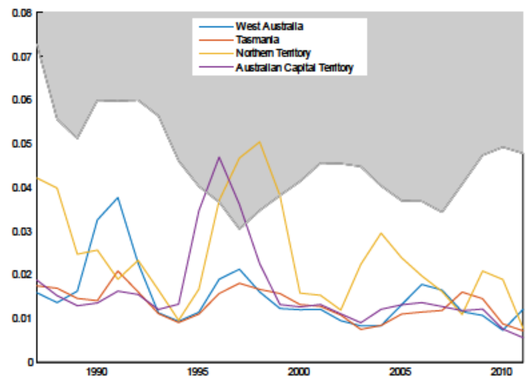

Figure 27: Dissimilarity measure for western Australia Unemployment rate

dynamics that have been significantly different from the control group. Looking at the charts, there also appears to have been a fall in the average dissimilarity level as well.

5 Empirical Results II - Group Comparisons

In this section we first use the dissimilarity measures shown in the previous section to derive some general results relating to monetary unions, and then secondly, we use the observations as a cross sectional distribution by monetary union, and then compare the distribution with that of the non-monetary union control group. Lastly, we conduct some statistical tests in order to evaluate the question posed in the paper title.

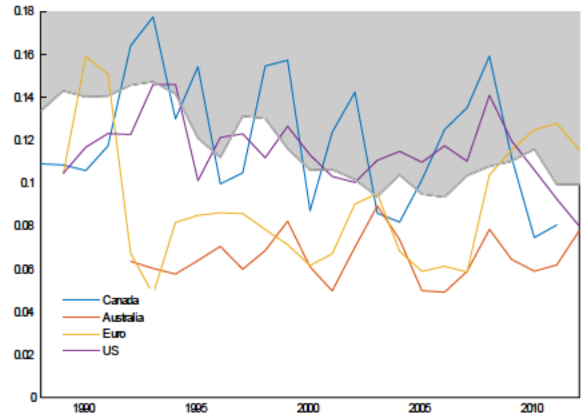

Figure 28: Average dissimilarity measure for real GDP growth by monetary union.

5.1 Real GDP growth

In figure 28 we plot the average dissimilarity measure by monetary union, and compare with the 95% confidence interval derived from a t-test for the non-monetary unions. Clearly only Australia has growth dynamics that are on average always significantly different to the non-monetary union countries. Although the euro area is more synchronous than both the US and Canada, since the start of the great recession the euro area has become much less synchronous.

We next plot estimates of the kernel of the distribution that we observe on a cross-sectional basis, based on the whole time period for each monetary union and compare with the non-monetary distribution. Figure 29 shows that the distributions for Canada and the US are almost identical to that of the non-monetary unions. But the euro area and Australia have distributions appear to be located to the left of the others, signifying a distribution that is lower than that of the non-monetary unions.

Lastly, we repeat the exercise above by combining the monetary unions by using a weighted average of the monetary unions (- by using all observations), and compare the mean and distribution with the non-monetary union mean and distribution. This is shown in figures 30 and 31 below. While it is clear that the mean for monetary unions is below that of non-monetary unions from figure 30, when comparing the kernel estimates of the distributions, it is apparent that the dispersion of the two distributions is not that different. This is a surprising result, as it goes against the notion that monetary unions should have significantly higher synchronicity in economic growth rates compared to non-monetary

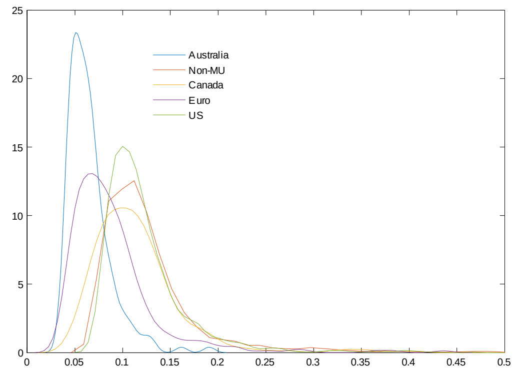

Figure 29: Kernel distribution estimate of real GDP growth rates by monetary union.

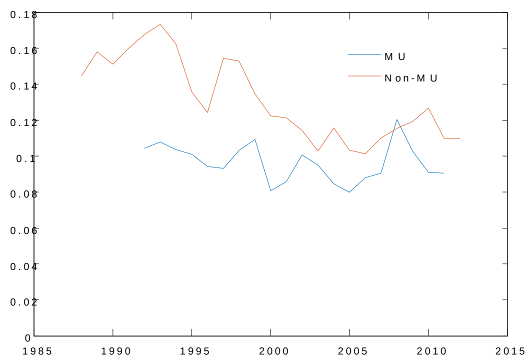

Figure 30: Comparison of mean for monetary unions and non-monetary unions

unions.

Finally, in table 1 below, we present a battery of statistical tests for each monetary union vs the non-monetary union control group. It is clear that Australia and the euro area are significantly more synchronous than the control group, but that the US and Canada are clearly not significantly more synchronous.

5.2 GDP deflator inflation

Here we repeat the exercise above, but for GSP/GDP deflator inflation. Figure 32 shows the average dissimilarity measure for each monetary union together with the 95% confidence limits for the non-monetary union control group. The figure shows that in recent years Canada has been the least synchronous and the average Canadian province could not be distinguished from a member of the non-monetary control group. The euro area

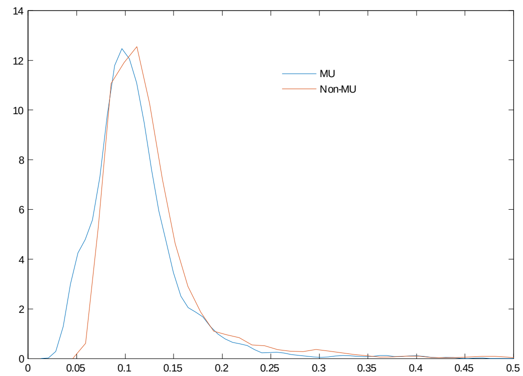

Figure 31: Comparison of kernel distribution estimates for monetary unions and non-monetary unions

Real GDP growth	US	Euro Area	Canada	Australia
Student t-test	-2.103 (0.042)	-6.673 (0)	-0.828 (0.441)	-11.633 (0)
Kolmogorov Smirnoff	0.3 (0.275)	0.8 (0)	0.3 (0.275)	1 (0)
Wilcoxon Test	-2.539 (0.011)	-3.733 (0)	-1.083 (0.279)	-3.9199 (0)
Mann-Whitney	-1.853 (0.064)	-4.558 (0)	-0.717 (0.473)	-5.3965 (0)
F Test	0.424 (0.069)	0.991 (0.984)	1.985 (0.144)	0.20913 (0.001)
Ansari-Bradley	235 (0.146)	200 (0.588)	175 (0.058)	252 (0.023)

Table 1: Statisitical Tests for Real GDP growth Differences

dissimilarity measure has on average become more synchronous since the beginning of the time period, but the average appears to have stopped falling and is now level.The US and Australia are clearly the most synchronous monetary union in terms of mean inflation dynamics, with Australia consistently having the lowest dissimilarity, which implies it has the highest average level of synchronicity between its constituent members.

When comparing the kernels estimates of the pdfs for each of the monetary unions in figure 33, we find that, as expected, there is very little overlap between Australia's distribution and the non-monetary control group, but there is considerable overlap for Canada, and some overlap for the euro area.

We now turn to the group comparisons. In figure 34 the mean of the dissimilarities for monetary unions and non-monetary unions are plotted. Two interesting observations can be gleaned from the figure - first that dissimilarity for the non-monetary union control group has clearly increased over the sample period, and second that if anything there appears to have been a slight fall in mean dissimilarity for monetary unions. Put another way -

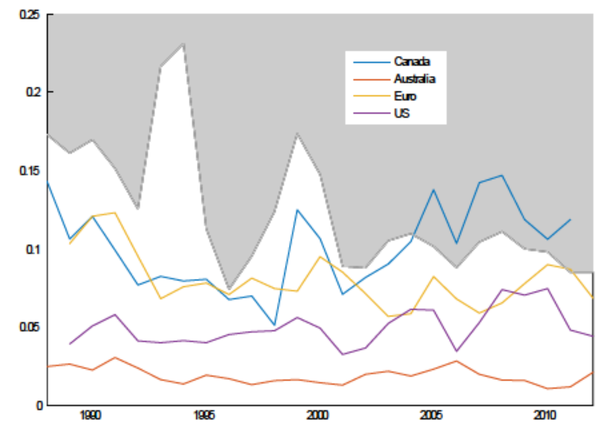

Figure 32: Average dissimilarity measure for GDP deflator growth by monetary union

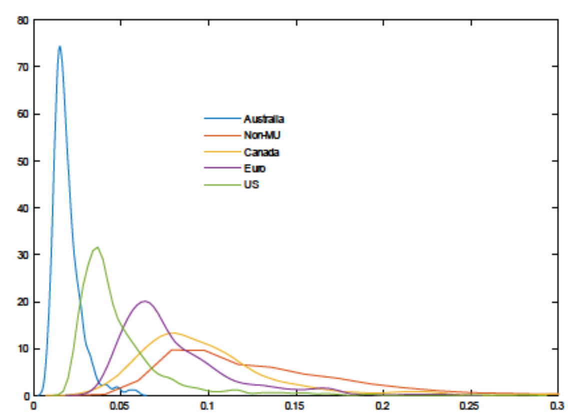

Figure 33: Kernel distribution estimate of GDP deflator growth by monetary union.

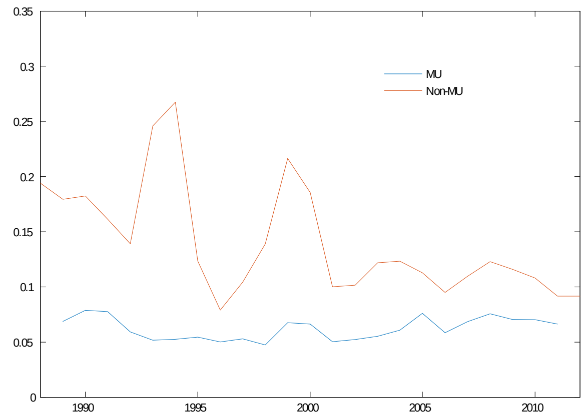

Figure 34: Comparison of mean for monetary unions and non-monetary unions

25 years ago the degree of difference in synchronicity between monetary unions and non-monetary unions appears to have been much larger than it is today. One might hypothesise that this is due to the impact of globalization on the similarity in inflation dynamics, but there again, if so, we should observe a fall in the dissimilarity for monetary unions as well.

In figure 35 we show the difference between the kernel estimate for the dissimilarity measures of inflation within the monetary union group compared to the non-monetary union group. Clearly the monetary unions are more synchronous, but there is sizeable overlap between the distributions, suggesting that the result may not be statistically significant.

In table 2 statistical tests for differences between the monetary union and non-monetary union are conducted. In all cases there are significant differences between the monetary unions and the non-monetary union control group.

GDP deflator growth	US	Euro Area	Canada	Australia
Student t-test	-8.783 (0)	-5.728 (0)	-3.544 (0.00)	-11.988 (0)
Kolmogorov Smirnoff	1 (0)	0.75 (0)	0.417 (0.020)	1 (0)
Wilcoxon Test	-4.286 (0)	-4.257 (0)	-3.114 (0.002)	-4.2857 (0)
Mann-Whitney	-5.928 (0)	-5.165 (0)	-3.00 (0.002)	-5.9282 (0)
F Test	0.054 (0)	0.119 (0)	0.277 (0.003)	0.011321 (0)
Ansari-Bradley	385 (0.0)	367 (0.006)	312 (0.620)	396 (0)

Table 2: Statisitical Tests for GDP deflator inflation Differences

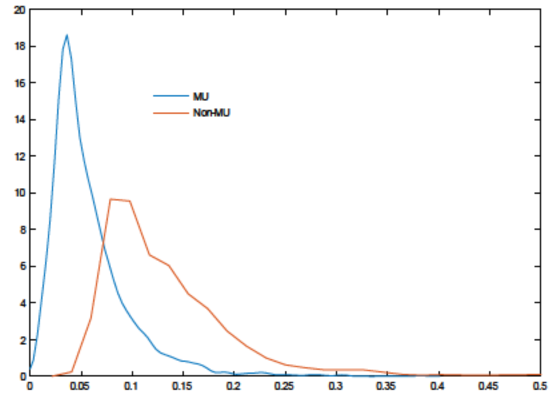

Figure 35: Comparison of kernel distribution estimates for monetary unions and non-monetary unions

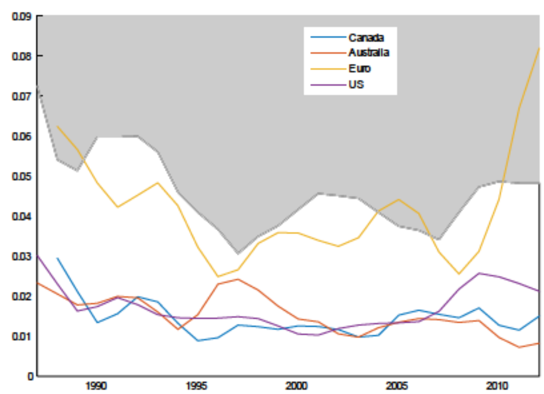

Figure 36: Average dissimilarity measure for Unemployment rate by monetary union

5.3 Unemployment

Finally we conduct the same group analysis for synchronization in unemployment rate dynamics. In figure 36 the dissimilarity measure for unemployment rate dynamics within each monetary union are plotted. It is clear that the euro area average could be part of the non-monetary union control group for some of the time, and particularly recently. And yet the other monetary unions have means that are significantly different from the non-monetary union control group.

When plotting the kernel estimates for the distribution of dissimilarity observations for each monetary union, it is immediately apparent that the euro area has more in common

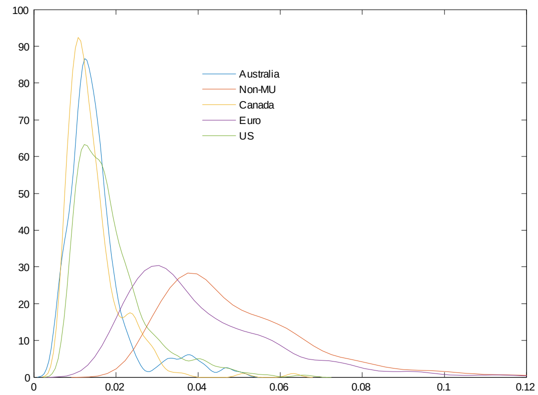

Figure 37: Kernel distribution estimate of Unemployment rate by monetary union.

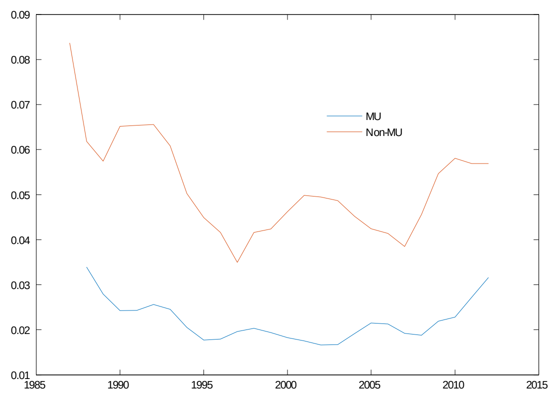

Figure 38: Comparison of mean unemployment rate dissimilarity measure for monetary unions vs non-monetary unions

with the non-monetary union control group levels of dissimilarity than with the other monetary unions. This is shown in figure 37.

In figure 38, when plotting the average for the monetary union dissimilarity measure against the non-monetary union group, it appears that although average dissimilarity has declined for the non-monetary union control group, it first declined to around 1995, and then has started to increase since 2003.

Lastly, in figure 39 we show the kernel density estimates of the dissimilarity distributions for the monetary unions and the non-monetary unions. In this case there is clearly a distinct and significant difference between the two distributions, with monetary unions clearly having greater synchronicity between most members compared with the non-monetary union

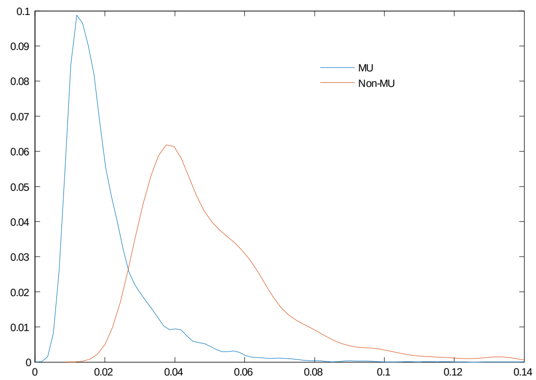

Figure 39: Comparison of kernel distribution estimates for dissimilarity of unemployment rates in monetary unions vs non-monetary unions

control group.

Lastly, a variety of statistical tests are conducted to discern whether unemployment rate synchronization is different between monetary unions and non-monetary unions. In all cases there are significant differences noted between the monetary unions and non-monetary unions, with the exception of Canada, in terms of only one statistic - the Ansari-Bradley non-parametric test of a difference in dispersion.

GDP deflator growth	US	Euro Area	Canada	Australia
Student t-test	-8.783 (0)	-5.7275 (0)	-3.544 (0.001)	-11.988 (0)
Kolmogorov Smirnoff	1 (0)	0.75 (0)	0.417 (0.021)	1 (0)
Wilcoxon Test	-4.286 (0)	-4.2571 (0)	-3.114 (0.002)	-4.286 (0)
Mann-Whitney	-5.928 (0)	-5.1652 (0)	-3.000 (0.003)	-5.928 (0)
F Test	0.054 (0)	0.11912 (0)	0.277 (0.003)	0.011 (0)
Ansari-Bradley	385 (0)	367 (0.0)	312 (0.620)	396 (0)

Table 3: Statisitical Tests for Unemployment rate Differences

6 Conclusions

The main purpose of this paper is to apply a new measure of time series synchronicity derived from the recurrence plot approach, to macroeconomic data in monetary unions and a control group of non-monetary unions. The measure is non-parametric, is not dependent on stationarity of data and is fully flexible in terms of encompassing specified lead and lag dynamics. In this paper we used this synchronicity measure as a means of statistically testing whether synchronicity in macroeconomic variables in monetary unions is higher than in non-monetary unions.

Our main findings are that in general, monetary unions lead to greater synchronicity in inflation and unemployment, but not always in economic growth. This is a surprising result, as it goes against the priors which most economists have when undertaking research on monetary unions. A secondary result is that not all monetary unions have similar internal dynamics - for example the euro area appears to have more synchronous movements in real GDP growth than both the US and Canada, and Canada appears to have less synchronous inflation than other monetary unions. A third result shows that if any comparisons are to be made with a "model" monetary union that appears to have very high macroeconomic synchronicity between its constituent parts, then from the findings in this study, that monetary union would be Australia. This is once again a surprising result, given that although there is homogeneity of culture and language between all the Australian States, and therefore intrinsically high labor mobility, the States themselves possess quite different industry compositions.

Further research will test for differences in synchronicity between euro area member states and non-euro area member states using a comparable dataset to the one presented here - this will better indicate the degree to which the euro area itself has fostered greater macroeconomic synchronicity.

Appendix

A Non-Monetary Union Countries

a. Real GDP growth (61 countries):

Argentina, Bahrain, Bahrain, Bangladesh, Barbados, Belize, Benin, Bolivia, Botswana, Brazil, Brunei Darussalam, Burkina Faso, Burundi, Chile, China, P.R., Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Guinea-Bissau, Haiti, Honduras, Iceland, India, Indonesia, Israel, Jamaica, Japan, Korea, Lao People's Democratic Republic, Madagascar, Malawi, Malaysia, Maldives, Mali, Mauritius, Mexico, Mongolia, Morocco, Namibia, New Zealand, Niger, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, South Africa, Switzerland, Thailand, Togo, Turkey, and Uganda

b. GDP deflator growth (63 countries):

Argentina, Bahrain, Bangladesh, Barbados, Belize, Benin, Bhutan, Bolivia, Botswana, Brunei Darussalam, Burkina Faso, Burundi, Cameroon, Chile, China, P.R., Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Guinea-Bissau, Haiti, Honduras, Iceland, India, Indonesia, Israel, Jamaica, Japan, Korea, Lao People's Democratic Republic, Madagascar, Malawi, Malaysia, Maldives, Mali, Mauritius, Mexico, Mongolia, Morocco, Namibia, New Zealand, Niger, Norway, Pakistan, Panama, Paraguay, Philippines, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Switzerland, Thailand, Togo, Uganda, Uruguay, and Venezuela.

c. Unemployment rate (24 countries):

Albania, Argentina, Bahamas, Barbados, Brazil, Chile, China, P.R., Costa Rica, Iceland, Indonesia, Israel, Jamaica, Japan, Korea, Malaysia, New Zealand, Norway, Peru, Philippines, Singapore, Switzerland, Thailand, Trinidad and Tobago, Uruguay

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