Macroeconomic Synchronization and Monetary Unions: Is the Euro Area more Synchronous than other Monetary Unions and 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 has not been tested compared to a base sample of countries that do not belong to a monetary union, so this paper endeavors to do exactly that. Although the US is probably one of the longest standing monetary unions in existence, there are others such as Canada and Australia, which have similar federalist structures and relatively independent States or Provinces. In this paper we take euro area data, US State macro data, Canadian provincial data and Australian state data – namely real Gross State Product (GSP), the GSP deflator and unemployment data – and use techniques relating to recurrence plots to measure the degree of synchronicity of movement over time. The results are expected to show that for the most part monetary unions are more synchronous than non-monetary unions and that the euro area data is highly synchronous, particularly since the financial crisis, compared to other monetary unions.

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

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1 Introduction

Synchronization occurs naturally in nature, usually because of some external driving force (such as the time of day or month or year). Given that synchronization is also a facet of human behavior, it would seem logical to expect synchronization to occur in economic growth when entities are subject to the similar external forces. In the particular circumstance of a monetary union between countries, this external force in the form of a common monetary policy, might be expected to coerce a greater degree of synchronization in macroeconomic variables between the members of the monetary union. This conjecture forms the basis of the subject matter for this research, and to our knowledge no previous research has focused specifically on this.

Synchronization does not have any agreed upon definition in economics (- unlike in other disciplines, such as physics), and so correlations are often used to denote synchronization. But correlations can be very misleading in terms of dynamics, and highly correlated series can exhibit completely unsynchronized movements in terms of directional movements over time. Economists have struggled with this, 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. 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. So most of the co-movement measures are not suited to measuring short-term dynamic similarity. To address this shortcoming, we use a recently developed measure of dynamic synchronicity based on recurrence plots (see Crowley and Hughes Hallett (2014)), which is particularly suited to small macroeconomic datasets.

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 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.

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 the euro area in particular (see, for example, Gogas (2013)[1]), 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[2].

Of course being part of an economic and monetary union could also generate specific 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 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 industries) might dominate regionally, giving a higher degree of regional co-movement.

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

[1]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".

[2]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).

supranational fiscal policy in the euro area, but the recent "fiscal compact" constraining national governments within the euro area. Several papers have established that the US can be regarded as an optimal currency area not only because of the convergence in many macroeconomic measures, but also 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)). Of course the major policy measures taken at the Federal level. So centralization of fiscal policy, coupled with co-insurance schemes (such as Canada's equalization policy), can also impact macroeconomic variables, either collectively, or in an asymmetric manner.

In addition to this, Mundell (1961) states in his description of what would constitue an OCA (see also McKinnon (1963), Kenen (1969) and Krugman (1991)), that monetary unions should be able to withstand less synchronization of business cycles if there is a high degree of labour mobility between the constituent parts of the 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 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.

Given that one accepts the OCA framework, together with the caveats described above, there should be statistically significant differences in the degree of synchronicity observed between both monetary unions and non-monetary unions, and between monetary unions themselves, dependent on such factors as labor mobility and longevity.

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[3]. In Crowley (2008) and in Crowley and Shultz (2011) synchronicity was

[3] The business cycle is defined as the phases of economic expansion ("boom" periods), and economic

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 sub-cycles, the cycles in growth showed signs of only "intermittent synchronicity". 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

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

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

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

i) *ex-ante* the suitability for adopting the same monetary policy (- known as the optimal currency area (OCA) theory[4]); or

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

There has long been recognition of the propagation phenomenon of business cycles between countries (- the main mechnanisms being trade and capital flows). The main indicator of this propagation is the synchronicity of turning points in business cycles (noted by Backus and Kehoe (1992) and Backus, Kehoe, and Kydland (1995) in the real business cycle literature) but what is not recognized 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

contraction or recessionary ("bust") periods that typically characterise the path of real GDP through time.

[4]The original and seminal contribution here was made by Mundell (1961).

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

In the 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 shows 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) do exhibit some independent growth dynamics. 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 in some instances the shift to the adoption of the euro within the Economic and Monetary Union (EMU) process (- using specified economic convergence criteria), has not fostered greater synchronisation of euro area growth rates. As this is a much greater 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, does not 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. This is an important issue for monetary union central banks for several reasons:

a) First, the OCA theory suggests that similar ("convergent") growth rates will ease the problems associated with the differential impact of monetary policy;

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

c) Third, OCA theory also suggests that even without this increased synchronicity of business and growth cycles, increased mobility of factors of production can counter any lack of synchronicity and so aid implementation of monetary policy as resources can flow from one part of the monetary union to another to offset adverse idiosyncratic economic shocks.

d) Fourth, another offset to lack of synchronisation can be found in autonomy of fiscal policy, particularly at the supranational, federal or confederal level. This has caused considerable concerns in the US in recent years, as cuts to the Federal budget appeared to severely limit policy adjustment in certain States (- for example California), given that State balanced budget laws had already necessitated significant curtailment of expenditures, so that State budgets could not be expanded to compensate.

e) Lastly, there is also a feedback effect involved, as a single monetary policy should impact all growth rates across the monetary union, implying that an OCA might be endogenously created (- see Frankel and Rose (1997)), with more similar business

[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.

cycle dynamics, if US monetary and fiscal policy are partially causing the business cycles themselves.

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, and whether this is significantly different from a control group of countries that are not part of a monetary union.

3 Methodology and Data

3.1 Synchronicity Assessment

The technique used to derive a measure of synchronicity presented here is based on recurrence plots, and is described in detail in Crowley and Hughes Hallett (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[6]. 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 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. In this section we first explore the cross-recurrence methodology for synchronicity detection, and then we introduce the new measure, both of which are specifically applied to small sample measurement of synchronization.

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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.

Each time series is first transformed into a stationary growth rate (e.g. by log first differencing real GDP to obtain economic growth rates) or stationary source variables are used (such as unemployment rates), and then a cumulative summation variable of this stationary variable is created:

$$X_i = \sum_{j=1}^{i} (\log x_j - \log x_{j-1}) \tag{1}$$

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

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We refer to these modified time-series, X_i, as cumulative unsigned summation (CUS) series. Distance matrices, $D_{i,j}$ for each CUS series are then created using the standard Euclidean distance metric as described in Marwan, Romano, Thiel, and Kurths (2007). To evaluate the dissimilarity between two time series, we then perform an epoch (moving window) analysis with a three sample window incremented one sample at a time, where in the bivariate case $D1_{i,j}$ denotes the epoch window for X_i containing NN values of $D_{i,j}$ for the epoch window of size $N \times N$. For each epoch the DDM is computed by taking the difference between the paired values in the epochs from each time series, which for the bivariate case we denote as $D1_{i,j}$ and $D2_{i,j}$:

$$E_{i,j} = |D1_{i,j} - D2_{i,j}| \tag{2}$$

where $E_{i,j}$ represents the differenced epoch window for the first series etc, and i, j are the time points in a particular epoch. 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 $E_{i,j}$ matrix incorporates both lead and lag dynamics as it includes off-diagonal elements as well; and iii) that the range in values for $E_{i,j}$ is from 0 to $\max\{D1_{i,j}, D2_{i,j}\}$. A value of $E_{i,j} = 0$ clearly denotes complete synchronization between the two series.

Finally we take the average value of the components of $E_{i,j}$:

$$DDM = \frac{\sum_{i,j=1}^{N} E_{i,j}}{N^2} \tag{3}$$

to obtain a DDM which represents the total dissimilarity between $D1$ and $D2$ for a particular epoch. This process can be done for a single variable against another variable (as is shown above) 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 - this is the version of the DDM used in the analysis below. The final product is then a one dimensional time series representing the synchronization in dynamic between members of a set with smaller values indicating greater synchronicity.

To summarize then, the methodology is as follows:

i) Cumulate all the (signed or unsigned) series;

ii) Form a distance matrix $D_{i,j}$ for the cumulative series by calculating the distance of every point from every other point, then squaring, sum and square root;

iii) Now form an epoch window over the set of cumulative distance measures $D_{i,j}$ which we label as matrix $D1_{i,j}$;

iv) Now subtract the matrix $D2_{i,j}$ from the equivalent matrix $D1_{i,j}$ to form another matrix, $E_{i,j}$;

v) Average the values of $E_{i,j}$ to obtain a dissimilarity/synchronicity measure between the two series.

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 measure of synchronicity. This 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.

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:

$$g_t = \ln(y_t) - \ln(y_{t-1}) \tag{4}$$

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.

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

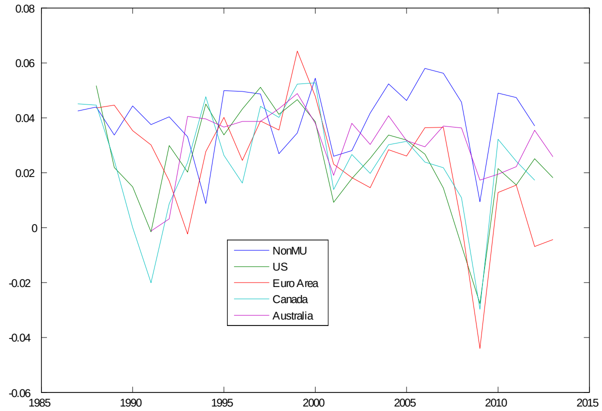

Figure 1: Mean of Aggregate Economic Growth

Figure 1 shows that there international business cycles are clearly at play for all countries, as the downturn in economic growth in the early 1990s occurs in a staggered fashion, and then there is clearly a synchronized downturn in both the 2001 recession, and similarly 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 (to create the equivalent of an inflation rate). The data is sourced from the BEA[8] for the US, from Eurostat for the euro area, from Statcan for Canada, from the Australian Bureau of Statistics and from the IMF IFS for the non-monetary union countries. For the US, this dataset had to be 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.

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

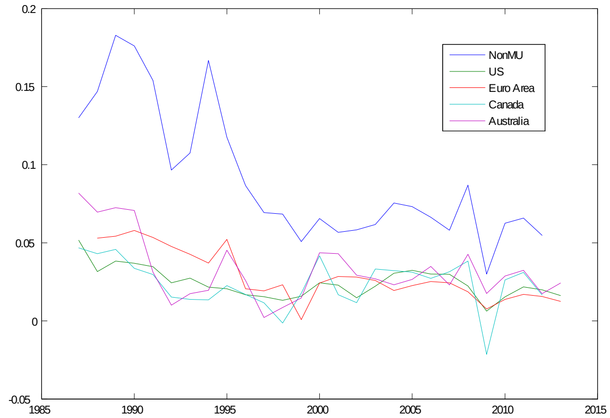

Figure 2: GSP/GDP Deflator Aggregate Growth

c) Unemployment - this is taken as the usual definition of the unemployment rate, i.e. the number of unemployed divided by 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 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 great recession, and then in the aftermath of the great recession 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 use a control group of non-monetary unions in order to construct a one sided hypothesis test of similar synchronicity. A surrogate is used to construct the two-sided test at the 90% confidence interval that the synchronicity measure for a country is significantly higher or lower than for the other States. We take the lower confidence interval as a one-sided test at a 5% level of significance for monetary unions having a greater degree

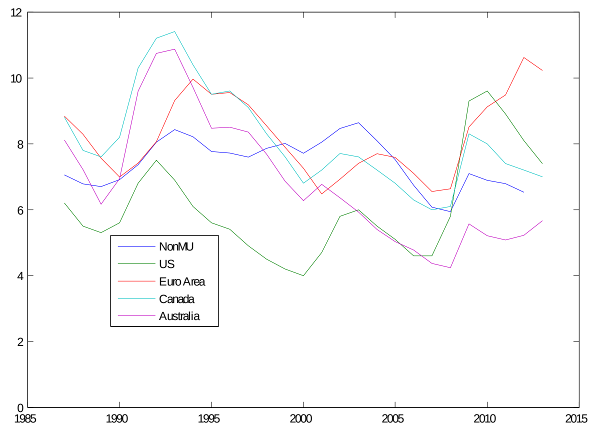

Figure 3: Aggregate Unemployment Rates

of synchronicity (and therefore significantly lower dissimilarity). So 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 63 countries in the control group and the list of countries can be found in the appendix. The cross sectional mean and standard deviation of the dynamic dissimilarity measure for the non-monetary union control group 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 dissimilarity measure for the non-monetary union control group. 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 dissimilarity measure for unemployment rates for the control group of non-monetary union

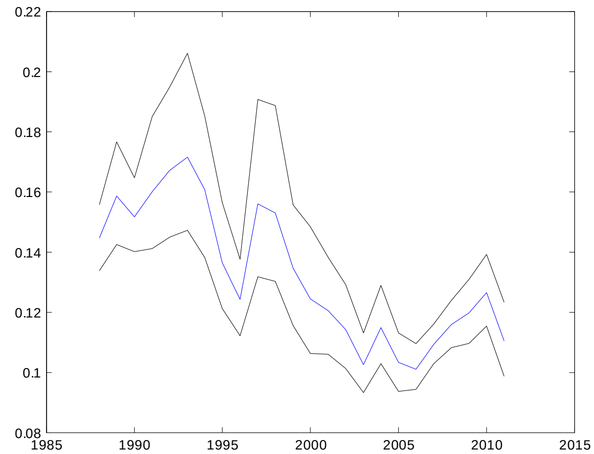

Figure 4: Mean and 90% confidence interval for Real GDP growth for non-MU Countries

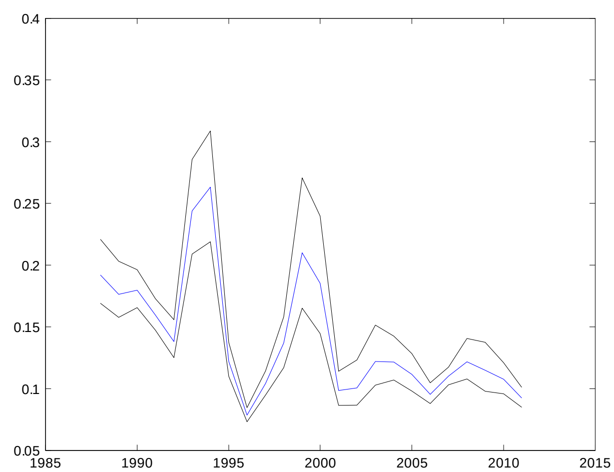

Figure 5: Mean and 90% confidence interval for GDP deflator growth for non-MU Countries

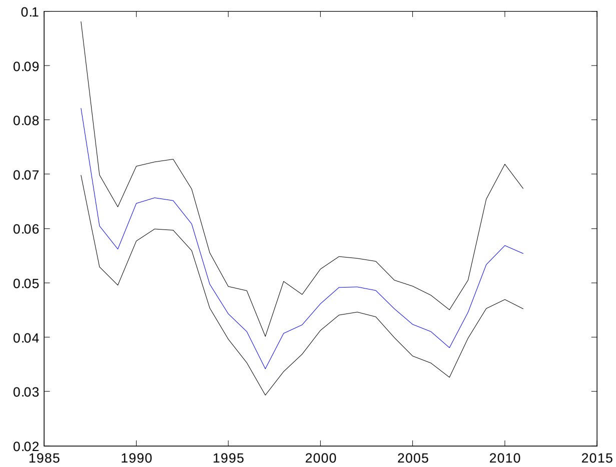

Figure 6: Mean and 90% confidence interval for Unemployment rate for non-MU Countries

countries. There are 25 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 intra-member dissimilarity measures by monetary union for real GDP growth, and compare them with the baseline established by the 90% confidence level.

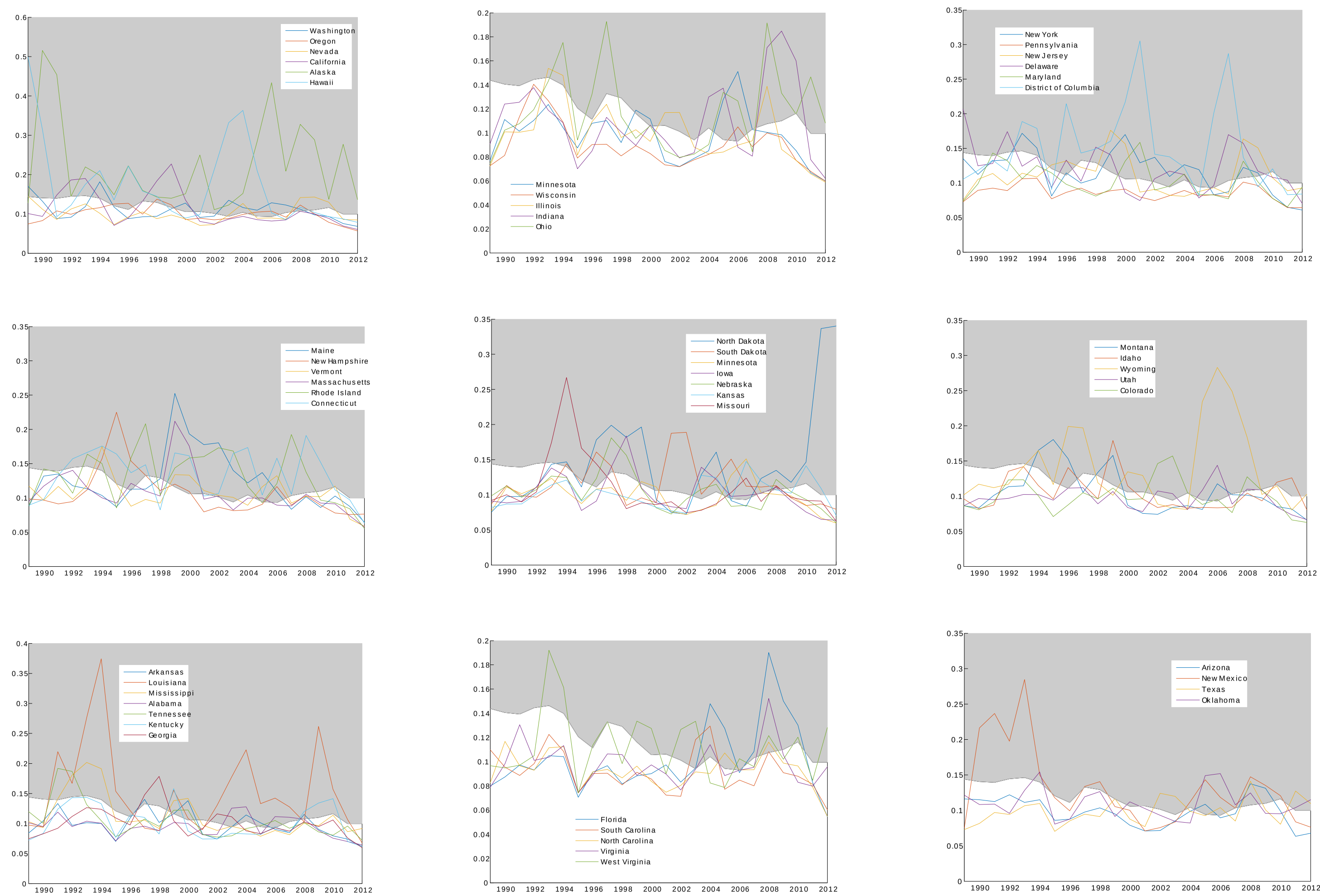

Table 1: Dissimilarity measure for US Real GDP

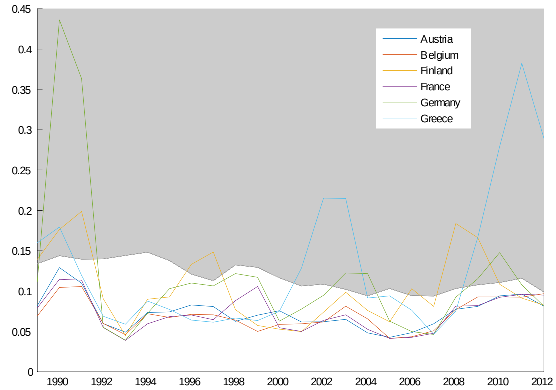

Figure 7: Dissimilarity Measure for euro area real GDP growth

4.2.1 US

In figure 1 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 group 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 oilfield 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 captures the intra-group dissimilarity.

4.2.2 Euro area

In figures 7 and 8, 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 was taking place 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.

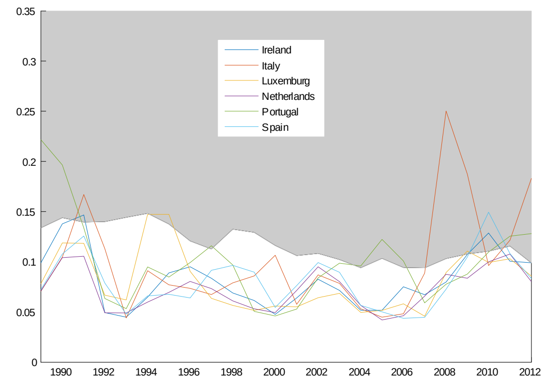

Figure 8: Dissimilarity measure for euro area real GDP growth

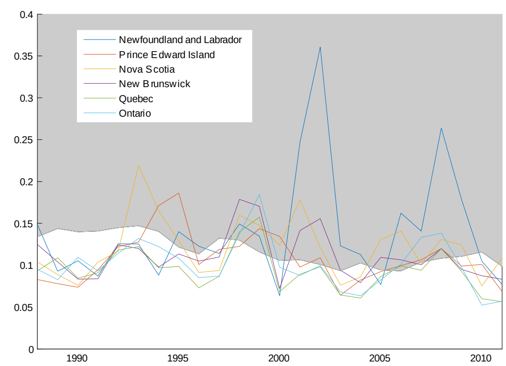

Figure 9: Dissimilarity measure for Eastern Canada real GDP growth

4.2.3 Canada

In figure 9 and 10 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 oil, as large amounts of oil were discovered in both of these two provinces. Another thing that is also noticable is that synchronicity doesn't seem to have fallen or increased in absolute terms.

4.2.4 Australia

Lastly, in figures 11 and 12 we plot the dissimilarity measure for Australian states. Here the results are quite different. Apart from Tasmania in the early 2000s, Australian states appear to collectively have a different economic growth dynamic from the non-monetary

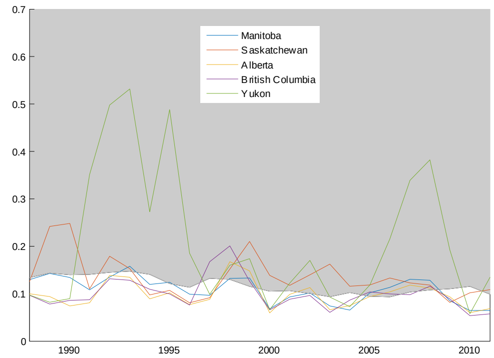

Figure 10: Dissimilarity measure for Western Canada real GDP growth

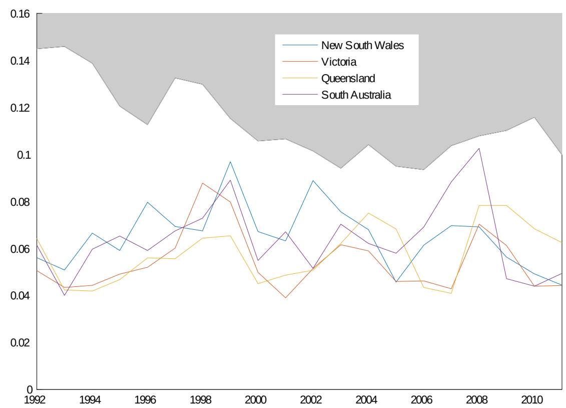

Figure 11: Dissimilarity measure for Eastern Australia real GDP growth

union countries. Certainly nearly all levels of synchronization in any given year are significantly different from the control group, signifying greater synchronization in economic for all the members of this particular monetary union.

4.3 GDP deflator inflation

4.3.1 US

In figure 1 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 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

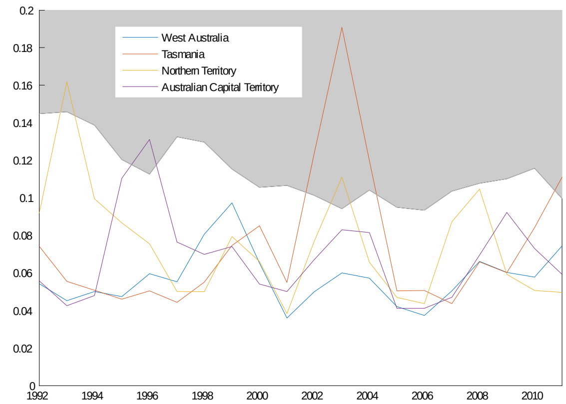

Figure 12: Dissimilarity measure for Western Australia real GDP growth

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.

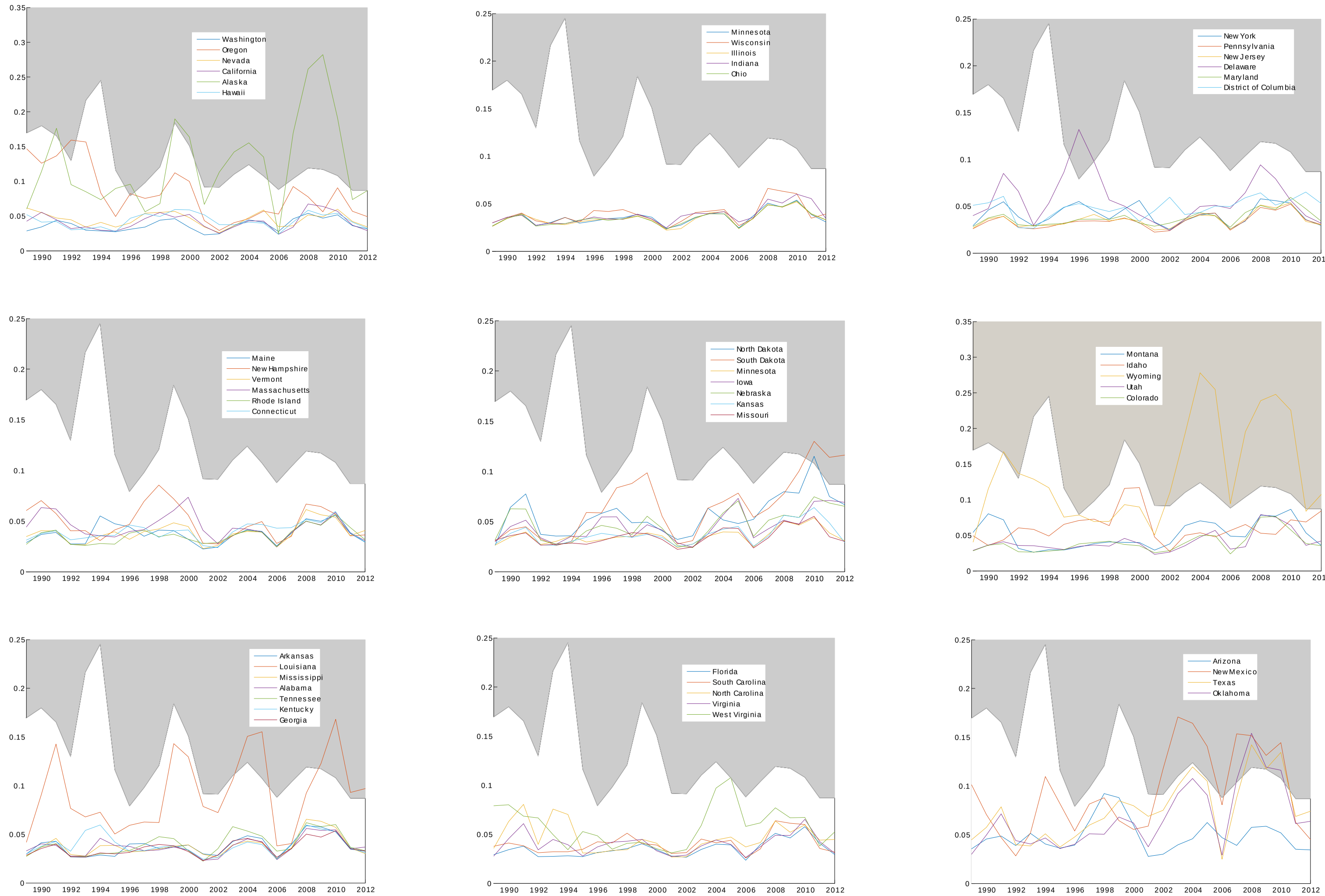

Table 2: Dissimilarity measure for US GSP deflator inflation

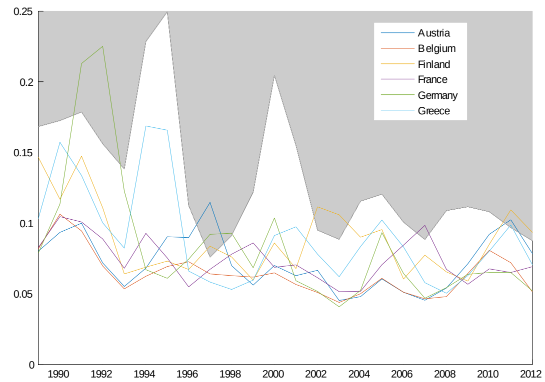

Figure 13: Dissimilarity measure for Euro area GDP deflator inflation

4.3.2 Euro area

In figures 13 and 14, 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 once most noteworthy the way Germany clearly was not synchronous with the other euro area members in the early 1990s.

4.3.3 Canada

Here, in figures 15 and 16, 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 17 and 18 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.

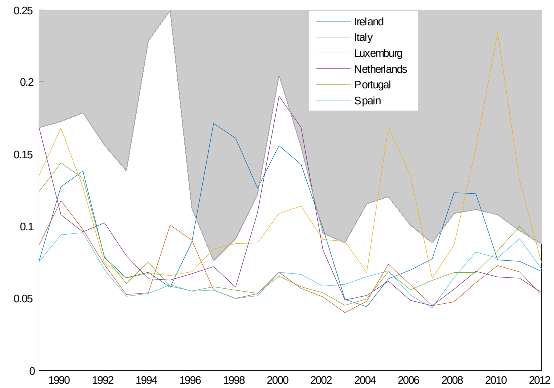

Figure 14: Dissimilarity measure for Euro area GDP deflator inflation

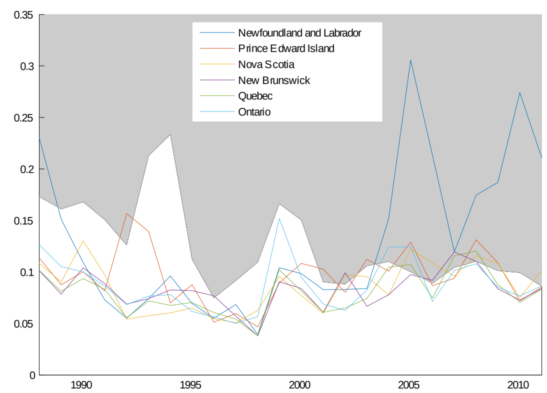

Figure 15: Dissimilarity for Eastern Canada GDP deflator inflation

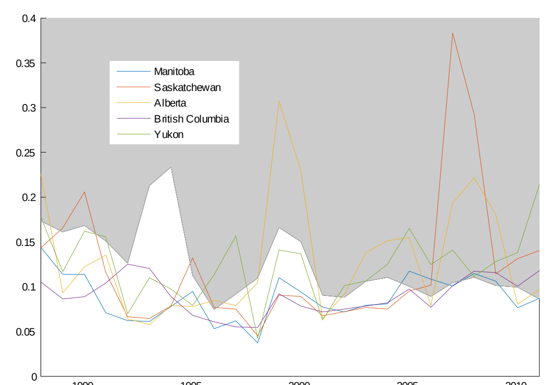

Figure 16: Dissimilarity for Western Canada GDP deflator inflation

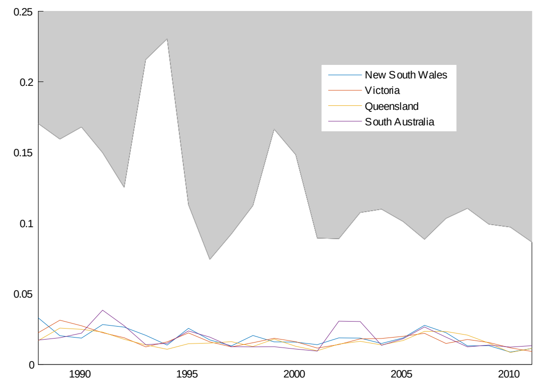

Figure 17: Dissimilarity measure for Eastern Australia GDP deflator inflation

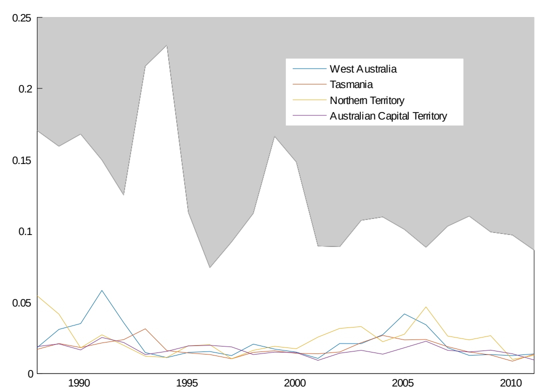

Figure 18: Dissimilarity measure for Western Australia GDP deflator inflation

4.4 Unemployment

4.4.1 US

Figure 3 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 related to the oil and gas sector with North Dakota, but Hawaii and Nevada have different dynamics for reasons likely pertaining to the tourist industry.

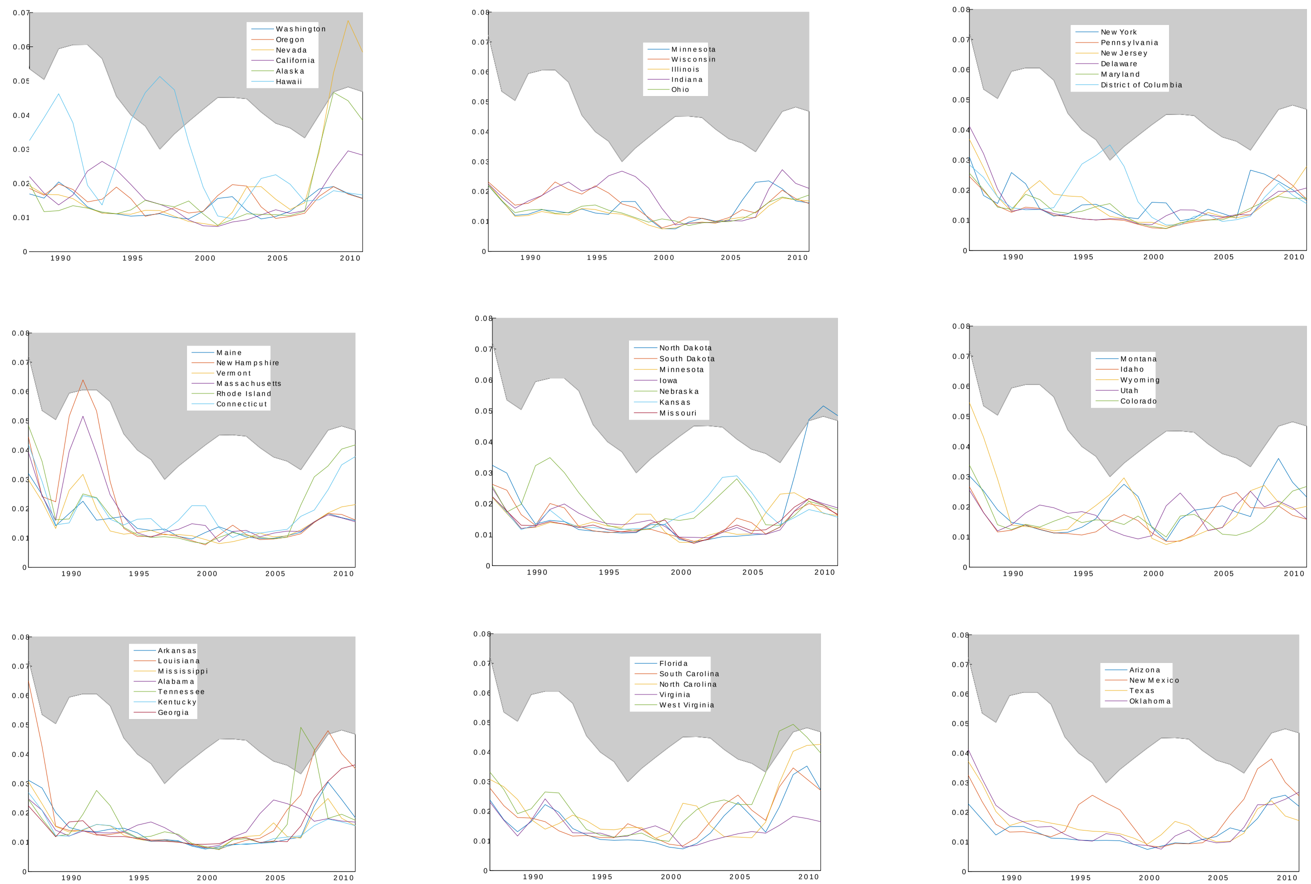

Table 3: Dissimilarity measure for US Unemployment rate

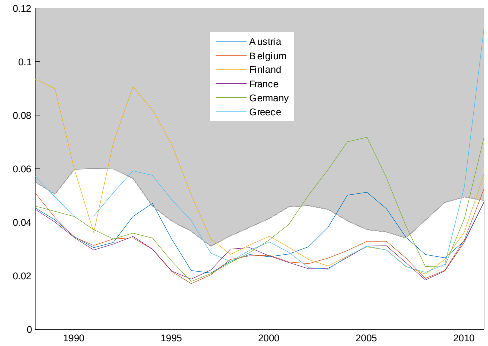

Figure 19: Dissimilarity measure for Euro Area Unemployment rate

4.4.2 Euro area

In figures 19 and 20, 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 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 21 and 22, 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 23 and 24. 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

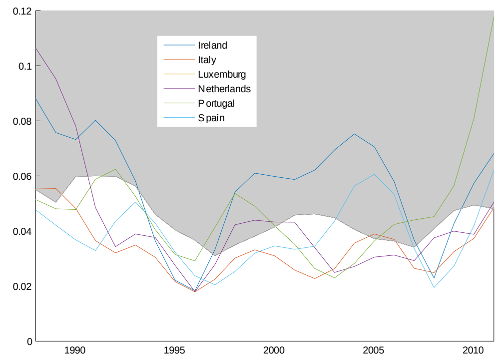

Figure 20: Dissimilarity measure for Euro Area Unemployment rate

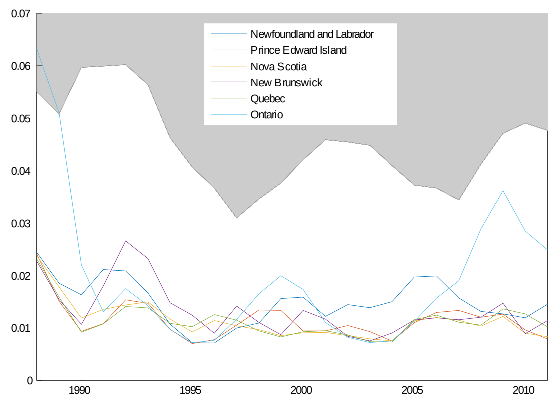

Figure 21: Dissimilarity measure for eastern Canada Unemployment rate

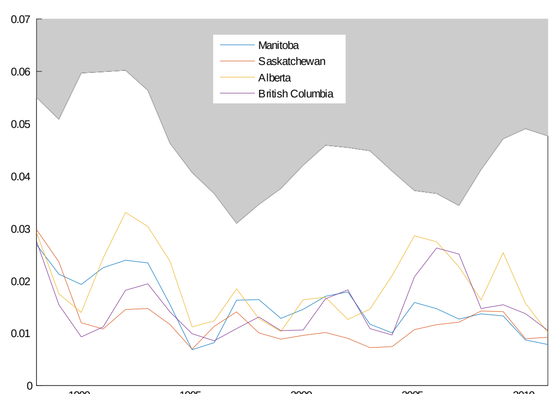

Figure 22: Dissimilarity measure for western Canada Unemployment rate

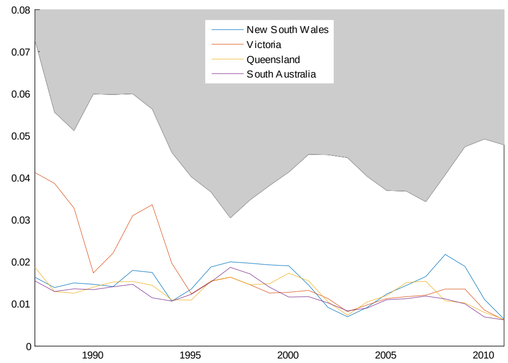

Figure 23: Dissimilarity measure for eastern Australia Unemployment rate

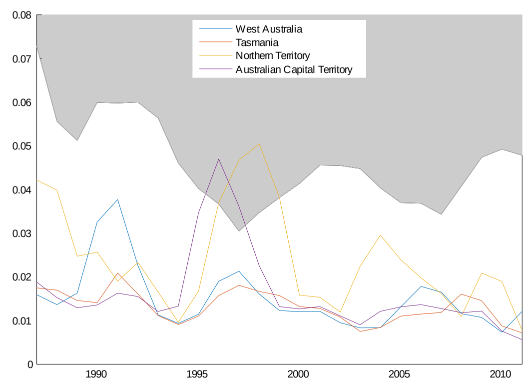

Figure 24: Dissimilarity measure for western Australia Unemployment rate

dynamics that have been significantly different from the control group. Looking at the chart, there also appears to be 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 distribution for each 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.

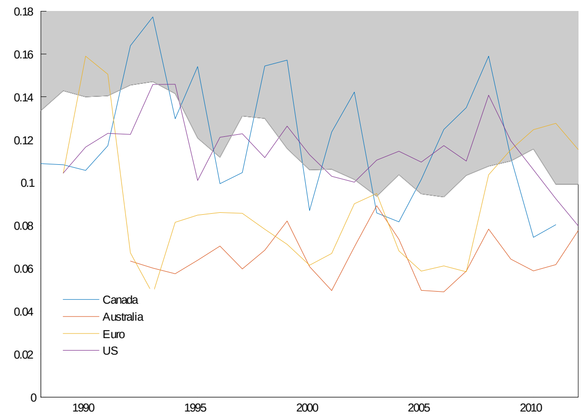

Figure 25: Average dissimilarity measure for real GDP growth by monetary union.

5.1 Real GDP growth

In figure 25 we plot the average dissimilarity measure by monetary union, and compare with the 95% confidence interval 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 26 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 27 and 28 below. While it is clear that the mean for monetary unions is below that of non-monetary unions from figure 27, 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 unions.

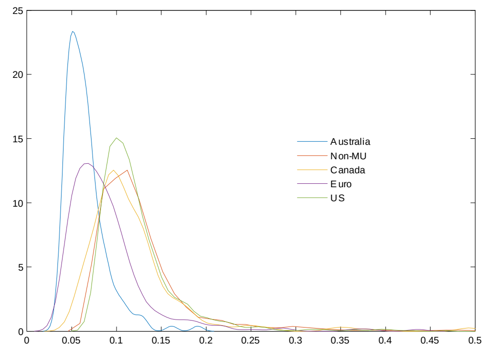

Figure 26: Kernel distribution estimate of real GDP growth rates by monetary union.

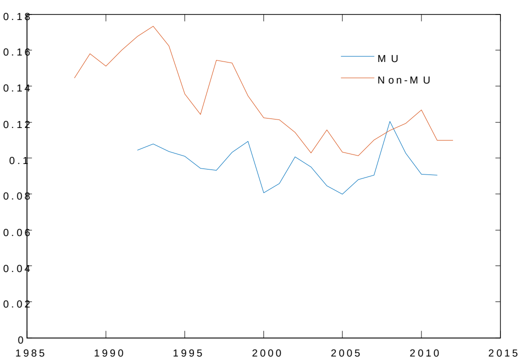

Figure 27: Comparison of mean for monetary unions and non-monetary unions

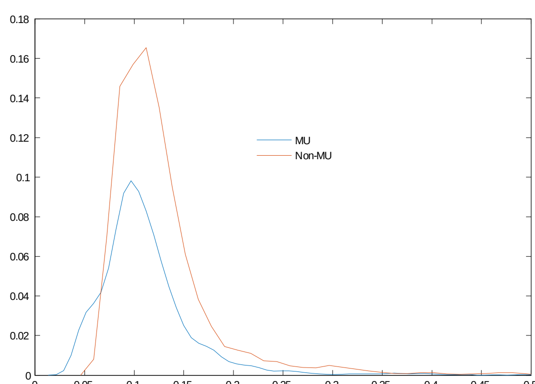

Figure 28: Comparison of kernel distribution estimates for monetary unions and non-monetary unions

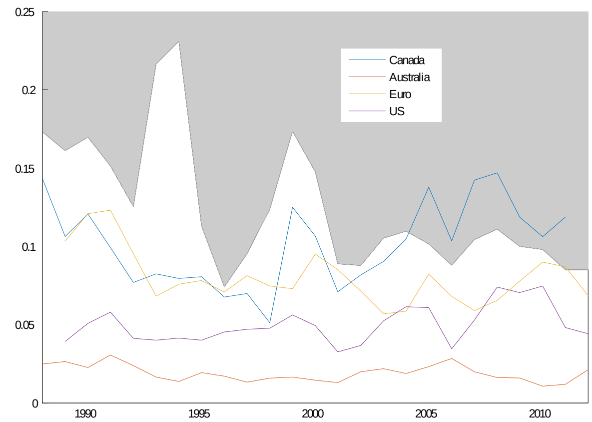

Figure 29: Average dissimilarity measure for GDP deflator growth by monetary union

5.2 GDP deflator inflation

Here we repeat the exercise above, but for GSP/GDP deflator inflation. Figure 29 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 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 movements, 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 30, 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 both the US and Canada, with actually very little apparent overlap for the euro area.

We now turn to the group comparisons. In figure 31 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 anythig there appears to have been a slight fall in mean dissimilarity for the monetary unions. Put another way - 25 years ago the degree of difference in synchronicity between monetary unions and non-

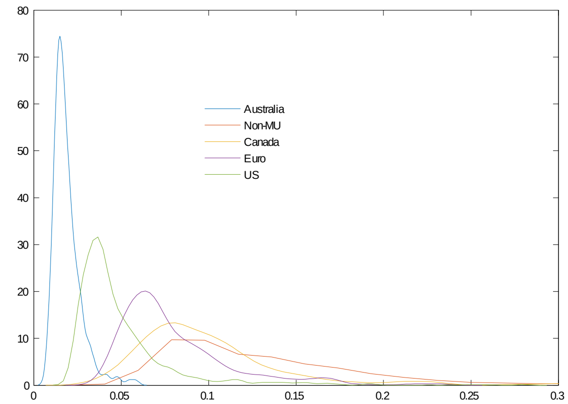

Figure 30: Kernel distribution estimate of GDP deflator growth by monetary union.

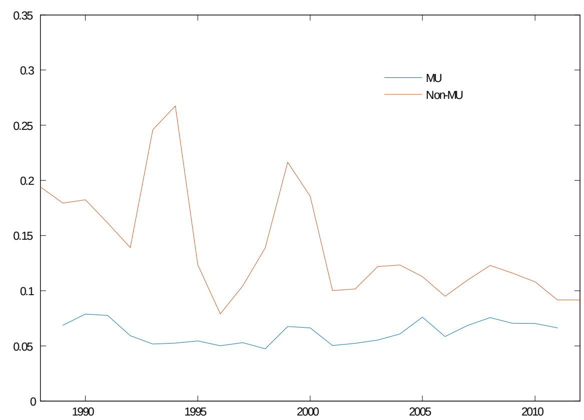

Figure 31: Comparison of mean for monetary unions and non-monetary unions

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 32 we show the difference between the kernel estimate for the synchronicity within the monetary union group compared to the non-monetary 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.

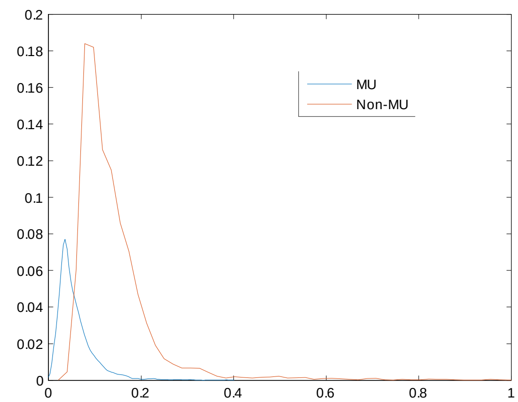

Figure 32: Comparison of kernel distribution estimates for monetary unions and non-monetary unions

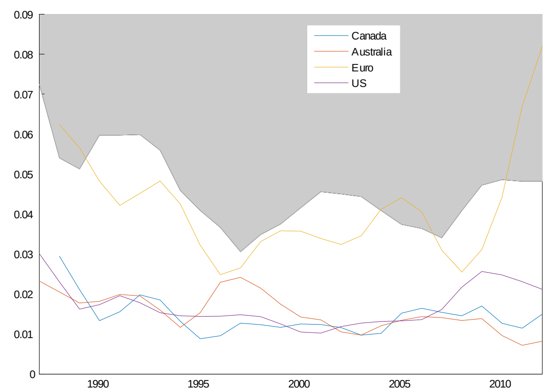

Figure 33: Average dissimilarity measure for Unemployment rate by monetary union

5.3 Unemployment

Finally we conduct the same group analysis for synchronization in unemployment rate dynamics. In figure 33 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 much 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

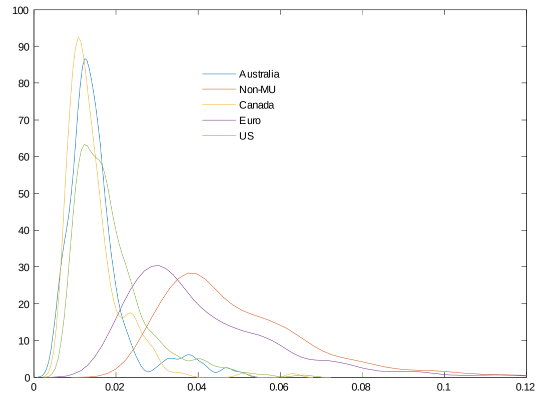

Figure 34: Kernel distribution estimate of Unemployment rate by monetary union.

Figure 35: 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 34.

In figure 35, 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 36 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

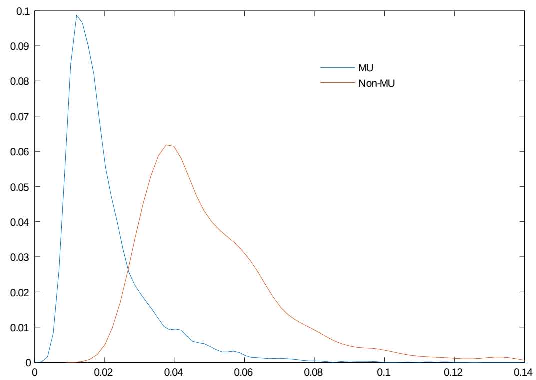

Figure 36: Comparison of kernel distribution estimates for dissimilarity of unemployment rates in monetary unions vs non-monetary unions

control group.

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 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 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 that monetary union would be Australia. This is once again a surprising result, given that there is homogeneity of culture and language between all the Australian states, and therefore high labor mobility.

Appendices

A Non-Monetary Union Countries

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