Time-varying Business Cycles Synchronisation in Europe

Stavros Degiannakis[1,2], David Duffy[3], George Filis[4]*

[1]Department of Statistics, Athens University of Economics and Business,
76 Patission Str., GR 10434, Athens, Greece.

[2]Economic Research Department, Bank of Greece,
21 E. Venizelos Avenue, GR10250, Athens, Greece

[3]Department of Accounting, Finance and Economics, University of Ulster,
Jordanstown campus, Shore Road, Newtownabbey, Co. Antrim, BT37 0QB, UK.

[4]Department of Accounting, Finance and Economics, Bournemouth University,
Executive Business Centre, 89 Holdenhurst Road, BH8 8EB, Bournemouth, UK.

*Corresponding author:
email: gfilis@bournemouth.ac.uk,
tel: 0044 (0) 1202 968739,
fax: 0044 (0) 1202 968833

Abstract

The paper investigates the time-varying correlation between the EU12-wide business cycle and the initial EU12 member-countries based on scalar-BEKK and multivariate Riskmetrics model frameworks for the period 1980-2009. The paper provides evidence that changes in the business cycle synchronisation correspond to institutional changes that have taken place at a European level. Business cycle synchronisation has moved in a direction positive for the operation of a single currency suggesting that the common monetary policy is less costly in terms of lost flexibility at the national level. Thus, any questions regarding the optimality and sustainability of the common currency area in Europe should not be attributed to the lack of cyclical synchronisation.

Keywords: Scalar BEKK, Multivariate Riskmetrics, time varying correlation, EU business cycle, business cycle synchronisation.

JEL: C32, E32, F43, O52.

1. Introduction

This paper investigates the time-varying business cycles synchronisation between the initial EMU12 member-countries and the EMU12-wide business cycle[1], using quarterly data from 1980 until 2009. In addition, we investigate this relation for Denmark, Sweden and the UK, the non-EMU members, but originally EU15 members. The motivation for the selection of this group of EU countries is that business cycle synchronisation is an important pre-requisite to forming a successful currency union as implied by the insights of Optimal Currency Area Theory. In the UK, for instance, one of Gordon Brown famous 5 tests for joining the Euro was the assurance that the UK and the European-wide business cycles would be synchronised. In addition, the recent economic crisis signified the importance of business cycle synchronisation in EU with regards to the application of a suitable union wide monetary policy response. This study explores a current economic topic in light of recent economic developments.

Pioneers in the study of business cycles are, *inter alia*, Mitchell (1946), Burns and Mitchell (1946) and Kuznets (1958). Since then, a significant amount of literature has been produced in the study of business cycle synchronisation. Papageorgiou, Michaelides and Milios (2010) and de Haan, Inklaar and Jong-A-Pin (2008) provide an extensive review of the literature.

Previous studies have used a wide range of techniques and data to study the level of synchronisation in European business cycles and other bilateral business cycles synchronisations. The various techniques that have been applied to this research question range from constant contemporaneous and lagged correlations for entire periods or sub-periods[2] to Vector Autoregressive (VAR) models[3] and from frequency-domain dynamic correlations[4] to rolling windows correlations[5]. Although these methods provide a sufficient understanding of the business cycle synchronisation in Europe, they share some limitations. To start with, a static correlation figure is not able to capture any fluctuations of the correlation level between the business cycles under the period of a study. In addition, the

---

[1] Luxemburg was omitted due to data unavailability. The results are not sensitive to the exclusion of Luxemburg data due to its small size. The European Union-wide business cycle is estimated in the same spirit with de Haan, Jacobs and Mink (2007) and Artis, Krolzig and Toro (2004). Stylized facts for the European-wide business cycle are provided by Artis, *et al.* (2004).

[2] See, *inter alia*, Gogas and Kothroulas (2009), Ferreira-Lopes and Pina (2009), Furceri and Karras (2008), Artis and Zhang (1999), Fatas (1997), Inklaar and de Haan (2001).

[3] For further details on VAR models the reader is directed to Bergman and Jonung (2010).

[4] For further details on frequency-domain correlations the reader is directed to Concaria and Soares (2009), Azevedo (2002), Croux, *et al*. (2001), as well as references in de Haan, et al. (2008).

[5] See, for example, Dopke (1999).

robustness of the results obtained for rolling windows correlations is subject to the length of the rolling window[6]. Furthermore, choosing sub-periods exogenously in an effort to produce a quasi time-varying correlation could have several drawbacks (see Sebastien, 2009, for additional explanation of these drawbacks). These shortcomings are important and it is a development of this paper that the techniques do not suffer from these shortcomings.

The present study directly addresses all the above issues by employing two robust quantitative techniques, namely the scalar-BEKK and multivariate Riskmetrics models, as these were suggested by Baba, Engle, Kraft and Kroner (1990) and J.P. Morgan (1996), respectively. These techniques have not been applied before to investigate the time-varying correlation between the individual European member-countries and the European Union-wide business cycle without a priori imposing regime switches. In addition, for robustness purposes we use two different filtering methods for the extraction of the cyclical components namely the Hodrick-Prescott filter (Hodrick and Prescott, 1997) and the band-pass filter proposed by Baxter and King (1999)[7]. These filters were chosen in order for our study to be easily comparable with previous literature.

The main contribution of the paper to the existing literature can be described succinctly. First, we apply two different quantitative methods which enable us to examine the evolution of business cycle synchronisation in EU, and to limit the shortcomings of the methods that have been used so far. Second, we use two filtering methods for robustness purposes and the results are qualitatively similar. Third, the results from the time-varying measures show that the changes in the level of correlation correspond to institutional changes that have taken place at a European level. This has important policy implications for the operation of macroeconomic policy in a common currency area and contributes to the long lasting debate regarding the optimality of a common currency.

The rest of the paper proceeds as follows: Section 2 reviews the relevant literature, Section 3 presents the data, Section 4 describes the models used, Section 5 presents the empirical findings of the research and, finally, Section 6 concludes the study.

---

[6] See Savva, *et al.* (2010) for additional explanation.

[7] We considered these two filtering methods as they are the most commonly used methods and thus our results can be directly comparable to the existing literature.

2. Review of the Literature

The importance of business cycle synchronisation for the operation of a common currency area is implied by the seminal work on Optimum Currency Area theory - OCA by Kennen, (1969), McKinnon (1963), and Mundell (1961), as well as, more recent contributions by Furceri and Karras (2008) and Alesina and Barro (2002). In addition, some authors argue that business cycle synchronisation is not only a pre-requisite to the formation of a monetary union but they go further suggesting that the very survival of a common currency area depends on the commonality of business cycle fluctuations (see, for example, Bergman, 2006).[8]

The importance of business cycle synchronisation arises from the fact that the formation of a single currency area explicitly involves the synchronisation of monetary policy and this common monetary policy will be influenced by the union-wide business cycle. In order for a one size fits all monetary policy to be efficient there must be a high degree of synchronisation of business cycles. Consequently, if the member-countries' business cycles are closely related to the union-wide business cycle, then their individual monetary policies will be more closely substituted by a common monetary policy. Conversely, if countries' business cycles diverge from the union-wide business cycle, then they are more sensitive to asymmetric shocks and thus the common monetary policy will result in the destabilization of the individual economies, which will aggravate the cost of joining the monetary union (Savva, Neanidis and Osborn, 2010; Sebastien, 2009; Furceri and Karras, 2008; Fidrmuc and Korhonen, 2006). Hence, it is clear that business cycle synchronisation has a consequence for the policies of the central bank. If synchronised business cycles exist, it will be easier for the central bank to impose its stabilising interventions (Savva, *et al.*, 2010; Crowley and Schultz, 2010; Furceri and Karras, 2008; Clarida, Gali and Getler, 1999; Rogoff, 1985).

Apart from the fact that business cycles synchronisation impacts on the central bank and its monetary policy decisions; the level of synchronisation has implications for the fiscal policy of each member-country also. If the monetary policy response from the central bank to an

[8] Although important for the application of policy in a monetary union it must be noted that business cycle synchronisation does not necessarily mean that economic convergence is occurring (i.e. synchronisation may exist, however the cycles could have different amplitudes due to non-convergence). The term convergence is related to the catch-up effect between countries' growth rates, whereas synchronisation has the meaning of similar movements of the countries' growth rates over time (Crowley and Schultz, 2010). Synchronisation, if it exists, can lead to economic convergence between the member-countries of a monetary union.

asymmetric shock is not suitable for every member-country, then members will be able to use their independent fiscal policy to counterbalance the negative effects of the common monetary policy (Crowley and Schultz, 2010). The problem that European countries face, in the presence of the Stability and Growth Pact (SGP), is that the use of fiscal policy, as a protection against the adverse effects of the common monetary policy, becomes limited (Crowley and Schultz, 2010; Furceri and Karras, 2008; Furceri, 2005; Gali and Perotti, 2003). All the aforementioned authors, implicitly or explicitly, suggest that business cycle synchronisation should be considered as an exogenous criterion for the formation of an OCA, such as the EMU.

However, over the last 15 years the literature has challenged the exogenous character of business cycle synchronisation for monetary unions. Bower and Guillemineau (2006), Fidrmuc (2004), Maurel (2002) and Frankel and Rose (1998), for example, have argued that business cycle synchronisation is actually an endogenous OCA criterion in the sense that the formation of a monetary union will lead to the higher synchronisation of the members' business cycles. Thus, many authors argue that one of the main determinants of business cycle synchronisation is the formation of a monetary union itself (see, *inter alia*, Bergman and Jonung, 2010; Rose and Stanley, 2005; López-Córdova and Meissner, 2003; Rose and Engel, 2002; Fatas, 1997).

Overall, the literature on business cycle synchronisation does not provide consistent evidence on the level of European Union business cycle synchronisation and how this level has changed over time. Different studies paint somewhat different pictures[9]. Several of these studies have reached the conclusion that there is a greater level of synchronisation in the European Union after 1992, i.e. (during the post European Rate Mechanism (ERM) period and the Maastricht Treaty period). Furthermore, there are those studies which demonstrated that there is an increase in business cycle synchronisation after the adoption of the common currency in 1999. Some studies pointed out that there are two country clusters in European business cycle synchronisation, the core member-countries and the periphery. In addition, there are those studies that argue that synchronisation existed prior to the EMU and ERM. Nevertheless, Hughes Hallett and Richter (2008) suggest that since the introduction of the common currency the level of synchronisation has declined for the core

[9] A review of these studies along with their findings can be found in Papageorgiou, *et al.* (2010) and de Haan, *et al.* (2008).

European countries. All that said, Canova, *et al.* (2009) argued that changes in the European business cycles synchronisation cannot be attributed to institutional changes.

To the best of our knowledge there is only one paper in the literature that applies a time-varying correlation method in time-domain (Savva, *et al.* (2010) apply a switch-regime time-varying correlation, named DSTCC-VAR-GARCH model). The paper by Savva, *et al.*, (2010) presents a regime-switch time-varying correlation between the EU member-countries and the EU-wide business cycles. Regime-switch models determine a priori the number of regime switches. In this paper, however, regime changes are not imposed a priori by the researchers but rather they are exposed by the data. Allowing the data to expose regime shifts is useful in the context of EU business cycle synchronisation given the potential for the institutional changes associated with the process of economic integration to produce changes in business cycle synchronisation over time. This is important given the conflicting evidence that has mounted regarding European business cycle synchronisation over this period. Additionally with a business cycle synchronisation measure that varies over time it is possible to assess the effects of the recent financial crisis on EU business cycle synchronisation.

3. Data Description

The dataset includes quarterly GDP data from 14 EU member-countries and the aggregate EMU12 GDP (EMU members: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain; non-EMU members: Denmark, Sweden and UK). The data cover the period from 1980:Q1 to 2009:Q4. All GDP prices are converted in logarithms; they are seasonally adjusted and refer to constant levels. We use GDP, as according to de Haan, *et al.* (2008) studies on business cycle synchronisation should focus on GDP (rather than industrial production, for example), as this represents the broadest measure of output.

Still, there are very few studies that examine the robustness of their results using different filtering methods for their cyclical components. For illustration purposes and the analysis of the empirical results we only show the output of one filtering method, namely the Hodrick-Prescott (1997). However, the results for both filtering methods are qualitatively similar[10].

[10] The results for the band-pass filter are available upon request.

4. Models Description

As suggested by the literature, business cycle synchronisation is measured by the level of correlation between two countries' business cycles (x and y). In simple terms this can be shown as follows:

$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_x \times \sigma_y} \tag{1}$$

where, $\rho_{x,y}$ denotes the correlation coefficient, $\sigma_{x,y}$, σ_x and σ_y denote the covariance and the standard deviations of the two countries' business cycles, respectively. Nevertheless, this measure is static and is not able to capture the full dynamics of the business cycle synchronisation. Thus, a time-varying measure is required and the econometric literature has proposed a large number of models for modelling correlation in a multivariate framework (see for example, Dynamic Conditional Correlation GARCH model by Engle (2002), which has been applied in many occasions in empirical work in finance and macroeconometrics, and the Generalised Orthogonal ARCH model by Van Der Weide (2002), among others). However, these models require a large number of estimated parameters. Riskmetrics and Scalar-BEKK are some of the most parsimonious models among the powerful multivariate frameworks and thus they were chosen for this study. Both these models have the ability to generate the conditional variance matrix in a time-varying environment, which can then be used to estimate the correlation level at each time point. A detailed explanation of both frameworks follows.

4.1. Scalar-BEKK

The present study focuses on investigating the undeviating time-varying correlation between business cycles of 14 EU countries and the aggregate EMU12 cycle. Thus, we do not intend to investigate any exogenous variables that might have influenced the relationship between the business cycles nor any other endogenous variables that might have determined our system.

In the following paragraphs, the scalar-BEKK framework of our study is presented. Let the $(n \times 1)$ vector $\{\mathbf{y}_t\}$ refer to the multivariate stochastic process to be estimated. In the present model framework, $n = 15$ and $\mathbf{y}_t = (y_{1,t} \quad y_{2,t} \quad \ldots \quad y_{14,t} \quad y_{15,t})'$, where $y_{i,t}$, for i=1,2,...,14, denotes the business cycles of 14 countries and $y_{15,t}$ denotes the business cycle of EMU12. The innovation process for the conditional mean $\boldsymbol{\varepsilon}_t \equiv \mathbf{y}_t - \boldsymbol{\mu}_t$ has an $(n \times n)$ conditional covariance matrix $V_{t-1}(\mathbf{y}_t) \equiv \mathbf{H}_t$:

$$\begin{aligned} \mathbf{y}_t &= \boldsymbol{\mu}_t + \boldsymbol{\varepsilon}_t \\ \boldsymbol{\varepsilon}_t &= \mathbf{H}_t^{1/2}\mathbf{z}_t \\ \mathbf{z}_t &\sim N(\mathbf{z}_t; \mathbf{0}, \mathbf{I}) \\ \mathbf{H}_t &= \sigma(\mathbf{H}_{t-1}, \mathbf{H}_{t-2}, \ldots, \boldsymbol{\varepsilon}_{t-1}, \boldsymbol{\varepsilon}_{t-2}, \ldots), \end{aligned} \quad (2)$$

where $E_{t-1}(\mathbf{y}_t) \equiv \boldsymbol{\mu}_t$ denotes the mean of $\mathbf{y}_t$ conditional the available information at time $t-1$, I_{t-1}. $\mathbf{z}_t$ is an $(n \times 1)$ vector process such that $E(\mathbf{z}_t) = \mathbf{0}$ and $E(\mathbf{z}_t \mathbf{z}_t') = \mathbf{I}$, whereas $N(\mathbf{z}_t; \mathbf{0}, \mathbf{I})$ is the multivariate standard normal density function. $\sigma(.)$ is a positive measurable function of the lagged conditional covariance matrices and the innovation process.

Engle and Kroner (1995) and Baba et al. (1990) propose the BEKK model, which has been successively estimated for large time-varying covariance matrices. However, the BEKK model requires the estimation of $(n(n+1)/2) + 2n^2$ parameters. A less general version is commonly applied, named the scalar-BEKK model. The advantage is that the scalar-BEKK model is guaranteed to be positive definite and requires the estimation of fewer parameters than the BEKK model, i.e. $(n(n+1)/2) + 2$ parameters. The covariance matrix of the scalar-BEKK model is defined as:

$$\mathbf{H}_t = \mathbf{A_0}\mathbf{A_0}' + a\mathbf{i}\mathbf{i}'\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}_{t-1}' + b\mathbf{i}\mathbf{i}'\mathbf{H}_{t-1}, \quad (3)$$

where $\mathbf{A_0}$ is a lower triangular matrix with $(n(n+1)/2)$ parameters, a and b are positive scalars and $\mathbf{i}$ is an $(n \times 1)$ vector of ones. This parameterization guarantees that $\mathbf{H}_t$ is positive definite, if $\mathbf{A_0}\mathbf{A_0}'$ is a positive definite matrix. For technical details about the estimation of the model, the interested reader is referred to Xekalaki and Degiannakis (2010). The models were estimated in G@RCH package for Ox Metrics®; for technical details about the estimation of the model in Ox Metrics®, see Laurent (2007).

The detailed presentation of scalar-BEKK model for $n=15$ dimensions follows[11]:

$$\begin{pmatrix} y_{1,t} \\ y_{2,t} \\ . \\ . \\ . \\ y_{15,t} \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ . \\ . \\ . \\ b_{15} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ . \\ . \\ . \\ \varepsilon_{15,t} \end{pmatrix}$$

$$\left(\varepsilon_{1,t} \quad \varepsilon_{2,t} \quad . \quad . \quad . \quad \varepsilon_{15,t}\right)' = \mathbf{H}_t^{1/2}\left(z_{1,t} \quad z_{2,t} \quad . \quad . \quad . \quad z_{15,t}\right)'$$

$$\left(z_{1,t} \quad z_{2,t} \quad . \quad . \quad . \quad z_{15,t}\right)' \sim N(\mathbf{0},\mathbf{I})$$

$$\mathbf{H}_t = \mathbf{A_0}\mathbf{A_0}' + a\begin{pmatrix} 1 & 1 & . & . & . & 1 \\ 1 & 1 & . & . & . & 1 \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ 1 & 1 & . & . & . & 1 \end{pmatrix}\begin{pmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \\ . \\ . \\ . \\ \varepsilon_{15,t-1} \end{pmatrix}\left(\varepsilon_{1,t-1} \quad \varepsilon_{2,t-1} \quad . \quad . \quad . \quad \varepsilon_{15,t-1}\right)' + b\begin{pmatrix} 1 & 1 & . & . & . & 1 \\ 1 & 1 & . & . & . & 1 \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ 1 & 1 & . & . & . & 1 \end{pmatrix}\mathbf{H}_{t-1} \tag{4}$$

$$\mathbf{H}_t = \begin{pmatrix} \sigma_{1,t}^2 & \sigma_{1,2,t} & . & . & . & \sigma_{1,15,t} \\ \sigma_{1,2,t} & \sigma_{2,t}^2 & . & . & . & \sigma_{2,15,t} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ \sigma_{1,15,t} & \sigma_{2,15,t} & . & . & . & \sigma_{15,t}^2 \end{pmatrix}$$

$$\mathbf{A_0} = \begin{pmatrix} a_{1,1} & a_{1,2} & . & . & . & a_{1,15} \\ 0 & a_{2,2} & . & . & . & a_{2,15} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ 0 & 0 & . & . & . & a_{15,15} \end{pmatrix}$$

4.2. Multivariate Riskmetrics

A simplified multivariate ARCH framework is the multivariate Riskmetrics® model proposed by J.P. Morgan (1996). The multivariate Riskmetrics® model is guaranteed to be positive definite, does not require the estimation of any parameters of $\mathbf{H}_t$, is easy to work with in practice but the assumption of imposing the same dynamics on every component in a multivariate ARCH model is difficult to justify. The covariance matrix of the multivariate Riskmetrics model is defined as:

[11] The incorporation of a first-order autoregressive term, AR(1), in the conditional mean, provides qualitative similar results.

$$\mathbf{H}_t = (1-\lambda)\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1} + \lambda\mathbf{H}_{t-1} \tag{5}$$

where $0 < \lambda < 1$ is a scalar, which according to Riskmetrics® equals to 0.94 for daily data and 0.97 for monthly and quarterly data. The detailed presentation of multivariate Riskmetrics model for $n = 15$ dimensions follows[12]:

$$\begin{pmatrix} y_{1,t} \\ y_{2,t} \\ . \\ . \\ . \\ y_{15,t} \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ . \\ . \\ . \\ b_{15} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ . \\ . \\ . \\ \varepsilon_{15,t} \end{pmatrix}$$

$$\begin{pmatrix} \varepsilon_{1,t} & \varepsilon_{2,t} & . & . & . & \varepsilon_{15,t} \end{pmatrix}' = \mathbf{H}_t^{1/2} \begin{pmatrix} z_{1,t} & z_{2,t} & . & . & . & z_{15,t} \end{pmatrix}' \tag{6}$$

$$\begin{pmatrix} z_{1,t} & z_{2,t} & . & . & . & z_{15,t} \end{pmatrix}' \sim N(\mathbf{0}, \mathbf{I})$$

$$\mathbf{H}_t = \begin{pmatrix} \sigma^2_{1,t} & \sigma_{1,2,t} & . & . & . & \sigma_{1,15,t} \\ \sigma_{1,2,t} & \sigma^2_{2,t} & . & . & . & \sigma_{2,15,t} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ \sigma_{1,15,t} & \sigma_{2,15,t} & . & . & . & \sigma^2_{15,t} \end{pmatrix} = 0.03 \begin{pmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \\ . \\ . \\ . \\ \varepsilon_{15,t-1} \end{pmatrix} \begin{pmatrix} \varepsilon_{1,t-1} & \varepsilon_{2,t-1} & . & . & . & \varepsilon_{15,t-1} \end{pmatrix}' + 0.97\mathbf{H}_{t-1}.$$

5. Empirical Results

5.1. Overall EU Business Cycle Synchronisation Results

An important advantage of the time varying measure of synchronisation is that regime changes are not imposed a priori by the researcher, rather they are exposed by the data and analysed qualitatively in this section. This is an innovation from previous studies that observe a correlation coefficient for a full period and then split the correlation into sup-period regimes and compare the correlation across these sub-periods. A visual inspection also allows for the identification of the abruptness of regime changes as well as the extent of the effects of these changes over time. In line with previous findings these regime changes are shown to be large and abrupt for some countries but less so for others.

The dynamics of business cycle synchronisation are first investigated for the full sample period for all countries without imposing any regime change but rather allowing the data itself to suggest regime shifts. Figure 1 shows the average level of business cycle

[12] The incorporation of AR(1) in the conditional mean, provides qualitative similar results.

synchronisation across the 14 countries as well as the standard deviation of synchronisation across countries. For robustness, the graphs show business cycle synchronisation and the standard deviation for both the multivariate Riskmetrics and scalar-BEKK models.

[FIGURE 1 HERE]

The most distinguishing feature of the time varying business cycle synchronisation, captured by both the scalar-BEKK and the multivariate Riskmetrics models is the immediate, large and reasonably consistent move to a greater level of business cycle synchronisation from the late 1990s onwards. In addition this period is also characterised by an equally abrupt and consistent reduction in the variability of the degree of business cycle synchronisation across the EU countries. The most plausible explanation for this change is the launch of the European single currency, which was the single most important event that took place across these countries at that period. The evidence suggests that the adoption of the single currency has been endogenous in bringing about greater synchronisation in European business cycles. This is consistent with the identification of a European business cycle by Artis et al. (2004) which is shown here to have become stronger since the adoption of the single currency. In addition this finding corroborates the results of Darvas and Szapary (2005) who observe an improvement in business cycle synchronisation between new and old EU members in the post 1998 period, providing further evidence of the endogeneity of the effects of EMU.

The evidence clearly suggests that the adoption of the single currency has had an effect on business cycle synchronisation in Europe. EMU however is not the only change in international exchange rate arrangements shown to affect business cycle synchronisation in Europe during the sample period.

The predecessor to monetary union, the European Exchange Rate Mechanism (ERM) is also associated with regime changes in business cycle synchronisation. The ERM which was established in 1979 to coordinate exchange rate policy in Europe operated in two phases. The first phase from 1979 until 1985 operated with more flexibility than the later more rigid phase from 1986. The ERM was eventually to be effectively suspended following the European currency crisis of 1992/93[13].

The period of operation of the flexible version of ERM (that is until the mid 1980s) is observed to be characterised by a sizeable reduction in business cycle synchronisation and a relatively low standard deviation across the countries. Following the mid 1980s, business cycle synchronisation in Europe continues to experience a relatively low level of synchronisation but with much more volatility along with a substantial increase in the standard deviation of synchronisation across countries. This regime corresponds with the latter rigid period of ERM until its eventual suspension in 1993. The period surrounding the suspension of ERM is characterised by a peak in the standard deviation of synchronisation across countries. Later it will be shown that this is capturing a sharp reduction in synchronisation across a several countries.

These findings are consistent with those of Inklaar and de Haan (2001) who found that there is a decline in synchronisation during the period 1979-1987 with further declines for many countries during the period 1987-1997.

Overall, it is clear that the measure of business cycle synchronisation is not constant over time and in understanding business cycle synchronisation in Europe during the post 1980 period it is informative to use a time varying measure of synchronisation. So far in this paper, an average measure of synchronisation has been only presented. The analysis that follows considers the dynamics of business cycle synchronisation both across time and across countries. For convenience the remainder of the analysis will consider the multivariate Riskmetrics measure of business cycle fluctuation. This choice is motivated by the higher volatility in the scalar-BEKK measure which makes the qualitative analysis more difficult when essentially as Figure 1 demonstrates there is no qualitative difference in the outcome of the two measures[14].

5.2. EU Business Cycle Synchronisation Results by Country

Investigating the dynamics of business cycle synchronisation at the individual country level using the multivariate Riskmetrics measure reveals a dynamic much the same as the

[13] See the popular text "The Economics of European Integration" by Baldwin and Wyplosz (2006, pp.333-340) for further discussion of the operation and breakup of the ERM.
[14] Scalar-BEKK estimated are available upon request.

average business cycle synchronisation identified in Figure 1. This is the case for most of the sample countries but not for all. The plot shown in Figure 2 illustrates the level of synchronisation across 12 of the 14 sample countries over the period 1980-2009. We exclude Italy and Spain for now, as their time-varying correlation plots tell a somewhat different story from the rest of the countries (these countries' plots will be considered in Figure 3). Although it is difficult to identify individual countries from Figure 2, some clear patterns of change in the measure of synchronisation are apparent from this figure. A moderate level of synchronisation is observed across many countries during the early 1980s which is relatively stable until the later part of the decade. An abrupt change in the variability and the dispersion of the measure of synchronisation across countries occurs during the rigid period of ERM that is from the late 1980s through to the early 1990s. This change is clearly evident across countries and is rather abrupt both in its beginnings and in its conclusion. The latter part of the period (late 1990s until 2009) is characterised by a steady but substantial rise in the level of synchronisation and a corresponding decrease in dispersion in the measure across all 12 of these sample countries as shown in Figure 2.

[FIGURE 2 HERE]

As revealed in Figure 2, it is not reasonable to assume that business cycle correlations remain constant across countries over long periods of time. *Prima facie* evidence suggest that overall, regime changes do affect the synchronisation level over time. These effects are broadly identifiable from Figure 2 and country specific effects will be further identified in following diagrams. There are however two countries for which the broad patterns outlined do not fit, that is Italy and Spain, their time varying measure of synchronisation is shown in Figure 3.

[FIGURE 3 HERE]

Figure 3 illustrates that the measure of synchronisation in Italy and Spain follows a dynamic that is different to the other sample countries but similar to each other. While other countries synchronisation was declining in the late 1980s, Spain and Italy were to increase their synchronisation with the European cycle. Their synchronisation was to remain relatively high (although declining somewhat) until the later part of the sample period when the measure increases once again to a very high level of synchronisation. These countries cycles remained highly synchronised with the European cycle from the late 1990s onwards. This is perhaps a surprising result given the periphery status of these economies. In addition it indicates that any difficulties these countries may have in operating policy within the single currency are not due to a lack of synchronisation of business cycles.

5.3. EU Business Cycle Synchronisation Results Focusing on Sub-Periods

For ease of exposition and in the spirit of previous studies the remaining charts will examine the synchronisation of business cycles across countries for various sub-periods corresponding with the regimes identified thus far in the analysis. This is in the spirit of previous studies into changes in levels of business cycle synchronisation such as Papageorgiou, *et al.* (2010), Artis, *et al.* (1999) and Inklaar and De Haan (2001). This also allows further investigation into the dynamic of synchronisation across individual countries and country groups. The country groups have been split based on the observed similarities in their time-varying synchronisation plots for ease of exposition and discussion.

The sub-periods correspond not only to the stylised observations from section 5.1. but also correspond to institutional changes that have taken place at a European level. This is a key finding with regards to the effects of these institutional changes on business cycle synchronisation, which is exposed by the time-varying measures applied in this paper.

The first period considered is from 1980-1985 which corresponds to the early flexible period of ERM which operated from 1979-1985, the second sub-period considered is from 1986-1993 corresponding to the later more rigid period of the ERM until its de-facto suspension in 1993. The third period from 1994-1998 corresponds to the period of the Maastricht Treaty of 1991, while the fourth period from 1999-2007 corresponds to the launch of the single European currency. The final short period from 2008-2009 provides us with an early indication of how the current crisis has affected the level of business cycle synchronisation in Europe. For ease of exposition the sub-period graphs of the synchronisation measure are arranged into groups of countries with similar characteristics. Flexibility must be allowed for in the choice of sample periods to account for any lags in the effects of these institutional changes on business cycle synchronisation. Indeed in exploratory studies, the precise timing of a sub-period change or the inclusion or exclusion of any country from a group could be debated, the emphasis here is in outlining broad trends which require further explanation and raise questions for future studies.

The first sub-period to be considered is that from 1980-1985 as shown in Figure 4. The business cycle synchronisation measure for this period highlights the moderately high degree of synchronisation at the time and the relative stability of the measure across countries. In all cases the degree of synchronisation was positive and relatively high ranging from about 0.2 to 0.8.

[FIGURE 4 HERE]

This period of relative stability in the degree of business cycle synchronisation corresponds with the flexible period of ERM. This first period of ERM involved countries operating different inflation rates and making frequent re-alignments of their currency pegs helping to ensure macroeconomic and exchange rate stability. This more flexible version of the ERM contrasts with the later more rigid version of ERM from 1986 to 1993. Under this version of ERM there were no currency re-alignments within the system for almost 6 years until the European currency crisis of 1992/93. Rather than re-aligning currency pegs countries aimed (unsuccessfully for many) to converge their inflation rates with those of the lowest member country. At the time this was Germany, making Germany the anchor currency for the regime until its essential suspension in 1993[15].

Operating a currency in the face of cross country inflation differentials will eventually lead to a loss of international price competitiveness and macroeconomic instability for the high inflation countries. The essential suspension of the ERM in 1993 followed the UK and Italian exit from the system in 1992, as well as speculative attacks and devaluations in the currencies of several other member countries.

A major cause of the breakup of ERM was the tight monetary policy of Germany, imposed in the face of rising domestic inflation following reunification with the former East Germany. Other member countries who did not wish to experience depreciation against the Deutsch Mark were forced to follow this tight German monetary policy, but for many this was a monetary contraction in already weak economies. Difficulties at the time would have been

[15] The ERM continued to operate post 1993 but with bands of fluctuation increased from ±2.25% to ±15% this represented an effective suspension.

exacerbated by the fact that business cycles were becoming less synchronised during this period as is captured in the measure of synchronisation estimated here. Overall, the business cycle synchronisation was low and relatively volatile during this period. Additionally, several countries were to experience a substantial decline in their synchronisation with the European-wide business cycle. The fall off in the level of synchronisation and the increase in divergence across countries peaked around 1993, co-incident with the suspension of the narrow bands of ERM and the advent of closer policy co-ordination ushered in soon after with the Maastricht Treaty. This is shown in Figure 5.

[FIGURE 5 HERE]

Figure 5 shows the evolution of the measure of business cycle synchronisation during the period 1986-1993. The countries have been split into four groups. The first panel shows the synchronisation measure for the ERM anchor currency Germany, along with its close neighbours Austria and the Netherlands. During this rigid period of ERM synchronisation remains reasonable stable and high in both Austria and Germany reflecting Germany's role as the anchor currency in ERM. Tellingly it is not until after the suspension of ERM that the measure of synchronisation declines in both these countries which reaches ebb of below 0.5 for both by the mid 1990s. However for the Netherlands, viewed by the markets as "just another German Lander" Eichengreen (2000), the measure of business cycle synchronisation was to decline markedly during this period.

Along with the Netherlands, other long term ERM member countries were to experience sizeable reductions in their measure of cyclical synchronisation during this period. This included Belgium, Denmark, France and Ireland shown in Panel B of Figure 5. Unlike the Netherlands, these countries were either forced to devalue within the ERM or were to see speculative attacks on their currency. Another long term member of the ERM to suffer speculative attack and to be eventually driven from the ERM was Italy. However Italy maintained a high level of business cycle synchronisation during this period.

Indeed countries that joined ERM late in its operation, Spain (1989), UK (1990) and Portugal (1992) are shown to have increasing business cycle synchronisation (see, Panel C). Despite this all these countries were forced to devalue during the European currency crisis of

1992/1993. The countries shown in Panel D of Figure 5, who were never members of ERM, show no discernable pattern in the evolution of their business cycle synchronisation.

Overall during this rigid period of ERM there is no evidence of an ERM effect nor is there any evidence of a core periphery divide between the countries, nor is there evidence that the currencies to experience speculative attack and devaluation were any less synchronised than others. The findings are consistent with those of Dickerson et al. (1998) who find no evidence of an ERM effect on the correspondence of European business cycles using data from 1960-1993.

In the years following the blow up of the ERM institutional changes resulting in more policy co-ordination were more conducive to increasing cyclical synchronisation in Europe. The blow up of the ERM was not the only major institutional change taking place in Europe during the early 1990s. Despite Denmark's failure to ratify the Maastricht Treaty in 1992, shaking confidence in Europe's ability to proceed with Currency Union, The Maastricht Treaty was to eventually pave the way for increased convergence on the path to eventual EMU in 1999. The Maastricht Treaty and the subsequent Stability and Growth Pact did promote a convergence in inflation rates, interest rates and fiscal policy in the run up to EMU. For an example of the effects of Maastricht on the convergence of fiscal policy outcomes see Considine and Duffy (2006). Cyclical synchronisation, although low was to remain stable during this period as shown in Figure 6.

[FIGURE 6 HERE]

That synchronisation did not increase during this period is perhaps surprising but may have been due to settling in effects of the convergences in fiscal policy, interest rates and inflation rates. Some core European countries (e.g. Netherlands and Belgium) were to exhibit negative, although low, synchronisation during this period. It was however not until the late 1990s with the advent of EMU that the most dramatic increase in cyclical synchronisation and convergence in the level of synchronisation across countries took place (see Figure 7).

[FIGURE 7 HERE]

The image captured in Figure 7 Panel A clearly emphasises the relatively steady and consistent move towards greater business cycle synchronisation across most of the sample countries following the adoption of the single currency. Also evident is the relatively steady and consistent reduction in the dispersion of the correlation coefficient across countries. The range of the synchronisation measure decreases from -0.1–0.51 in 1999 to 0.43-0.8 in 2007. This contrasts substantially with the experience of earlier periods and the process of convergence continues up until the beginning of the current economic crisis in 2007. In adition the experience of increasing synchronisation is enjoyed by both EMU and non-EMU members alike. Panel B of Figure 7 shows the experience of 3 EMU countries, Spain, Italy and Greece who although experiencing relatively high levels of cyclical synchronisation were to experience a delince in their synchronisation during this period, a signal that does perhaps not bode well for these countries in the single currency.

Since the beginnings of the crisis in 2007 the process of convergence in the measure of synchronisation to a high level has drawn to a halt. The effects of the economic crisis are best shown by focusing in on the later part of the sample period as shown in Figure 8.

[FIGURE 8 HERE]

Figure 8 shows the effect of the economic crisis on the measure of synchronisation across all sample countries. Panel A shows those countries for whom the convergence in the measure of synchronisation halts in its move towards convergence at a high level. In several countries this is not a surprising result as the measure of cyclical synchronisation has stopped increasing having reached high levels, but for other countries the halt in the move towards increasing synchronisation is at levels somewhat lower. Of potentially greater concern for the operation of the single currency is the move to lower levels of synchronisation in the countries shown in Panel B. This includes in Belgium, Ireland and the Netherlands. The UK and Sweden although not EMU members also reverse the process of increasing business cycle synchronisation. This suggests that for the countries in Panel B the effects of the economic crissis are somewhat asymmetric to the European business cycle and have prompted a move towards desynchronisation. Although this is not favourable for the operation of the single currency area the measure of synchronisation thus far still remains high.

6. Concluding Remarks

This paper has contributed to existing literature through the application of two quantitative methods to examine the evolution of business cycle synchronisation in Europe. In addition, for robustness purposes, two filtering methods have been applied to extract the cyclical component of GDP from the data. The results produced in this paper show that there have been important regime changes in European business cycle synchronisation over the sample period. Importantly, these regime changes, as depicted from the time-varying measures, correspond to institutional changes that have taken place at a European level. In addition, the current study has produced some findings which have not been reported by the literature yet. In particular, these findings can be summarised as a reduction in synchronisation during the latter ERM period and the reduction of synchronisation since the 2008 financial crisis. This study, though, agrees with some of the past findings as it also provides evidence of the consistently higher levels of synchronisation during the period of the monetary union.

That monetary union has been effective in increasing business cycle synchronisation in Europe and that ERM failed to do so is an important finding. In addition the increasing synchronisation during the EMU period is evidenced in both EMU and non-EMU countries. This suggests that EMU has promoted a more prevalent European business cycle which influences both EMU member and non-member countries alike. Overall, the dynamics of the measure of business cycle synchronisation have moved in a direction conducive to the operation of the single currency and a common monetary policy. As business cycles have become more correlated, a common monetary policy seems to be less costly in terms of lost flexibility at the national level. The results are supportive of Trichet's (2001) argument who suggested that business cycles are becoming more synchronised across Europe.

The recent data available to this study has also allowed for an examination of the effects of the current economic crisis on synchronisation. Although the crisis has disturbed the process of increasing synchronisation there is no evidence of a substantial reduction in synchronisation thus far. The reduction in synchronisation evidenced as a result of the crisis is much less in magnitude than that evidenced in the run up to the currency crisis of the early 1990s. This is an important finding as any questions regarding the optimality and sustainability of the common currency area, particularly in the presence of the current crisis, are not due to a lack of cyclical synchronisation. Hence, this should not need to be a primary concern for common monetary and national policy makers.

The qualitative analysis conducted here indicates that the time varying measure of business cycle synchronisation tells a tale of business cycle synchronisation that is influenced by changes in instutions promoting greater policy co-ordination in Europe. Further study could model and explain the time-varying effects of the endogenous or exogenous determinants of business cycle synchronisation, including determinants such as, economic, institutional and policy coordination.

Acknowledgements

Dr. Stavros Degiannakis acknowledges the support from the European Community's Seventh Framework Programme (FP7-PEOPLE-2010-RG) funded under grant agreement no. PERG08-GA-2010-276904. The views expressed are those of the authors and should not be interpreted as those of their respective institutions. The authors are solely responsible for any remaining errors and deficiencies.

References

Alesina, A. and Barro, R.J. (2002) Currency unions, *Quarterly Journal of Economics*, **117**, 409–36.

Artis, M., Krolzig, H.M. and Toro, J. (2004) The European business cycle, *Oxford Economic Papers*, **56,** 1-44.

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

Azevedo, J.V. (2002) Business cycles: cyclical comovement within the European Union in the period 1960-1999: a frequency domain approach, Banco de Portugal Working Paper, No. 5-02.

Baba, Y., Engle, R.F., Kraft, D. and Kroner, K.F. (1990) Multivariate simultaneous generalized ARCH. Department of Economics, University of California, San Diego, Mimeo.

Baxter, M. and King, R.G. (1999) Measuring business cycles: Approximate band-pass filters for economic time series, *The Review of Economics and Statistics*, **81**, 575-93.

Bergman, U.M. (2006) Are European business cycles converging?, available at http://web.econ.ku.dk/okombe/BusinessNew.pdf.

Bergman, U.M. and Jonung, L. (2010) Business cycle synchronization in Europe: Evidence from the Scandinavian Currency Union, European Commission, Economic Papers 402.

Böwer, U. and Guillemineau, C. (2006) Determinants of business cycle synchronisation across Euro area countries, ECB Working paper series No. 587.

Burns, A.F. and Mitchell, W.C. (1946) *Measuring Business Cycles*, New York, NBER.

Canova, F., Ciccarelli, M. and Ortega, E. (2009) Do institutional changes affect business cycles? Evidence from Europe, BANCO DE ESPAÑA, Documentos de Trabajo, No 0921.

Christiano, L. and Fitzgerald, T.J. (2003) The bandpass filter, *International Economic Review*, **44,** 435-65.

Clarida, R., Gali, J. and Gertler, M. (1999) The science of monetary policy: A New Keynesian perspective, *Journal of Economic Literature*, **37,** 1661–707.

Concaria, L.A. and Soares, M.J. (2009) Business cycle synchronization across the Euro area: A wavelet analysis, NIPE working papers 8/2009.

Considine, J. and Duffy, D. (2006) Partially sighted persons and the public debt elephant, *Constitutional Political Economy,* **17**, 237-49.

Croux, C., Forni, M. and Reichlin, L. (2001) A measure for comovement of economic variables: theory and empirics, *Review of Economics and Statistics*, **83**, 232-241.

Crowley, P.M. and Schultz, A. (2010) Measuring the intermittent synchronicity of macroeconomic growth in Europe, American Consortium on European Union Studies (ACES), Working Paper No. 2010.1.

Dickerson, A.P., Gibson, H.D. and Tsakalatos, E. (1998) Business cycle correspondence in the European Union, *Empirica*, **25,** 51–77.

Döpke, J. (1999) Stylised facts of Euroland's business cycle, *Jahrbücher für National Ökonomie und Statistik*, **219**, 591-610.

Eichengreen, B. (2000) The EMS in retrospect, National Bureau of Economic Research working paper 8035.

Engle, R.F. (2002) Dynamic Conditional Correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models, *Journal of Business and Economic Statistics*, **20**, 339–350.

Engle, R.F. and Kroner, K.F. (1995) Multivariate simultaneous generalized ARCH. *Econometric Theory*, **11**, 122-150.

Fatas, A. (1997) EMU: countries or regions? Lessons from the EMS experience, *European Economic Review*, **41**, 743-51.

Ferreira-Lopes, A. and Pina, A. (2009) Business cycles, core and periphery in monetary unions: Comparing Europe and North America, *Open Economies Review*, forthcoming.

Fidrmuc, J. (2004) The endogeneity of the optimum currency area criteria, intra-industry trade, and EMU enlargement, *Contemporary Economic Policy*, **22**, 1–12.

Fidrmuc, J. and Korhinen, I. (2006) Meta-analysis of the business cycle correlation between the euro area and the CEECs, *Journal of Comparative Economics*, **34**, 518–37.

Frankel, J.A. and Rose, A.K. (1998) The endogeneity of the optimum currency area criteria, *Economic Journal*, **108**, 1009–25.

Furceri, D. (2005) Is an increase of the fiscal budget at EMU level desirable?, in P. Arestis, J. Ferreiro, and F. Serrano (Eds) *Financial Development in National and International Markets*, Palgrave Macmillan, London.

Furceri, D. and Karras, G. (2008) Business-cycle synchronization in the EMU, *Applied Economics*, **40**, 1491-501.

Gali, J. and Perotti, R. (2003) Fiscal policy and monetary integration in Europe, *Economic Policy*, **18**, 533–72.

Gogas, P. And Kothroulas, G. (2009) Two speed Europe and business cycle synchronization in the European Union: The effect of the common currency, MPRA Paper No. 13909.

de Haan, J., Jacobs, J., and Mink, M. (2007) Measuring synchronicity and co-movement of business cycles with an application to the Euro area, CESifo Working Paper Series with No. 2112.

de Haan, J., Inklaar, R. and Jong-a Pin, R. (2008) Will business cycles in the euro area converge? A critical survey of empirical research, *Journal of Economic Surveys*, **22**, 234-73.

Hodrick, R. and Prescott, E. (1997) Postwar U.S. business cycles: An empirical investigation, *Journal of Money, Credit and Banking,* **29**, 1-16.

Hughes Hallett, A. and Richter, C. (2008) Have the Eurozone economies converged on a common European cycle?, *International Economics and Economic Policy*, **5**, 71-101.

Inklaar, R. and de Haan, J. (2001) Is there really a European business cycle? A comment, *Oxford Economic Papers*, **53**, 215-220.

Inklaar, R., Jong-a Pin, R. and de Haan, J. (2008) Trade and business cycle synchronization in OECD countries - A re-examination, *European Economic Review*, **52**, 646-66.

J.P. Morgan (1996) Riskmetrics technical document, 4th edition, J.P. Morgan: New York.

Kenen, P.B. (1969) The optimum currency area: An eclectic view, in R.A. Mundell and A. Swoboda (Eds) *Monetary Problems of the International Economy*, University of Chicago Press, Chicago.

Kuznets, S. (1958) Long swings in the growth of population and in related economic variables. *Proceedings of the American Philosophical Society,* **102**, 25-57.

Laurent, S. (2007) Estimating and Forecasting ARCH Models Using G@RCH *5*. London: Timberlake Consultants Press.

López-Córdova, J.E. and Meissner, C. (2003) Exchange rate regimes and international trade: Evidence from the classical gold standard era, *American Economic Review*, **93**, 344-53.

Maurel, M. (2002) On the way of EMU enlargement towards CEECs: What is the appropriate exchange rate regime?, Discussion paper No. 3409. CEPR.

McKinnon, R. (1963) Optimum currency areas, *American Economic Review*, **53**, 717–25.

Mitchell, W. (1946) *Business Cycles: The problem and its setting*, New York, USA.

Mundell, R.A. (1961) A theory of optimum currency areas, *American Economic Review*, **51,** 657–65.

Papageorgiou, T., Michaelides, G. and Milios, J.G. (2010) Business cycles synchronization and clustering in Europe (1960–2009), *Journal of Economics and Business*, **62**, 419–70.

Rogoff, K. (1985) The optimal degree of commitment to intermediate monetary target, *Quarterly Journal of Economics*, **100**, 1169–190.

Rose, A. and Engel, C. (2002) Currency unions and international integration, *Journal of Money, Credit and Banking*, **34**, 1067-89.

Rose, A. and Stanley, T.D. (2005) A Meta-analysis of the effect of common currencies on international trade, *Journal of Economic Surveys*, **19**, 347-65.

Savva, C.S, Neanidis, K.C. and Osborn, D.R. (2010) Business cycle synchronisation of the Euro area with the new and negotiating member countries, *International Journal of Finance and Economics*, **15**, 288–306.

Sebastien, W. (2009) Business cycle synchronicity, amplitude and the euro: one size does not yet fit all, MPRA Working Paper 21065.

Trichet, J. C. (2001) The Euro after two years, *Journal of Common Market Studies*, **39(1)**, 1-13.

Van der Weide, R. (2002) GO-GARCH: A multivariate generalised orthogonal GARCH model, *Journal of Applied Econometrics*, **17**, 549-564.

Xekalaki, E. and Degiannakis, S. (2010) ARCH models for financial applications. New York: Wiley.

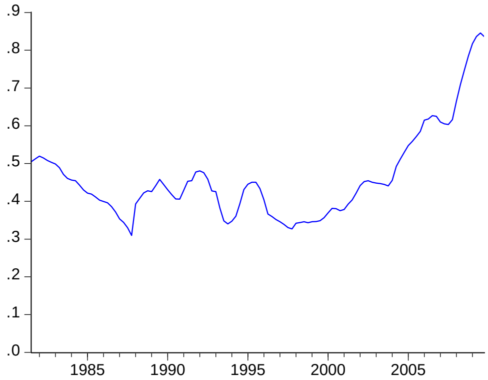
Figures

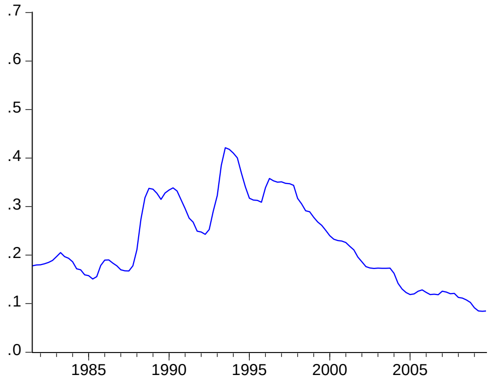
Figure 1: Mean synchronisation and standard deviation of synchronisation. Period 1980-2009.

Multivariate Riskmetrics

Mean synchronisation, $\overline{\rho}_t = 14^{-1}\sum_{i=1}^{14}\rho_{i,15,t}$.

Standard deviation of synchronisation, $\sqrt{13^{-1}\sum_{i=1}^{14}\left(\rho_{i,15,t}-\overline{\rho}_t\right)^2}$.

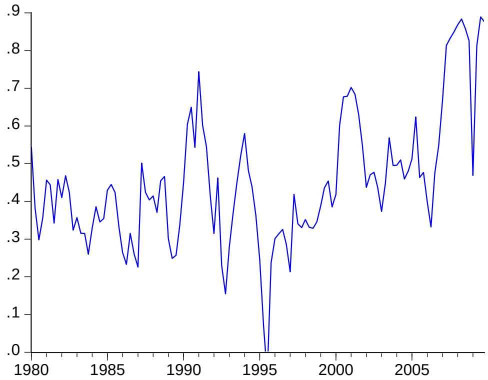




Scalar - BEKK

Mean synchronisation, $\overline{\rho}_t = 14^{-1}\sum_{i=1}^{14}\rho_{i,15,t}$.

Standard deviation of synchronisation, $\sqrt{13^{-1}\sum_{i=1}^{14}\left(\rho_{i,15,t}-\overline{\rho}_t\right)^2}$.



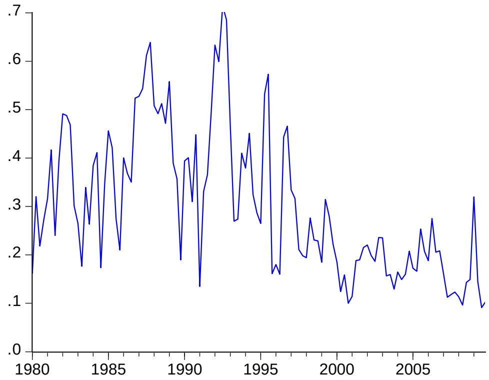
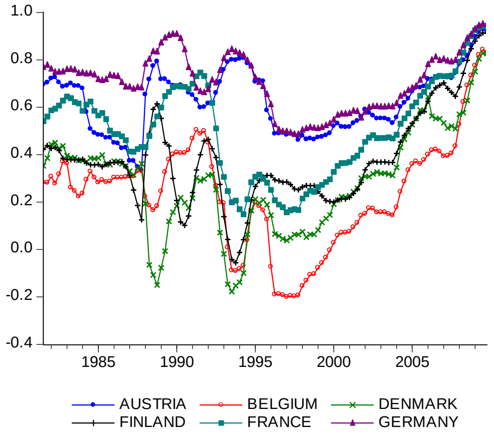
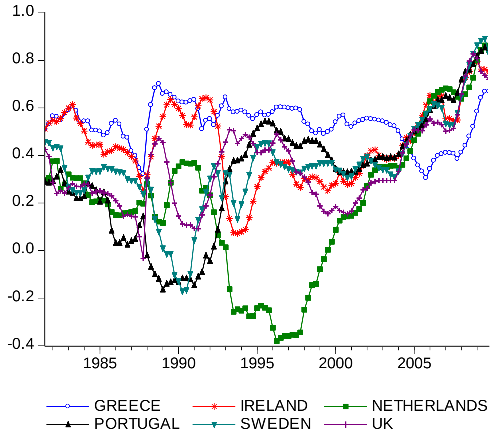


Figure 2: The time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...12, for 12 EU countries. Period 1980-2009.





Note: The sample countries Italy and Spain are excluded from this image.

Figure 3: The time varying synchronisation, $\rho_{i,15,t}$, for i=13,14 for Italy and Spain. Period 1980-2009.

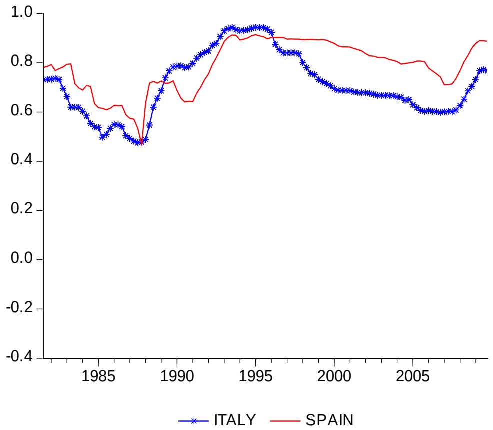


Figure 4: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1980-1985.

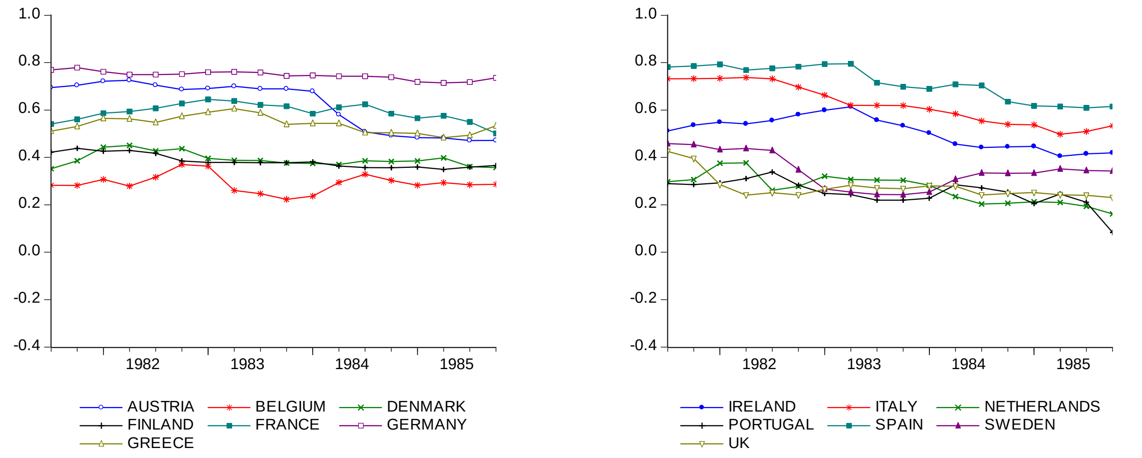
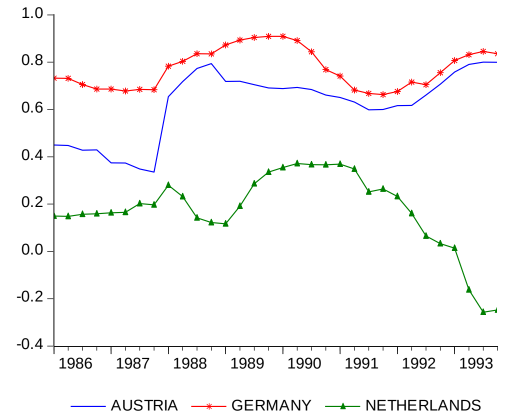
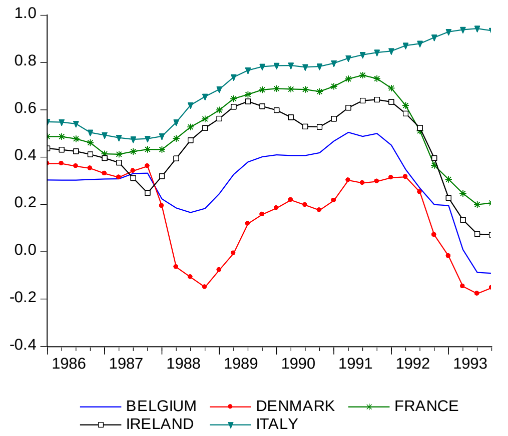


Figure 5: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1986-1993.

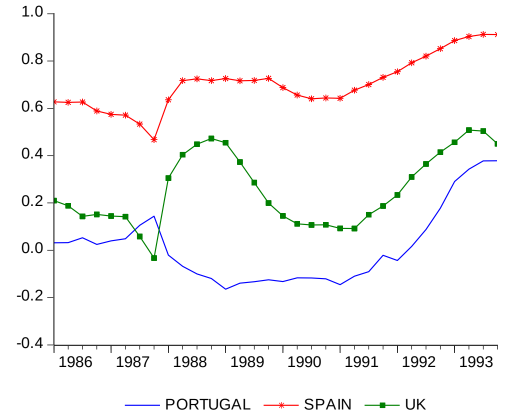
Panel A



Panel B



Panel C



Panel D

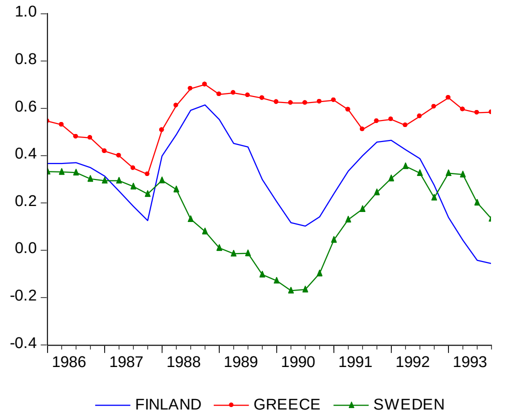


Figure 6: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1994-1998.

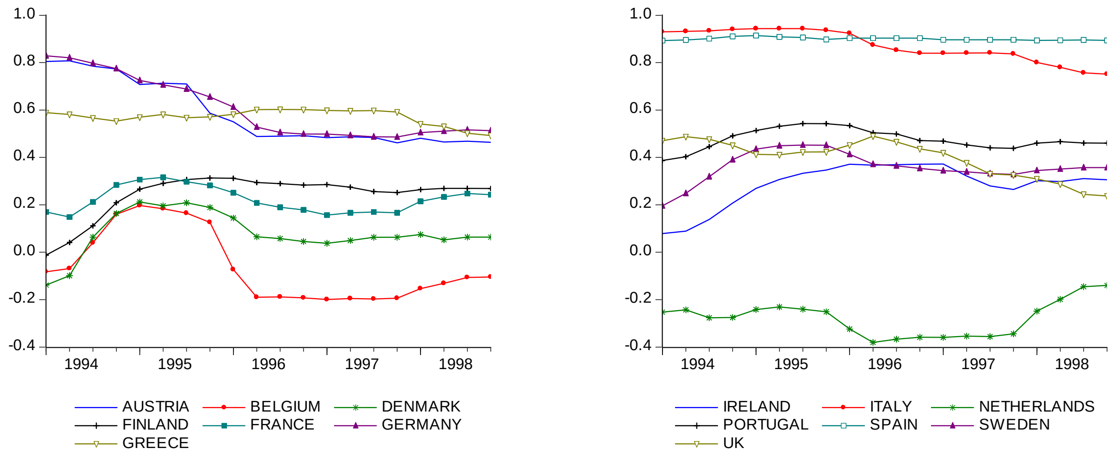


Figure 7: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1999-2007.

Panel A	Panel B

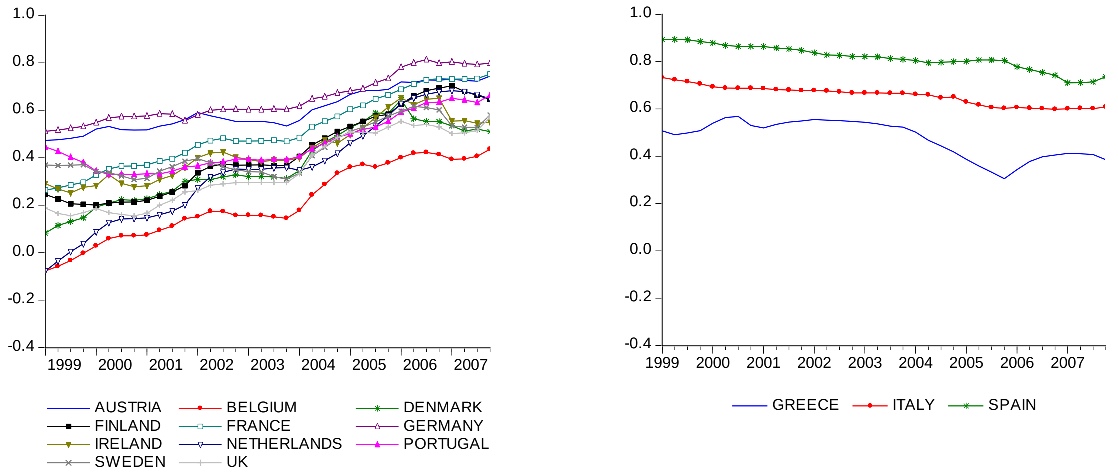


Figure 8: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 2008-2009.

Panel A	Panel B