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Degiannakis, Stavros and Duffy, David and Filis, George

Department of Statistics, Athens University of Economics and Business, Economic Research Department, Bank of Greece, Department of Economics, University of Portsmouth, Department of Accounting, Finance and Economics, Bournemouth University

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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 Economics, University of Portsmouth,
Portsmouth Business School, Portsmouth, Portland Street, PO1 3DE, United Kingdom.

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

Abstract

This 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 1980-2012. The paper provides evidence that changes in the business cycle synchronisation correspond to major economic events that have taken place at a European level. In the main, business cycle synchronisation until 2007 had moved in a direction positive for the operation of a single currency, suggesting that the common monetary policy was less costly in terms of lost flexibility at the national level. However, as a result of the Great Recession of 2007 and the subsequent Eurozone Crisis a number of periphery countries, most notably Greece, have experienced desynchronisation of their business cycles with the EU12-wide cycle. Nevertheless, for most countries, any questions regarding the optimality and sustainability of the common currency area in Europe should not be attributed to a lack of cyclical synchronisation.

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

JEL: C32, E32, F44, 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 2012. 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 the 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 include, *inter alia*, Mitchell (1946), Burns and Mitchell (1946) and Kuznets (1958). Since then, a significant amount of literature has been produced on 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.

[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).

To start with, a static correlation figure is not able to capture any fluctuations of the correlation level across time. In addition, the 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 proposed techniques do not suffer from such drawbacks.

The present study directly addresses all the above issues by employing two robust quantitative techniques, namely the Scalar-BEKK and multivariate Riskmetrics models, as were suggested by Baba, Engle, Kraft and Kroner (1990) and J.P. Morgan (1996), respectively. To our knowledge, these techniques have not previously been applied 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 more 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 the EU and to limit the shortcomings of the methods that have been used thus far. Second, we use two filtering methods for robustness purposes showing qualitatively similar results. Third, the results from the time-varying measures show that changes in the level of correlation correspond to major economic events that have taken place at a European level. In addition, following the economic crisis of 2007 (the terms economic crisis and Great Recession will be used interchangeably), a change in the dynamics of European business cycle synchronisation have emerged. This has important policy implications for the operation of macroeconomic policy in a common currency area and contributes to the long standing debate regarding the optimality of a common currency.

[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.

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.

2. Review of the Literature

This paper examines time varying business cycle synchronisation in a common currency area. 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 adoption of a common monetary policy which 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 business cycle synchronisation. Consequently, if 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 may result in the destabilization of the individual economies. As such it will be a case of a "one size fits none" common monetary policy, which will aggravate the cost of joining 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

[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.

synchronised business cycles exist, it will be easier for the central bank to impose its stabilising interventions (Crowley and Schultz, 2010; Furceri and Karras, 2008; Clarida, Gali and Getler, 1999; Rogoff, 1985).

Apart from the fact that business cycle synchronisation impacts on the central bank and its monetary policy decisions; the level of synchronisation has also implications for the fiscal policy of each member-country. If the monetary policy response from the central bank to an asymmetric shock is not suitable for every member-country, then members will be able to use their independent fiscal policy in a stabilising manner (Crowley and Schultz, 2010). The problem that European countries face, in the presence of the Stability and Growth Pact and the subsequent Fiscal Compact, is that the use of fiscal policy, as a protection against the potential adverse effects of common monetary policy, may become 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), Babetskii (2005), 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 greater 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 Exchange Rate Mechanism (ERM) period and the Maastricht Treaty period (Weyerstrass, van Aarle, Kappler and

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

Seymen, 2011; Altavilla, 2004; Belo, 2001; Fatas, 1997; Angeloni and Dedola, 1999). Other authors have argued that synchronisation has increased further in the post EMU period (see, for example, Darvas and Szapary, 2008; Gayer, 2007). Yet, Lehwald (2012) recently argued that this only holds for the core EMU member countries.

On the other hand, there are some studies, which demonstrate that there is a decrease in business cycle synchronisation after the adoption of the Euro. Specifically, Hughes-Hallett and Richter (2008) suggest that since the introduction of the common currency the level of synchronisation has declined for the core European countries. Similarly, Crespo-Cuaresma and Fernandez-Amador (2013) corroborates Hughes-Hallett and Richter's (2008) results suggesting that since the birth of the common currency divergence is observed in the European member-countries business cycles. Lee (2012a,b) reports similar results, as both studies show evidence that the level of synchronisation for the European countries was higher in the pre-EMU period.

Given the literature reviewed, there is an implicit expectation that changes in European business cycles synchronisation levels are influenced by institutional changes. However, a recent study by Canova, Ciccarelli and Ortega (2012) provides evidence that changes in European business cycle synchronisation cannot be attributed to institutional changes. Although, they claim that the evidence is less clear cut for the effects of the Maastricht Treaty, leading them to argue that conclusions suggesting that business cycle synchronisation are not influenced by institutional changes should be treated with caution.

In addition to studies focusing on business cycle synchronisation during the periods before and after EMU, a recent strand of the literature examines the effects of the latest financial crisis on synchronisation levels. Indicatively, Gächter, Riedl and Ritzberger-Grunwald (2012) find that the 2007 financial crisis led to a desynchronisation of business cycles in the Euro Area, as well as, an increase in the dispersion of synchronisation levels. In addition, Gomez, Ortega and Torgler (2012) report that Greece is experiencing a significant reduction in synchronisation level since the Great Recession.

Much of the previous literature suggests that synchronisation changes over time. However, only few recent studies examined synchronisation in a time-varying environment (see, for example, Fidrmuc, Ikeda and Iwatsubo 2012; Rozmahel, 2011; Savva, *et al*., 2010; Fidrmuc and Korhonen, 2009). Fidrmuc, *et al*. (2012) and Fidrmuc and Korhonen (2009) develop a frequency-domain dynamic correlation model. Rozmahel (2011), on the other hand, identifies changes in business cycle synchronisation in time-domain, using rolling windows. Despite the fact that this method has been used extensively in the literature, the frameworks applied in the present paper have several advantages over rolling windows. These advantages include (i) that there is no requirement for the researcher either to set a window span or to lose some observations at the start of the sample period and (ii) that they do not exhibit the so called "ghost features", as the impact of a shock may not be reflected in *n* consecutive periods (where *n* denotes the window span)[10].

Savva, *et al.* (2010) is the only study to our knowledge to apply a pure dynamic correlation model in time-domain, similar to our study. Savva, *et al.*, (2010) use a regime-switch time-varying correlation (DSTCC-VAR-GARCH) between the EU member-countries and the EU-wide business cycles. Regime-switch models determine a priori the number of regime switches. In our paper, however, regime changes are not imposed a priori by the researchers, but rather they are exposed by the data. Allowing the data to identify regime shifts is useful in the context of EU business cycle synchronisation given the conflicting evidence that has emerged regarding European business cycle synchronisation over time. Additionally with a business cycle synchronisation measure that varies over time it is possible to assess the effects of the recent economic crisis and the subsequent European debt 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 2012:Q4. All GDP prices are converted to 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.

Furthermore, very few studies examine the robustness of their results using different filtering methods for their cyclical components. For illustration purposes and the analysis of

[10] For an additional explanation of the advantages of a time-varying framework over rolling windows see Cerqueira and Martins (2009).

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[11].

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:

$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_x \times \sigma_y} \quad (1)$$

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 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.

In short, sections 4.1 and 4.2 provide a detailed explanation of both frameworks which will be used to estimate how the correlation level between the individual business cycles of 14 EU countries and the aggregate EMU12 business cycle varies over time. These time-varying correlation levels are shown in Figures 1 to 7 and they are analysed in section 5.

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

4.1. Scalar-BEKK

The focus is on the investigation of time-varying correlation between the individual business cycles of 14 EU countries and the aggregate EMU12 business 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 the 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 $\mathbf{y}_t = \begin{pmatrix} y_{1,t} & y_{2,t} & \dots & y_{14,t} & y_{15,t} \end{pmatrix}'$, where $y_{i,t}$, for i=1,2,...,14, denotes the individual business cycles for each of the 14 EU countries and $y_{15,t}$ denotes the aggregate EMU12 business cycle[12]. 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 $V_{t-1}(\mathbf{y}_t) \equiv \mathbf{H}_t$:

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

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

[12] For robustness purposes, as well as calculating the correlation between each country's business cycle and the EMU12 wide cycle, the correlation between each country's business cycle and the EMU12 cycle with the respective countries GDP removed from the EMU12 aggregate, has been calculated. The results are qualitatively similar and they are available upon request.

than the BEKK model, i.e. $\left(n(n+1)/2\right)+2$ 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 $\left(n(n+1)/2\right)$ 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[13]:

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

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

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

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

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

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

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

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:

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

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[14]:

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

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

$$\left(z_{1,t} \quad z_{2,t} \quad . \quad . \quad . \quad z_{15,t}\right)' \sim N(\mathbf{0},\mathbf{I}) \qquad (6)$$

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

5. Empirical Results

5.1. Overall EU Business Cycle Synchronisation Results

The time varying expression of the correlation coefficient in eq.(1) of the i^{th} country's business cycles and the aggregate EMU12 business cycle is estimated as:

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

$$\rho_{i,15,t} = \frac{\sigma_{i,15,t}}{\sqrt{\sigma_{i,t}^2 \sigma_{15,t}^2}}, \tag{7}$$

where $\sigma_{i,t}^2$ is the i^{th} diagonal element of $\mathbf{H}_t$, and $\sigma_{i,15,t}$ is the i^{th} non-diagonal element in the 15th (last) column of $\mathbf{H}_t$.

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 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 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 most clearly in the multivariate Riskmetrics model but also apparent in the Scalar-BEKK model, is the immediate, large and reasonably consistent move to a greater level of business cycle synchronisation for all countries from the late 1990s until the beginning of 2007 economic crisis. Similar findings have been reported by Lehwald (2012). 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. This change coincides with the launch of the European single currency, which was the single most important economic event that took place across these countries at this time. 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 (2008) 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 latter part of our sample period, which covers the period of the Great Recession and the European sovereign debt crisis (or Eurozone crisis), indicates that there has been a break in this pattern of increasing synchronisation accompanied by an increase in the variability of synchronisation levels across countries. The evidence suggests that the adoption of the single currency has had an effect on business cycle synchronisation in Europe which has been upset by the latest economic crisis. Additionally, other changes in international exchange rate and monetary regimes during the sample period also accompany changes in European business cycle synchronisation and its variability across countries.

The predecessor to monetary union, the 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[15].

The periods of operation of both the flexible and the rigid version of ERM are characterised by a reasonably continuous and sizeable reduction in business cycle synchronisation, which is particularly evident in the period 1986-1993. 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. The results here show on average that this decline occurred in a relatively continuous manner until 1998. The most noticeable change in business cycle synchronisation between the flexible and rigid ERM regimes is the increase in the standard deviation of synchronisation levels across countries during the latter regime (i.e. during 1986-1993). Indeed the period surrounding the suspension of ERM is characterised by a peak in the standard deviation of synchronisation across countries.

[15] 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.

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, only an average measure of synchronisation has been 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 analysis more difficult when essentially as Figure 1 demonstrates there is no qualitative difference in the outcome of the two measures[16].

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 average business cycle synchronisation identified in Figure 1. This is the case for most of the sample countries but not for all. The plots shown in Figure 2 illustrate the level of synchronisation across the 14 sample countries over the period 1980-2012. Some clear patterns of change in the measure of synchronisation are apparent from this figure. A moderate to high level of synchronisation is observed across all countries during the early 1980s, which then declines until the later part of that decade. An abrupt change in the variability and the dispersion of the measure of synchronisation across countries occurs from the late 1980s through to the early 1990s, which coincides with the rigid period of ERM. This change is clearly evident across countries and is rather immediate. The period from the late 1990s until the Great Recession and the subsequent Eurozone crisis is characterised by a steady but substantial rise in the level of synchronisation for all countries which reaches a plateau from 2007 onwards. In correspondence with this rise in synchronisation across countries there is a decrease in the dispersion of synchronisation across the sample countries. The notable exception to this pattern in the post-2007 period is mainly Greece, as well as, Portugal which experience a substantial fall in their

[16] Scalar-BEKK estimates are available upon request.

synchronisation levels. In addition, it is observed that the non-EMU countries also exhibit a decrease in their synchronisation levels.

[FIGURE 2 HERE]

As revealed in Figure 2, it is not reasonable to assume that business cycle correlations remain constant across individual countries over long periods of time. *Prima facie* evidence suggests that overall, certain economic events (such as, the Euro introduction, the Great Recession and the Eurozone crisis, among others) 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.

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

For ease of exposition and in the spirit of previous studies the remaining figures will examine the synchronisation of business cycles across countries for various sub-periods corresponding to the principal changes in the synchronisation patterns 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. Flexibility must be allowed for in the choice of sample periods to accommodate changes in patterns that emerge over time. 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 on outlining broad trends which require further explanation and raise questions for future studies.

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 period from 2008-2012 provides us with evidence of how the 2007 economic crisis and the European sovereign debt 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.

The first sub-period to be considered is that from 1980-1985 as shown in Figure 3. 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 0.3 to just over 0.8.

[FIGURE 3 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 more rigid 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[17].

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. Overall, the business cycle

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

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. These patterns of synchronisation could be driven by the symmetry of policy response required by the ERM regime in countries with different inflation rates. The fall in the level of synchronisation and the increase in divergence across countries peaked around 1993. This was the time of the suspension of the policy constraining narrow bands of ERM. This is shown in Figure 4.

[FIGURE 4 HERE]

Figure 4 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 reasonably 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 an ebb of below 0.6 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 4. 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 4 were not members of ERM and they show no discernible pattern in the evolution of their business cycle synchronisation.

Overall during this rigid period of ERM there is no evidence 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.

In the years following the blow up of the ERM, institutional changes associated with the Maastricht Treaty resulted in the closer co-ordination of policy outcomes in inflation, nominal interest rates, budget deficits and public debt levels. 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 was to begin to increase in many countries during this period, whereas a decrease is also observed in others, as shown in Figure 5, panels A and B respectively.

[FIGURE 5 HERE]

The fact that synchronisation did not increase during this period for all countries is perhaps due to settling in effects of the convergences in fiscal policy, interest rates and inflation rates. Indeed the countries that experienced declining synchronisation during this period were periphery countries such as Ireland, Greece and Italy or countries that never became EMU members such as the UK and Sweden. Additionally, some core European countries (e.g. Netherlands and Belgium) were to begin this period with very low levels of synchronisation.

It was not however 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 6).

[FIGURE 6 HERE]

Panels A and B in Figure 6 clearly demonstrate the relatively steady and consistent move towards greater business cycle synchronisation across all of the sample countries following the adoption of the single currency. The relatively steady and consistent reduction in the dispersion of the correlation coefficient across countries is also evident. The range of the synchronisation measure decreases from (-0.2 , 0.8) in 1999 to (0.7 , 0.9) in 2007. The process of higher synchronisation continues until the beginning of the economic crisis in

2007. In addition, the experience of increasing synchronisation is enjoyed by both EMU and non-EMU members alike.

By the beginnings of the economic crisis in 2007 the process of higher synchronisation has drawn to a halt for a number of countries (see Panel A of Figure 7). This may be expected as at this stage the level of synchronisation is very high across these countries. However, as Panel B shows, synchronisation levels begin to decline for countries that have been impacted most adversly by the economic crisis, such as Greece, Portugal, Ireland and Spain, but also for the non-EMU countries of the UK and Sweden. The decline in the level of synchronisation is even more evident after the initiation of the European sovereign debt crisis in 2009. Most notably, Greece, the country worst effected by the current crisis, has experienced a huge decrease in its level of synchronisation bringing it close to zero.

[FIGURE 7 HERE]

The move to lower levels of synchronisation in the countries shown in Panel B could potentially constitute a great concern for the operation of the single currency. This suggests that for the countries in Panel B, and especially Greece, the effects of the economic crisis are somewhat asymmetric to the European business cycle and have prompted a move towards desynchronisation. The recent experience of Greece illustrates the effects of an asymmetric shock on business cycle synchronisation within a monetary union. The effects are potentially excerbated due to the symmetry of the Eurozone monetary policy response. Despite this fall in synchronisation in some countries, which is certainly not favourable for the operation of the single currency area, the measure of synchronisation thus far still remains high for most cases.

It is worth noting here that the experience of desynchronisation is not as great or as widespread across countries as that experienced during the 1986-1993 period. This ought to be an encouraging findings for the Eurozone, as a whole, but less encouraging for Greece.

6. Concluding Remarks

This paper has contributed to the 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 changes in European business cycle synchronisation across time. These changes, as depicted from the time-varying measures, seem to correspond to major economic events that have taken place at a European level. In addition, the current study has produced some findings which have not yet been reported by the literature. In particular, these findings can be summarised as a reduction in synchronisation during the latter ERM period and the reduction of synchronisation in some countries since the Great Recession of 2007 and the subsequent Eurozone 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 1999-2007.

The fact that monetary union appears to have been effective in increasing business cycle synchronisation in Europe and that ERM failed to do so is an interesting 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, in the lead up to the economic crisis of 2007, 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 had become more correlated, a common monetary policy seemed to be less costly in terms of lost flexibility at the national level.

However, the latter part of our dataset has also allowed for the examination of the effects of the 2007 economic crisis and the subsequent Eurozone crisis on synchronisation. There appears to be a tale of two country groups emerging. For the first group, which includes most of the EMU countries, the crisis has disrupted the process of increasing synchronisation but, thus far, there is no evidence of a substantial reduction in synchronisation. For the second group and most notably for Greece, the levels of synchronisation have declined during this period.

Overall, we observe two distinct periods where patterns of desynchronisation for the EMU countries emerge, namely the run up to the 1993 currency crisis and the 2007 economic and Eurozone crisis. The common characteristic of both periods was the symmetric policy responses to asymmetric shocks. However, the reduction in synchronisation in the post-2007 period is much less in magnitude than that evidenced in the currency crisis of the early 1990s. This findings complements the results by Gächter *et al.* (2012) who find that desynchronisation emerges during crisis periods.

This is an important finding as for most EMU countries any questions regarding the optimality and sustainability of the common currency area, particularly in the presence of the current debt crisis, do not seem to be due to a lack of cyclical synchronisation. Hence, this should not need to be a primary concern for common monetary and national policy makers in these countries. However, Greece needs special consideration, as its cycle has desynchronised with the aggregate EMU cycle. In addition, attention ought to be paid to Ireland, Portugal and Spain since their business cycle synchronisation levels show evidence of some decline and if this trend is to continue, this could constitute a threat to the existence of EMU.

Finally, we should emphasie that this study does not consider the determinants of business cycle synchronisation, but it employs a time-varying correlation measure to assess the dynamics of this synchronisation in Europe. The literaure has well documented that the main determinants of business cycle synchronisation include trade and financial integration, among others (see de Haan *et al.,* 2008 for a review of these studies, as well as, Dées and Zorell, 2011; Babetskii, 2005; Fidrmuc, 2004). Considering though that both aforementioned determinants increased steadily during our sample period, they may not be able to fully explain the substantial changes in the patterns of synchronisation that were identified in this paper. Thus, it would be interesting for further research to investigate the time-varying determinants of business cycle synchronisation. Furthremore, an interesting avenue for further research would be the formal examination of the impact of symmetric (asymmetric) policy responses to asymmetric (symmetric) shocks on business cycle synchronisation. Finally, as those policy responses are influenced by the institutional regimes, it would be interesting to establish how economic, institutional and policy coordination could potentially influence synchronisation levels.

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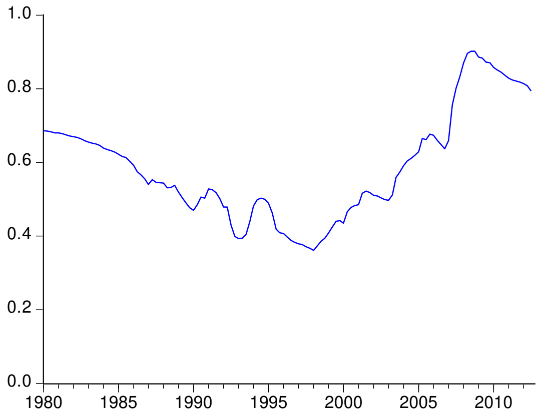
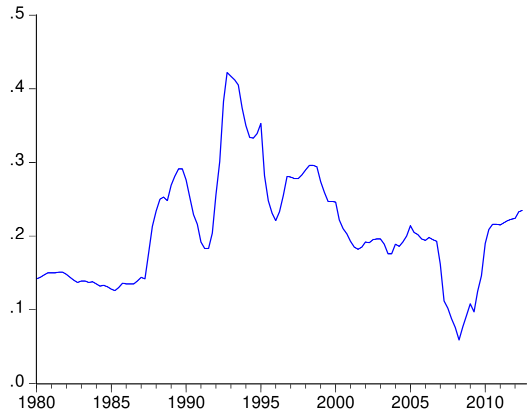
Figures

Figure 1: Mean synchronisation and standard deviation of synchronisation. Period 1980-2012.

Multivariate Riskmetrics

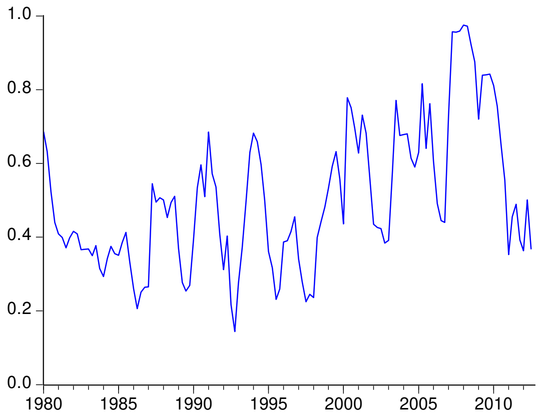
Mean synchronisation, $\overline{\rho}_t = 14^{-1}\sum_{i=1}^{14}\rho_{i,15,t}$.	Standard deviation of synchronisation, $\sqrt{13^{-1}\sum_{\mathrm{i}=1}^{14}\left(\rho_{\mathrm{i},15,\mathrm{t}}-\overline{\rho}_{\mathrm{t}}\right)^2}$.





Scalar - BEKK

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



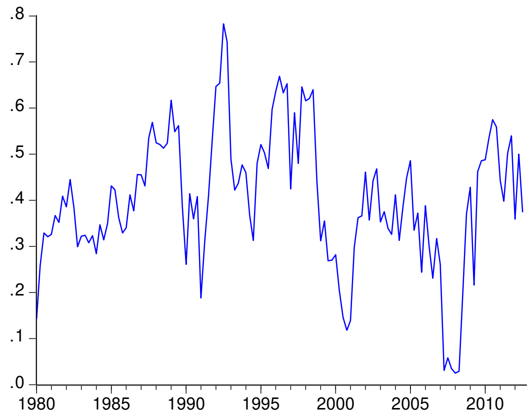


Figure 2: The time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...12, for 12 EU countries. Period 1980-2012.

Panel A	Panel B

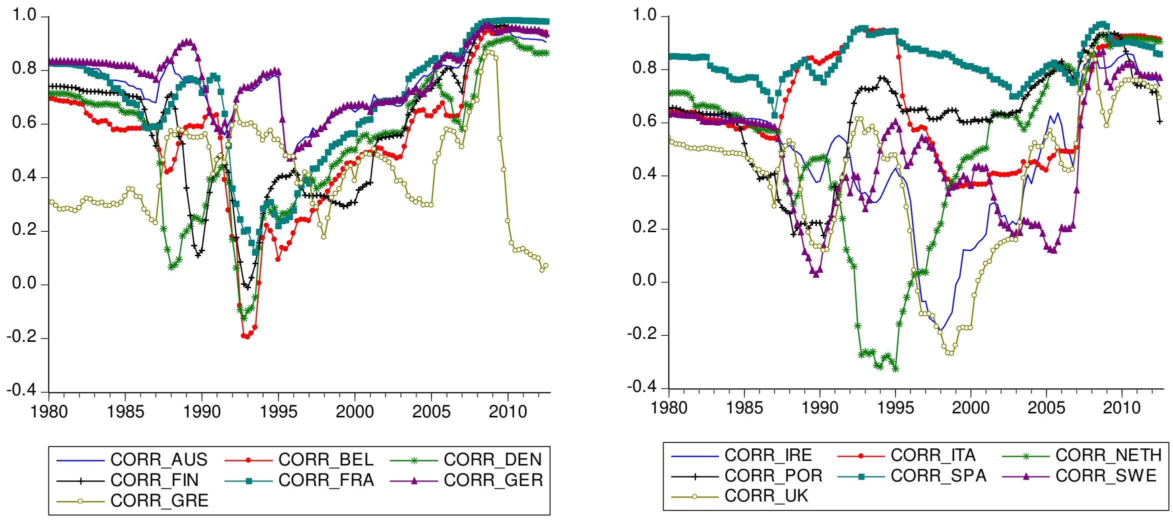


Figure 3: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1980-1985.

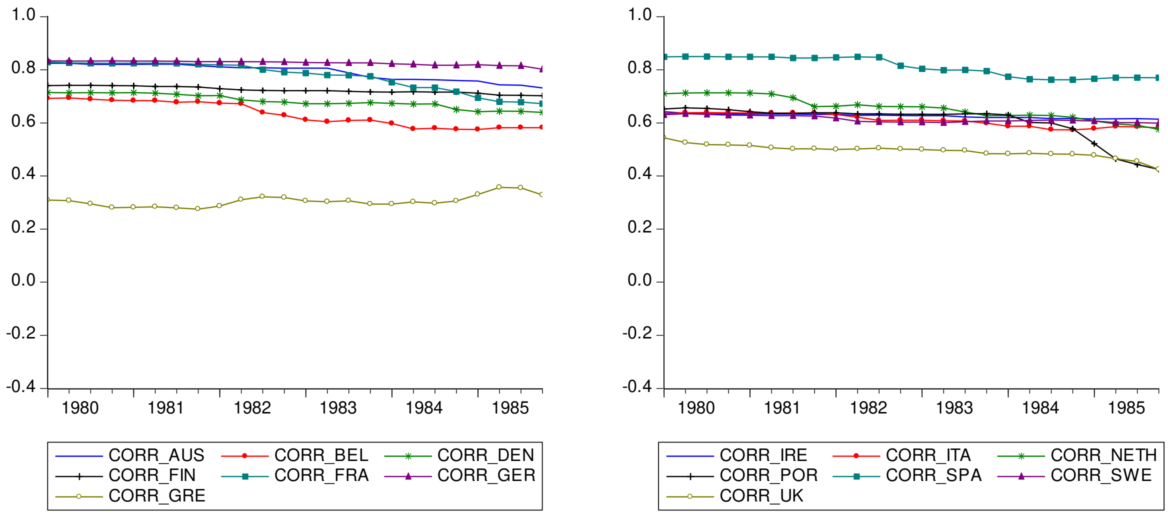
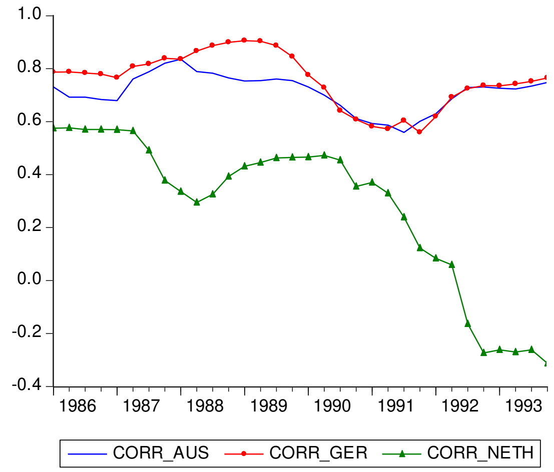
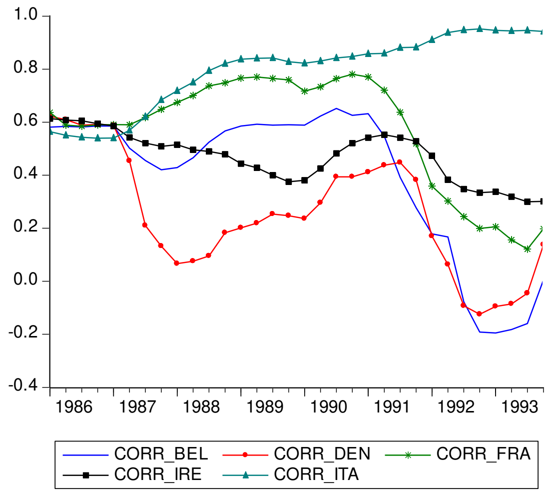


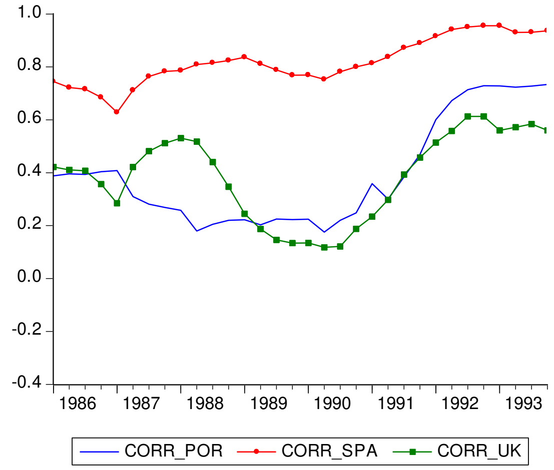
Figure 4: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1986-1993.

Panel A	Panel B





Panel C	Panel D



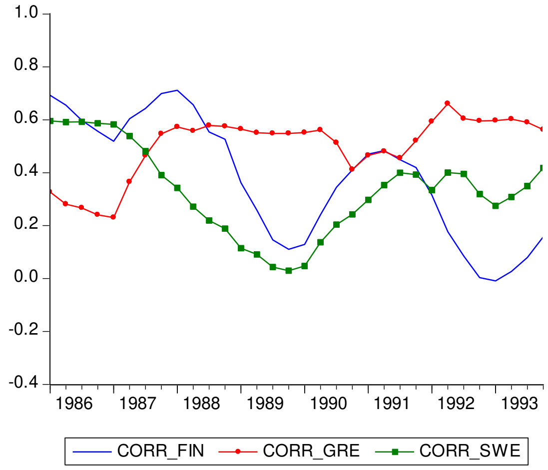
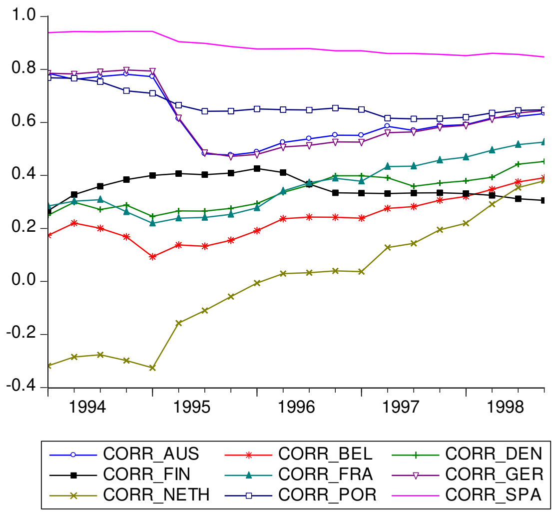


Figure 5: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1994-1998.

Panel A	Panel B



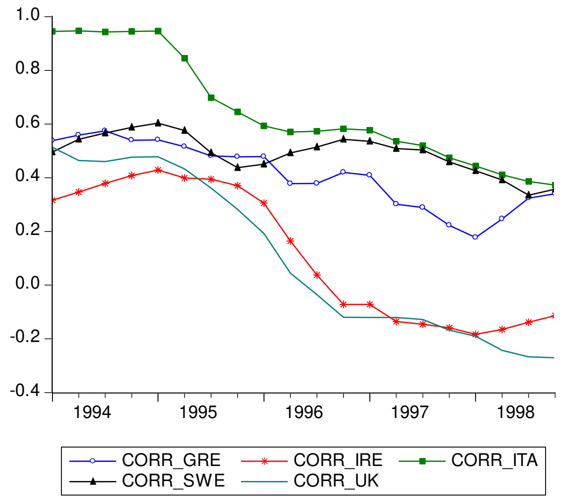
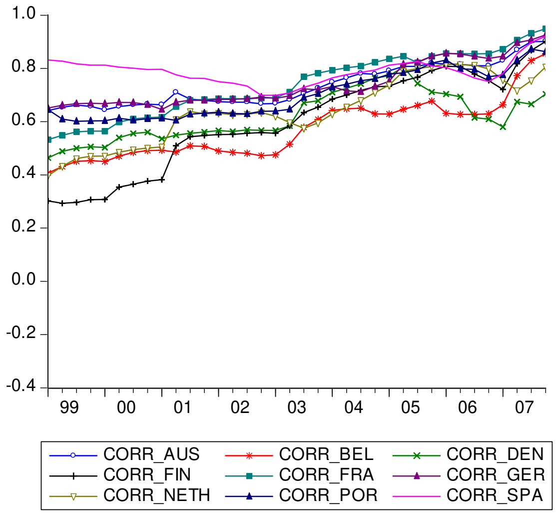


Figure 6: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 1999-2007.

Panel A	Panel B



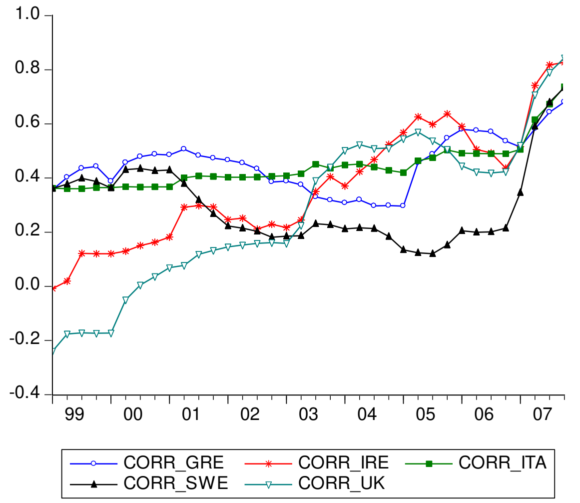


Figure 7: Time varying synchronisation, $\rho_{i,15,t}$, for i=1,2,...14 for 14 EU countries. Period 2008-2012.

Panel A	Panel B