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JEL : E32, E63, F02
Keywords: Business cycles, business cycle convergence, European Monetary Union

The authors

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1 Introduction

One of the most important debates concerning the European integration process since the end of the decade of the eighties dealt with the creation of the European Economic and Monetary Union (EMU). Two issues in relation to membership in EMU have been emphasized. Firstly, whether all members which want to and demonstrate to be able to join the currency area could be members of the arrangement or whether, on the contrary, only a core of countries in Europe should participate in EMU. The second issue deals with the Maastricht convergence and stability criteria and their importance for the performance of the currency area. Both issues have gained importance in the course of the European Union (EU) enlargement process. This is especially true for the latter since, under the Accession Treaty and due to the no opt-out provision stipulated in the Copenhagen European Council in 2002, all the new member states go straight into the Stage Three of EMU and have to take on the Maastricht convergence criteria. Recently, the relevance of the convergence criteria has come under heavy criticism due to the lack of fulfillment of the Stability and Growth Pact (SGP) criteria by some European countries since the first years of the new century and coinciding with the reform of the SGP in 2005. At the same time, several authors (see Kopits and Székely, 2003, for example) argue for the convenience of relaxing these convergence criteria for the new members in order to allow faster real convergence and the adoption of the *acquis communaitaire*. Nevertheless, the recent experience of new EU members has been very heterogeneous: some of them have successfully adopted the euro soon after EU accession (this is the case of Slovenia in 2007, Cyprus and Malta in 2008, and Slovakia in 2009), while others are not expected to join the EMU in the near future.

This discussion has to be assessed within the framework of the Optimum Currency Area (OCA) theory. This branch of literature had its formal birth with Mundell's (1961) seminal article and is often divided in two main branches, the first one centered in the optimum geographic domain of a currency area and the definition of criteria through which this optimality can be defined, and the second one, centered in the analysis of the trade-off between the costs and benefits from adopting a single currency. Since Mundell's proposition that a region, defined as an area within which there is factor mobility, but shows factor immobility with other regions, is an OCA, a vast body of literature has developed on the issue. Early on, McKinnon (1963) extended the criteria by considering optimality in terms of openness and size of the economy (see Dellas and Tavlas, 2009, for a revision of the developments of OCA theory). Together with factor mobility, openness and size of the economy, a large number of OCA criteria have been suggested in the literature (see for example Tavlas, 1993, or Mongelli, 2002). Most of these criteria can be summarized under the consideration that a region which shows a high degree of business cycle homogeneity is an OCA. Therefore, most of the empirical research in this area has concentrated in judging the suitability of potential or existing currency area members on the basis of these prerequisites. The current literature on OCA criteria has been highly influenced by the work of Frankel and Rose (1998), who put forward the "endogeneity of OCA" hypothesis by which the structure and relations of the economies that join a currency area are likely to change dramatically as a result of the effective participation in the currency area. As a corollary, a country would be able to satisfy the criteria for participation in a currency area better *ex post* (that is, after joining the currency area) than *ex ante* and thus, the suitability to form a currency area cannot be analyzed on the basis of these prerequisites without considering the possible endogeneity of the criteria. Frankel and Rose considered the endogeneity between two of the OCA criteria, trade integration and business cycle coherence, but other potential endogeneities have been considered (see De Grauwe and Mongelli, 2005, for a survey). The underlying rationale for the endogeneity defined by Frankel and Rose (1998) is theoretically ambiguous. The increase in trade after joining a monetary union may induce more synchronization in business cycles if intra-industry trade dominates over inter-industry trade (see European Commission, 1990) or, on the other hand, may induce business cycles to become more idiosyncratic if countries become more specialized as a result of the prevalence of inter-industry trade over the rest of effects (see Krugman, 1991). Frankel and Rose (1998) find evidence that this relationship is empirically unambiguous and that international trade integration is positively related with more synchronized business cycles (see also Fidrmuc, 2004, for evidence using intra-industry trade indicators).

The process of monetary integration in Europe has contributed to the development of the academic literature on European business cycle synchronization. Different variables and filtering procedures have been used to measure the business cycle and diverse measures have been used to analyze the coherence or similarity among business cycles. The most widely used measure of business cycle coherence is the correlation coefficient between national cycles. Within this line of study, several findings can be emphasized. Firstly, there exists evidence of homogeneity of business cycles in the EU (Agresti and Mojon, 2001, Christodoulakis *et al.*, 1995, Wynne and Koo, 2000) and certain authors claim that we can talk about a European business cycle almost in the same terms as we talk about a US business cycle (Agresti and Mojon, 2001, Wynne and Koo, 2000). Secondly, business cycle correlation in Europe is a relatively recent phenomenon. Artis and Zhang (1997 and 1999) point out that the emergence of a European cycle seems to coincide with the inception of the Exchange Rate Mechanism (ERM) and that it is a specific fact to the group of countries participating in ERM. Inklaar and De Haan (2001), using Artis and Zhang's (1997 and 1999) updated dataset but with different subsamples, found no evidence of a systematic relationship between business cycle homogeneity and monetary integration and pointed out that most ERM cycles are better correlated during the period 1971-1979 than in the period 1979-1987. Finally, other authors locate the convergence period starting in the early nineties (Angeloni and Dedola, 1999, Massmann and Mitchell, 2003, Darvas and Szápari, 2005) though there is evidence of an increase in the EU heterogeneity during the 2000-2002 recession (Fidrmuc and Korhonen, 2004). However, this recent birth of a European business cycle seems to dilute whithin a trend towards the appearance of an international business cycle (Artis, 2003, Pérez *et al.*, 2007).

While the first steps in the monetary integration process contributed to the development of business cycle synchronization literature, the EU enlargement and the no-opting out rule led to the development of a number of studies on the synchronization of the new member countries with the EU or the EMU (see Fidrmuc and Korhonen, 2006, for a meta-analysis on business cycle correlation between the euro area and Central and Eastern European countries, CEECs). From this literature it can be highlighted that several acceding countries show a high level of synchronization with the EU-15 countries, especially Hungary, Poland and Slovenia (Artis *et al.*, 2004, Fidrmuc and Korhonen, 2004 and 2006, Darvas and Szápari, 2005). However, the level of homogeneity amongst the new members is lower than those of the EMU-12 and the synchronization between the new members and the EMU is lower relative to the synchronization of countries taking part in past enlargements (Artis *et al.*, 2004). In addition to this, the synchronization of the group of new members seems to have decreased during the 2000-2002 recession as in the case of the EMU (Fidrmuc and Korhonen, 2004).

In this piece of research we analyze the dynamics of business cycle dispersion in Europe for the period 1960-2008. We extract the business cycle from quarterly Gross Domestic Product (GDP) series for 36 countries, all members of EMU-12, 10 new EU members and 11 OECD countries using an unobserved components model in the spirit of Harvey (1989) using Kalman (1961) filtering methods. As a measure of coherence, the time series of the cross-country standard deviation of business cycles is studied for different groups of economies, and significant changes in this measure are assessed using Carree and Klomp's (1997) convergence test. We also analyze the time series properties of our business cycle synchronization measure in order to characterize different systematic periods of convergence/divergence among the cycles of the groups considered applying the procedure proposed by Bai and Perron (1998 and 2003). To our knowledge, the dynamics of business cycle dispersion has not been exploited until now as an indicator of business cycle coherence. This indicator is complemented with an index of coherence of the state of the cycles. In addition to this, we compute an indicator of the cost of inclusion for the members of each group considered in our analysis. Such an indicator allows us to link the strand of the literature dealing with OCA criteria with that focused on costs and benefits of currency area membership. Our approach allows us to answer the main questions highlighted by the literature concerning business cycle synchronization in Europe such as the determination of the level of synchronization amongst the members of EMU, the existence of a core-periphery divide within the EMU, the impact of the recent enlargement, and the characteristics of the cyclical comovement in EMU in comparison with the global economy.

Our results show a significant convergence period observed since the beginning of the nineties which seems to finish with the birth of EMU, coinciding with the period of macroeconomic homogeneization following the implementation of the Maastricht convergence criteria. The strong pattern of convergence in the EMU-12 during the nineties came out onto a new regime since 1996, which characterized by more synchronization of business cycles. New EU members experienced a period of significant cyclical convergence among themselves and with the EMU-12. After the crisis of 2001-2002 and in particular since 2004, the enlargement of the euro area has had little impact on the optimality of the European currency area from the point of view of business cycle synchronization. However, we also find evidence that the European business cycle seems to dilute within a world-wide cycle from 2004 on. In recent years, new EU members are in similar or better levels of synchronization than some of the periphery countries (Greece, Ireland and Portugal).

The paper is structured as follows. In section two we present the business cycle extraction method and the basic characteristics of business cycle dispersion in EMU for the period under study. Section three presents the results of the convergence tests and identifies the different synchronization periods in the sample for EMU. Different alternative groupings are also considered and analyzed. In section four, the cost of inclusion of the countries in the current EMU and a hypothetically enlarged EMU is analyzed. Section five concludes.

2 Business cycles in EMU

In order to study the convergence of business cycles, an estimate of the cyclical component of the variable of interest (in our case, quarterly real GDP) needs to be obtained. For this purpose, following Harvey (1989) and Harvey and Jaeger (1993), we decompose the GDP series of each country under study into unobservable trend, cyclical and irregular components. Let y_{it} be the (logged) level of GDP corresponding to country i in period t then

$$y_{it} = \tau_{it} + \phi_{it} + \varepsilon_{it}^{y}, \;\; \varepsilon_{it}^{y} \sim \mathbf{NID}(0, \sigma_{\varepsilon^y}^2), \tag{1}$$

where τ_{it} is the trend component, ϕ_{it} is the cyclical component and ε_{it}^{y} is the (white noise) irregular component. The trend component, in its most general specification, will be assumed to be a random walk with a drift, where the drift follows a random walk as well, that is,

$$\tau_{it} = \tau_{it-1} + \beta_{it-1} + \varepsilon_{it}^{\tau}, \;\; \varepsilon_{it}^{\tau} \sim \mathbf{NID}(0, \sigma_{\varepsilon^\tau}^2), \tag{2}$$

$$\beta_{it} = \beta_{it-1} + \varepsilon_{it}^{\beta}, \;\; \varepsilon_{it}^{\beta} \sim \mathbf{NID}(0, \sigma_{\varepsilon^\beta}^2). \tag{3}$$

This specification of the trend component nests several interesting cases. It should be noticed that if $\sigma_{\varepsilon^\tau}^2 > 0$ and $\sigma_{\varepsilon^\beta}^2 > 0$, this component induces an $\mathsf{I}(2)$ trend on y_{it}. On the other hand, if $\sigma_{\varepsilon^\tau}^2 > 0$ and $\sigma_{\varepsilon^\beta}^2 = 0$, τ_{it} is a random walk trend with drift. The case $\sigma_{\varepsilon^\tau}^2 = 0$ and $\sigma_{\varepsilon^\beta}^2 > 0$ defines a smoothly changing trend,[1] and $\sigma_{\varepsilon^\tau}^2 = 0$ and $\sigma_{\varepsilon^\beta}^2 = 0$ implies a deterministic linear trend.

The cyclical component is assumed to follow a damped stochastic sine-cosine wave, specified as

$$\begin{bmatrix} \phi_{it} \\ \phi_{it}^{*} \end{bmatrix} = \rho_i \begin{bmatrix} \cos\lambda_i & \sin\lambda_i \\ -\sin\lambda_i & \cos\lambda_i \end{bmatrix} \begin{bmatrix} \phi_{it-1} \\ \phi_{it-1}^{*} \end{bmatrix} + \begin{bmatrix} \theta_{it} \\ \theta_{it}^{*} \end{bmatrix}, \;\; \begin{bmatrix} \theta_{it} \\ \theta_{it}^{*} \end{bmatrix} \sim \mathbf{NID}(\mathbf{0}, \mathbf{\Sigma}_\theta), \tag{4}$$

for $\rho_i \in [0,1]$, $\lambda_i \in (0,\pi)$ and $\mathbf{\Sigma}_\theta = \mathrm{diag}(\sigma_\theta^2, \sigma_\theta^2)$, so the disturbances of the cyclical component are assumed independent and of equal variance. It can be easily shown that the specification given by (4) implies that the cycle follows an ARMA(2,1) process, and that the constraints on the parameter space given above restrict the roots of the lag polynomial to lie on the region of the parameter space that leads to pseudo-cyclical behaviour in ϕ_{it}.

The model specified by (1)-(4) can be written in state space form in a straightforward manner and estimated using maximum likelihood methods via the Kalman (1961) filter and the prediction error decomposition. Once the estimates of the parameters in (1)-(4) are obtained, the cyclical component can be recovered as the smoothed estimate of ϕ_{it}, $\hat{\phi}_{it}$, which

[1] The Hodrick-Prescott trend (Hodrick and Prescott, 1997) appears as a special case of the decomposition of a series into a smooth trend and an irregular component for specific values of $\sigma_{\varepsilon^\beta}^2 / \sigma_{\varepsilon^y}^2 = \lambda$, and $\sigma_{\varepsilon^\tau}^2 = 0$ and $\phi_t = 0$, where λ is the smoothing parameter of the Hodrick-Prescott filter, 1600 for quarterly data. When $\lambda \to \infty$, the Hodrick-Prescott filter approaches to linear detrending. Thus, the Hodrick-Prescott estimate of the cyclical component is then symply given by the smoothed irregular component (see Harvey, 1989, and Harvey and Jaeger, 1993).

is given by $\mathsf{E}(\phi_{it}|\{y_{it}\}_{t=1}^{T})$.

The unobserved components model given by (1)-(4) is estimated for the real quarterly GDP data corresponding to all EU countries (with the exception of Malta and Romania) and 11 OECD countries which will be used as a control group for assessing the European idiosyncrasy of the results.[2] Using such a structural unobserved components model presents several advantages respect to other common filtering techniques. Firstly, as mentioned above, the model specified nests some other filters like the Hodrick-Prescott (1997) and linear detrending or first-differencing and thus offers more flexibility when extracting the components. Secondly, it implicitly specifies a band of frequencies which corresponds to business cycle, removing the long-run and irregular information. Thirdly, it allows for a rationale underlying the signal-extracting procedure and makes parametric assumptions concerning the data generating process. The latter is of importance when tracking the business cycle especially for two reasons. Part of the economies considered in the sample, CEECs which joined the EU in the 2004 and 2007 enlargements, are transition economies which experienced a crisis of particular features during the 90s associated to a transition process where political constraints are of importance (Roland, 2002).[3] In addition to this, Aguiar and Gopinath (2007) conclude that shocks to trend growth rather than transitory fluctuations around the trend are the primary source of observed volatility in emerging markets. The unobserved components model allows us to take account of sharp drops in GDP series ocurred during some periods of time, for example, in the case of the Finnish great depression in the 90s (see Conesa *et al.*, 2007, for an analysis of this case).[4] The proposed model can deal with these features by allowing a flexible estimation of movements in the trend component. Figures 1-3 present the smoothed cyclical components of the quarterly GDP series corresponding to each one of the countries considered. Together with the estimation of cyclical components, we obtain the state of the cycle in terms of recessions (peak-to-trough period) and expansion periods (trough-to-peak period).[5] This discretization was carried out using Canova's (1999) rule: a peak is defined at time t if $\hat{\phi}_{it} > \hat{\phi}_{it-1}$, $\hat{\phi}_{it-1} > \hat{\phi}_{it-2}$ and $\hat{\phi}_{it} > \hat{\phi}_{it+1}$ and a trough is defined at time t if $\hat{\phi}_{it} < \hat{\phi}_{it-1}$, $\hat{\phi}_{it-1} < \hat{\phi}_{it-2}$ and $\hat{\phi}_{it} < \hat{\phi}_{it+1}$, where $\hat{\phi}_{it}$ is the smoothed cycle at period t.

The synchronization among groups of N countries can be analyzed using the time series of (a) the cross-country (weighted) standard deviation of the smoothed cyclical component, on the one hand,

[2]GDP series of Bulgary, Estonia, Greece, Latvia, Slovenia and Switzerland were seasonally adjusted using TRAMO-SEATS (Gómez and Maravall, 1996). See *Appendix A* for the specification of countries, sample periods and sources.

[3]Campos and Coricelli (2002) characterized some stylized facts of transition economies during the 90s such as output fall, a dramatic decrease in the stock of physical capital, high geographic labor mobility, intense reorientation of trade towards the West, a change in the structure of the economy, a rapid collapse of institutions and a deterioration of social well-being (see also, Svejnar, 2002, and Foster and Stehrer, 2007, for characterizations of macroeconomic transitions during this period).

[4]Conesa *et al.* (2007) use the Finnish depression of the 90s as a case study for great depressions methodology developed by Kehoe and Prescott (2002 and 2007) recognizing that such a depression does not fulfill the Kehoe and Prescott criteria, but comes close to them.

[5]Detailed results of the estimated models and series of state variables can be obtained from the authors upon request.

$$\hat{S}_t = \sqrt{\sum_{j=1}^{N} \omega_{jt} (\hat{\phi}_{jt} - \sum_{k=1}^{N} \omega_{kt} \hat{\phi}_{kt})^2 / (1 - \sum_{j=1}^{N} \omega_{jt}^2}), \tag{5}$$

and (b) the series of a (weighted) indicator of comovement, defined as

$$C_t = |2(\bar{c}_t - 0.5)|\,, \tag{6}$$

where $\bar{c}_t = (\sum_j^N \omega_{jt} \hat{c}_{jt})$, with $\hat{c}_{jt}$ denoting the state of the cycle for country j at time t, which takes value one if the country is in expansion and zero if it is in recession. We use a weight ω_{jt} for each cycle, which may be based on the size of the country or assumed equal across economies. The indicator of comovement is based on the absolute value of $\bar{c}_t$, the (weighted) mean of all the state of the cycles at time t, after a change of scale and origin. The comovement indicator series ranges from 0 (complete asynchrony) to 1 (full synchronization).

Figure 4 plots the time series of the (unweighted) cross-country standard deviation of the cyclical component across the countries which composed EMU-12, together with the weighted standard deviation with weights based on country size (as proxied by total GDP), so as to weight down deviations from countries that amount to a small proportion of total production in the aggregate euro area.[6] The Hodrick-Precott (1997) trends of both series have been included in order to isolate the noisy component and to make it easier to distinguish the stylized facts of the dynamics of dispersion. Figure 5 shows the weighted standard deviation series and the comovement series for EMU-12. With the same aim as in Figure 4, we also present the Hodrick-Prescott trend of the dispersion series in Figure 5.

The overall dynamics of the weighted and unweighted dispersion measures present similar dynamic patterns, although the difference in the level of the standard deviation since the beginning of the seventies indicates that countries of relatively small size quantitatively induce a certain degree of business cycle divergence in the euro area. We discuss our results based on the weighted measure. The sample starts with strong convergence in business cycles in the beginning of the sixties, which turns into a period of increasing divergence that culminates in the mid 70s. After a period of cyclical convergence from the middle of the seventies to the beginning of the eighties, a persistent business cycle divergence trend takes place in the second half of the eighties, which is reversed in the first years of the decade of the nineties. The convergent pattern in the nineties ends with a reversion in the trend towards divergence in business cycles, which is more pronounced since the fourth quarter of 2006. By the end of the sample (end 2008), the dispersion of business cycles in EMU-12 has risen approximately to the levels observed in the mid-nineties.

The comovement series reveals a less clear pattern. However, some findings can be extracted from it. Some of the points of high coherence in the state of the business cycle coincide with the most relevant recessionary periods (mid 70s, beginning of the nineties, or beginning of the 2000s and the crisis period in 2008). Furthermore, there seems to be an increase of coherence in the phases of the cycles in EMU-12 since 1993, which is more evident since 2000.

[6] See *Appendix A* for a description on the weighting schemes used.

In the following section we analyze the statistical significance of the changes in business cycle dispersion across EMU economies for different horizons, and assess the issue of the existence of a structural break in the dynamics of business cycle dispersion across EMU countries.

3 Business cycle convergence and divergence patterns in the euro area

3.1 Testing for business cycle convergence/divergence

A first assessment of the patterns of convergence of business cycles across EMU economies can be done by studying the changes in dispersion plotted in Figure 5. The question that needs to be answered concerns whether the dynamics of the standard deviation of the cyclical component of GDP lead to statistically significant changes in the level of dispersion across cycles. Lichtenberg (1994) and Carree and Klomp (1997) tackle the issue of testing for convergence, defined as a reduction of the standard deviation of the variable of interest across economic units. In order to test for the significance of changes in the standard deviation of EMU business cycles, we computed Carree and Klomp's (1997) T_2 test statistic, given by

$$T_{2,t,\tau} = (N - 2.5)\log[1 + 0.25(\hat{S}_t^2 - \hat{S}_{t+\tau}^2)^2/(\hat{S}_t^2\hat{S}_{t+\tau}^2 - \hat{S}_{t,t+\tau}^2)], \quad (7)$$

where $\hat{S}_t$ is the cross-country standard deviation of $\hat{\phi}_{it}$ and $\hat{S}_{t,t+\tau}$ is the covariance between $\hat{\phi}_{it}$ and $\hat{\phi}_{it+\tau}$. Under the null hypothesis of no change in the standard deviation between period t and period $t+\tau$, T_2 is $\chi^2(1)$ distributed, and can thus be used to test for significant changes in dispersion.

$T_{2,t,\tau}$ was calculated for our sample using different potential convergence/divergence horizons ranging from one year ($\tau = 4$) to eight years ($\tau = 32$). Figure 6 presents the changes in the standard deviation of EMU business cycles that appeared significant at the 5% level for the horizons corresponding to two, four, six and eight years. That is, the variable which is plotted in Figure 6 is defined as

$$K_t = (\hat{S}_{t+\tau} - \hat{S}_t)I[T_{2,t,\tau} > \chi^2_{0.95}(1)], \quad (8)$$

where τ is alternatively equal to 8, 16, 24 and 32 quarters, $\chi^2_{0.95}(1)$ is the 95th percentile of the $\chi^2(1)$ distribution and $I[\cdot]$ is the indicator function, taking value one if the argument is true and zero otherwise.[7]

Figure 6 indicates that the medium run dynamics shown in Figure 5 actually led to significant changes in the dispersion of business cycles in EMU for the period under study. In particular, a long period of sizeable and significant convergence took place in the nineties and finished with the inception of the monetary union in 1999, when a period of smooth divergence started. This result can be considered as some evidence against the endogeneity of optimum currency area criteria (see Frankel and Rose, 1998), although it should be interpreted with care given the short size of the post-EMU sample.

[7] We also carried out the Carree and Klomp (1997) test using a 1% significance level. Results are robust to this stricter definition of convergence/divergence and are available from the authors upon request.

3.2 Synchronization regimes on the way to EMU

We can also analyze the time series properties of our business cycle dispersion measure in order to identify systematic periods where different degrees of business cycle synchronization take place. Table 2 displays the results of Augmented Dickey-Fuller test (ADF, Dickey and Fuller, 1979) and KPSS (Kwiatkowski *et al.*, 1992) unit root tests for the dispersion series of EMU-12, the OECD control group and the Global1 group including both the EMU-12 and OECD groups. Different unit root tests give contradicting results on the order of integration of the standard deviation of business cycles in EMU depending on the test statistic and the setting specified. A simple ADF test (Dickey and Fuller, 1979) rejects the null hypothesis of a unit root at any sensible significance level, whereas the KPSS test (Kwiatkowski *et al.*, 1992) rejects stationarity of the series under the null specification with intercept, but cannot reject stationarity under an specification with intercept and trend. We consider the series to be represented by an autoregressive process potentially subject to breaks in the intercept and the autoregressive parameter. This leads to the possible existence of different regimes of business cycle synchronization. Setting an autoregressive lag of one, which appears sufficient to account for the autocorrelation present in the data, the specification we are considering is the following,

$$\hat{S}_t = \sum_{j=1}^{R} (\alpha_{0,j} + \alpha_{1,j}\hat{S}_{t-1}) I(T_{j-1} \leq t < T_j) + \varepsilon_t, \tag{9}$$

where ε_t is a white noise disturbance, R is the number of regimes considered (therefore $R-1$ is the number of breaks in the parameters of the process), T_0 is the time index of the first observation and T_R is the time index of the last observation. We consider three specifications. A model with the structural change only in the intercept ($\alpha_{1,j} = \alpha_1$, $\forall j = 1, \ldots, R$), a specification with only the autoregressive parameter subject to structural change ($\alpha_{0,j} = \alpha_0$, $\forall j = 1, \ldots, R$), and a pure structural change model, where both parameters are allowed to present a break. Table 3 presents the results of the estimation of (9) for the cases of partial structural change models (with break in intercept and break in the autoregressive parameter, respectively), and pure structural change model, together with the sup-F test for the null of the model without breaks against each one of the models with breaks. In adittion to this, the unweighted and weighted double test (UDmax and WDmax, respectively), the sup-$F(\ell+1|\ell)$ test, and the number of breaks selected by the sequential procedure (Bai and Perron, 1998 and 2003), the Bayesian Information Criterion (BIC, Schwarz, 1978), and the modified BIC of Liu *et al.* (1997). The breaks were estimated in each case by choosing the values in the vector $\tau = (T_1 ... T_{R-1})$ that globally minimize the sum of squared residuals, allowing for a maximum of 4 regimes ($R = 4$, corresponding to 3 breaks). That is,

$$\{\hat{T}_1, \ldots, \hat{T}_{R-1}\} = \arg\min \sum_{t=1}^{T_R} \hat{\varepsilon}(\tau)_t^2, \tag{10}$$

where the search for the breaks is done after imposing a minimum of 15% of the full sample to be contained in each regime, in order to avoid spurious results caused by small subsample sizes. The significance levels of the sup-F tests are obtained in each case by simulating the critical values using the method proposed by Bai and Perron (1998 and 2003).

The results of the structural break analysis test shown in Table 3 present evidence for the model with one break in all the specifications considered. Together with the models estimated, we include the 95% and 90% confidence intervals for the break, the unconditional expectation and variance of the process implied by the model in each one of the regimes. The break is determined in the first quarter of 1996 for every model, being the structural change model with only the persistence parameter subject to break the preferred one in terms of model selection criteria.[8] In the first regime (1960/1-1995/4) the process presents high persistence and convergence to a very low level of dispersion. This is followed by a period of relatively lower persistence induced by the negative magnitude of the dummy associated with the autoregressive coefficient for the second regime (1996/1-2008/4). The unconditional expectation of the process goes down from the first to the second regime, as well as the variance of the process. Figure 7 summarizes the results by plotting the unconditional expectation of the autoregressive process corresponding to each one of the regimes together with the original dispersion series. The shaded area in Figure 7 shows the 95% confidence interval corresponding to the estimated break.

To sum up, two distinct regimes concerning the synchronization of business cycles can be found in the euro area for the period under study. A first period spanning from the beginning of the sample (1960/1) till the mid of the 90s, followed by a second regime from the mid of the 90s to the end of the sample in 2008/4 characterized by lower unconditional expectation and volatility in the dispersion series.

3.3 Is there an EMU business cycle?

Beyond the determination of the level of synchronization amongst the members of EMU, several issues highlighted by the literature can be addressed within the framework developed in this paper. In particular, the existence of a core-periphery divide within the EMU, the impact of the recent enlargement, and the characteristics of the cyclical comovement in EMU in comparison with the global economy can be easily assessed. The core-periphery debate in Europe had its climax during the beginning of the 1990s, coinciding with the preparation period for the currency union after the signing of the Maastricht Treaty in 1992 and until the decision stipulated in the Copenhagen European Council in 2002 that all the new members resulting from the enlargements of 2004 and 2007 would go straight into the Stage Three of EMU without an opting-out clause. Some scholars had concluded that a currency union beyond the core of countries identified by Germany, Benelux and France would not fulfill the OCA criteria to the degree needed to avoid problems if asymmetric shocks are sizable (see, for example, De Grauwe, 1993). Nevertheless, the comparison either with a core group or the periphery of countries of the EMU-12 has continued in the business cycle synchronization literature when assessing the costs and benefits of joining EMU for new EU members (see Fidrmuc and Korhonen, 2006, for a meta-analysis on the issue business cycle correlation between the Eurozone and CEECs). From this literature it can be highlighted that several acceding countries showed highly synchronized with the EU-15 countries, especially Hungary, Poland and Slovenia (Artis *et al.*, 2004, Fidrmuc and Korhonen, 2004 and 2006, Darvas and Szápari, 2005). However, the homogeneity between new EU members

[8]The model with breaks only in the intercept and the model where all parameters are allowed to be subject to breaks offer similar conclusions.

and EMU is lower than during past enlargements (Artis *et al.*, 2004) and seems to have decreased during the 2000-2002 recession as in the case of countries within EMU (Fidrmuc and Korhonen, 2004). Finally, several authors have recently found evidence in favour of the existence of a world-wide trend towards business cycle synchronization since the end of the nineties and the begining of the 2000s in which a hypothetical European business cycle would dilute (Artis, 2003, Pérez *et al.*, 2007).

The aim of this section is to analyze, on the one hand, whether the traditional core of EMU countries shows a higher degree of synchronization than the whole euro area. On the other hand, we also study whether the hypothetical inclusion of all the new EU members in the currency area induces relevant changes to the degree of optimality of EMU and whether the cyclical comovement among EMU countries presents some differential features relative to the rest of the world.

Figure 8 presents the standard deviation series of the core EMU, the group of new EU members, a hypothetical EMU-22 including all the new members of the recent enlargements in 2004 and 2007 considered in our analysis, and of the EU-25, relative to the EMU-12 (first column); together with their coherence indices (second column). Figure 9 shows the same for a control group called OECD, including developed countries that are not part of the European integration process and the three opt-out clausule members (Denmark, United Kingdom and Sweden) and two global groups, one (global1) which includes all the countries but the enlargement group, and a second group (global2), which includes all the countries considered in this piece of research.

The core group shows similar dynamics as EMU-12 but it presents in general a lower level in the dispersion series, reflecting higher synchronization, though in some specific periods of increasing divergence both dispersion series reach similar levels. In addition to this, the coherence measure presents higher values and more periods of full synchronization during the whole sample. The group of new EU members experienced strong cyclical convergence since 1995 and thus, since 2004 is in a level of synchronization similar to that of the EMU-12. The behavior of the dispersion series is much more volatile, however. This pattern is also consistent when looking at the coherence index. Common cyclical dynamics have thus also become more important in terms of the timing of cyclical phases. This allows us to conclude that the potential enlargement of the euro area does not induce any significant distortion from the point of view of synchronization of business cycles in the optimality of the currency area and thus in the management of the common monetary policy. Our results for the EMU-22 are also valid if we consider the full EU-25 group.

With respect to the OECD group, the EMU-12 group has experienced a more synchronized behavior since the beginning of the eighties. Since the beginning of the nineties (1992) until 2004, the levels and dynamics of synchronization became roughly similar in both groups. The coherence index reveals also a somehow more synchronized behavior in the phase of the cycle for EMU-12, but this is less clear than for the dispersion series. When considering a global economy group with these two groups of countries (Global1) a similar conclusion is obtained, with EMU showing a more synchronized behavior. This is also evident when the EMU-12 is compared to a global group (Global2) including all the countries here considered (the EMU-22 countries and the control group of OECD countries). The EMU shows a more synchronized behavior from the beginning of the comparison sample until 2004.

Structural break analysis was also carried out for the OECD and Global1 groups (see Tables 4 and 5, respectively).[9] An AR(1) model with one break was able to summarize the data generating process of the OECD group. After testing for parameter stability, a model with a break in persistence estimated in 1999/1 was chosen, a specification which performs slightly better than its competitors and makes the comparisons among groups easier. Concerning the Global1 group, an AR(1) model with one break in the autoregressive coefficient estimated in 1998/4 was also selected. Figure 10 shows the main results for both groups, which can be summarized in a decrease in the long-run unconditional expectation of the synchronization measure. Variances of the processes in Tables 4 and 5 show also a decrease from the first to the second regime. Results of Tables 4 and 5 in comparison to those of Table 3 report higher unconditional expectations in OECD and the global group considered (Global1) than in EMU-12 in the first and second regimes considered in each model. However, variances of the OECD and Global1 groups are lower than those of the EMU-12.

To sum up, the strong pattern of convergence in the EMU-12 during the nineties presents a new regime since 1996 which is characterized by more synchronization of business cycles and less volatility in our measure summarizing such synchronization. A core group which is characterized by a higher degree of cyclical synchronization is evident. The new EU members experienced a strong convergence in cyclical patterns both within the group and with respect to the EMU-12. After the recession of 2001-2002 and in particular since 2004, the enlargement of the euro area has no significant impact on the optimality of the European currency area from the point of view of business cycle synchronization. The EMU-12 group shows more synchronized business cycles than the group formed by other OECD countries or the global economy. However, from 2004 on the European differential disappears and the European business cycle is diluted within a global business cycle.

4 The cost of inclusion in a monetary union

Up to this point, the procedure of analysis used has proved to be an efficient instrument for the automatic determination of business cycle synchronization regimes given a group of countries. The cost-benefit balance of being part of a currency union for a single country is also of capital importance for policymakers. We analyze this issue from the point of view of the potential distortion in terms of synchronization implied by the inclusion of a country in the group. We propose to analyze the cost of inclusion of a country j in the group Ω by using the simple indicator

$$\mathrm{coi}_{t,j}|\Omega = \frac{\hat{S}_t|\Omega_{-j} - \hat{S}_t|\Omega}{\hat{S}_t|\Omega}, \qquad (11)$$

where $\hat{S}_t|\Omega_{-j}$ is the (weighted) cross-country standard deviation of smoothed cycles cor-

[9] Carree and Klomp's (1997) test was implemented for all the groups considered in our analysis. Results are not reported here because of reasons of space. They confirm the description of the dynamics above mentioned and are available from the authors upon request.

responding to the group Ω excluding country j and $\hat{S}_t|\Omega$ is the (weighted) cross-country standard deviation of smoothed cycles for the group Ω including country j, both evaluated at time t. The indicator is defined as a rate of change in dispersion, taking negative values when the standard deviation of the group increases as the country is included (that is, when the country induces cyclical divergence in the group), and positive values when the inclusion of the country induces a decrease in the dispersion (that is, when it induces cyclical convergence in the group). Using this measure of the cost of inclusion of a country is thus possible to obtain a quantification of the impact that each country has in the degree of synchronization of a (potential) currency union at a given period in time. Figure 11, 12 and 13 show the cost-of-inclusion of each member for the EMU and the hypothetical enlarged EMU considered in the section above.[10]

Figure 11 displays the cost-of-inclusion of the members of EMU-12. On one side, Austria, Belgium, France, Germany, Finland, Italy, and, since the 1990s, Spain, appear as countries that imply some benefit in terms of cyclical synchronization within this group. Only in specific periods some of these countries imply a cost for the euro area: the end of the eighties and the beginning of the nineties in the case of Finland, coinciding with the collapse of the soviet system and with the Finnish great depression, and during the recession of 2001-02 or around 2004-05. On the other side, the cost of inclusion for Greece, Ireland, Luxembourg and Portugal appears positive. When looking at the hypothetically enlarged EMU-22 in Figure 12, the results show that the inclusion of the majority of the new EU countries implies a larger degree of synchronization. Only Poland during the nineties, Ireland, Germany, and Spain at the end of the sample experience some cost of inclusion in specific periods. The rest of the countries show benefits of forming part of the EMU in most of the period considered (1995-2008). It seems to be quite evident that the small size of the new members makes the cost/benefit analysis quantitatively unimportant. When looking at the results without weights (Figure 13), the results of the old members of the EMU-12 remain quite similar to those of the EMU-12 group. Regarding the new members, the majority of them show some cost of joining the euro area during the nineties, generally coinciding with their transition periods and the recession of 2001-02. Cyprus, Czech Republic, Estonia and to a lesser extent Hungary do not represent an actual cost for the synchronization of the euro area and, surprisingly, Bulgaria does not exhibit high costs either. For the rest, the cost is not significantly larger than for Greece, Ireland, Luxembourg and Portugal.

5 Conclusions

In this paper, we analyze the dynamics of business cycle dispersion in EMU for the period 1960-2008. We extract business cycles from GDP data using an unobserved components model and analyze the significance of changes in the cross-country standard deviation of cycles and the coherence of cyclical phases across EMU countries. Our results show a significant period of convergence in business cycles spanning the end of the seventies and the first

[10] Results of the cost-of-inclusion computed using the standard deviation series of the state of the cycles become senseless, because this measure for state variables tends to exhibit negative values, unless the coherence index is close to the extremes of its range and the country is in the same state of the majority, or when all the countries are in the same state. That is, when the coherence of a group is relatively far away from the 0 and 1 cases, usually the inclusion of a country results in less synchronization.

years of the eighties, which is followed by a period of business cycle divergence. A significant convergence period is observed since the beginning of the nineties and finishes with the birth of EMU, when a smooth divergence period starts. Nevertheless, there exists some evidence for a period characterized by higher comovements in business cycles and less volatility in cyclical synchronization starting in the mid of the 90s. We also assess the features of business cycles in EMU relative to different relevant groups in order to give an answer to the most relevant questions highlighted by the literature: The existence of a core-periphery difference, the impact of the enlargement of the euro area and the dilution of the EMU cycle within a world-wide business cycle. The core group of the EMU shows stronger synchronization than EMU-12. The new members of the EU have experienced a process of convergence as a group and their inclusion in the euro area does not introduce a significant decrease in the degree of optimality of EMU since 2004. Also, EMU-12 has shown a differential cyclical comovement respect to the rest of the world during the period of macroeconomic convergence linked to the Maastricht Treaty. However, this European differential has dissipated since 2004 in a world-wide business cycle. Finally, we evaluate the role of each country forming the EMU-12 and an enlarged EMU including all the members from recent 2004 and 2007 enlargements. Some of the new members of the EU do not imply a significant cost in terms of business cycle synchronization when joining EMU and exhibit levels of cost/benefit similar to the old members of EMU.

Recently, several authors have shown strong empirical evidence of the relationship between trade intensity and business cycle synchronization, while for the rest of OCA criteria the evidence is mixed (see, De Haan *et al.*, 2008, for a survey). However, Inklaar *et al.* (2008) find that for countries with highly synchronized cycles trade intensity effects decrease and other factors have as strong an effect as trade. The importance of the link between fiscal policy and business cycle synchronization has been emphasized by the OCA literature. Darvas *et al.* (2005) find that convergence in fiscal balances is systematically linked to business cycle convergence, and that the relationship exists even when the potential endogeneity of fiscal policy responses is accounted for. Böwer and Guillemineau (2006) show that fiscal policy homogeneization has been one of the robust determinants of business cycle synchronization in EMU and Akin (2006) provides evidence of the importance of similarity in idyosincratic fiscal shocks as a determinant of cyclical convergence in a broader set of countries.

The last strong business cycle convergence period runs in parallel to the macroeconomic convergence initiated by the Maastricht Treaty and seems to be linked to the synchronization in fiscal policy implied by its implementation. It is in this period when a stronger European differential with respect to other advanced economies in terms of cyclical synchronization is found. This result sheds a light on the importance of similarity in idyosincratic fiscal shocks as a determinant of cyclical convergence, and highlights the relevance of fiscal policy as a source of asymmetric shocks in the context of OCA theory. Within a monetary union, a country experiencing large deficits and high debt-to-GDP ratios may create negative spillover effects for the rest of the currency area, increasing the interest rate of the monetary union and thus, the load of financing government debts in other members of the currency area (De Grauwe, 2007). In this sense, using a simple game-theoretical setting where the interaction of monetary, fiscal and wage policy is modelled, Onorante (2004) shows that fiscal activism is always increased by entry in a monetary union. The reason for such a result is that the potential costs of running higher deficits (in terms of higher interest rates) for a country in the monetary union are lower than if monetary policy was independent, since the costs entailed by the increase of interest rates partly fall on other member countries (for theoretical models of the interaction between monetary and fiscal policy in monetary unions, see for example Silbert, 1992, Levine and Brociner, 1994, or Dixit and Lambertini 2001, 2003).

The significant convergence trend observed since the beginning of the nineties and which seems to finish with the birth of EMU coincides with the period of widespread fiscal consolidation among European countries following the convergence lines stated in the Maastricht Treaty. To the extent that differences in the implementation of fiscal policy were responsible for asymmetric shocks in the countries of our sample, the homogenization of fiscal policies on the run-up to EMU may be held partly responsible for the business cycle synchronization trend observed in the nineties. Fatás and Mihov (2003a and 2003b) document a deeper convergence in the conduct of fiscal policy among EMU countries in this period, which they label "coherence" and which implies a reduction in the use of discretionary fiscal measures across euro area countries. To the extent that the observed differences in business cycle in Europe are due mostly to differences in variables that are under control of the government, the process of fiscal coordination would be behind this trend in business cycle synchronization (see also Christodoulakis *et al.*, 1995). From a theoretical point of view, the parallel divergence patterns in business cycles and fiscal stance following the birth of EMU can be seen as a result of the interplay between monetary policy in a currency union and national fiscal policies.

Finally, the role of financial integration needs to be clarified. Theoretically, this relationship implies that more financial integration should cause higher levels of synchronization in business cycles (see De Grauwe, 2007, for example). The empirical relationship is not clear, however. Although Imbs (2004 and 2005) finds evidence for a positive relationship, Inklaar *et al.* (2008) and Baxter and Kouparitsas (2005) find that financial integration is not robustly related to business cycle synchronization. Kalemli-Ozcan *et al.* (2009) find evidence for a negative relationship after controlling for country-pair time-invariant characteristics and global shocks. Further research to quantify the effects of trade intensity, financial integration, and differentials in fiscal positions on business cycle synchronization will be made easier by using the methods put forward in this study.

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Appendix A. Data sources

Table 1: **Dataset: Samples and Sources**

Country	Sample period	Source
Australia	1960q1-2008q4	OECD
Austria	1960q1-2008q4	OECD
Belgium	1960q1-2008q4	OECD
Bulgary	1960q1-2008q4	Eurostat
Canada	1960q1-2008q4	OECD
Cyprus	1994q1-2008q4	Eurostat
Czech Republic	1990q1-2008q4	OECD
Denmark	1966q1-2008q4	OECD
Estonia	1993q1-2008q4	Eurostat
Finland	1960q1-2008q4	OECD
France	1960q1-2008q4	OECD
Germany	1960q1-2008q4	OECD
Greece	1960q1-2008q4	OECD
Hungary	1991q1-2008q4	OECD
Iceland	1960q1-2008q4	OECD
Ireland	1960q1-2008q4	OECD
Italy	1960q1-2008q4	OECD
Japan	1960q1-2008q4	OECD
Latvia	1990q1-2008q4	Eurostat
Lithuania	1995q1-2008q4	Eurostat
Luxembourg	1960q1-2008q4	OECD
Mexico	1960q1-2008q4	OECD
New Zealand	1960q1-2008q4	OECD
Netherlands	1960q1-2008q4	OECD
Norway	1960q1-2008q4	OECD
Poland	1965q1-2008q4	OECD
Portugal	1960q1-2008q4	OECD
Republic of Korea	1970q1-2008q4	OECD
Slovenia	1992q1-2008q4	Eurostat
Slovak Republic	1993q1-2008q4	Eurostat
Spain	1960q1-2008q4	OECD
Sweden	1960q1-2008q4	OECD
Switzerland	1965q1-2008q4	OECD
Turkey	1960q1-2008q4	OECD
United Kingdom	1960q1-2008q4	OECD
USA	1960q1-2008q4	OECD

Weights for averaged indicators where computed by using annual data on real GDP (source: Penn World Table) in international dollars with reference in 1996 (Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.3, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, August 2009) for the period 1950-2007 updated up to 2008 using the GDP raw data described above and used for the extraction of business cycles. For each country, weights were calculated relative to the group considered. Two schemes of weights were used. The first one, a time-varying scheme in which for each year the weight was calculated and therefore a series of (annual) weights was used when computing the indicators. The second one is a scheme based on the mean weight for the whole sample period. This last weighting scheme was used when calculating the standard deviation series in the Carree and Klomp (1997) test. Our results are robust to the use of both weighting patterns.

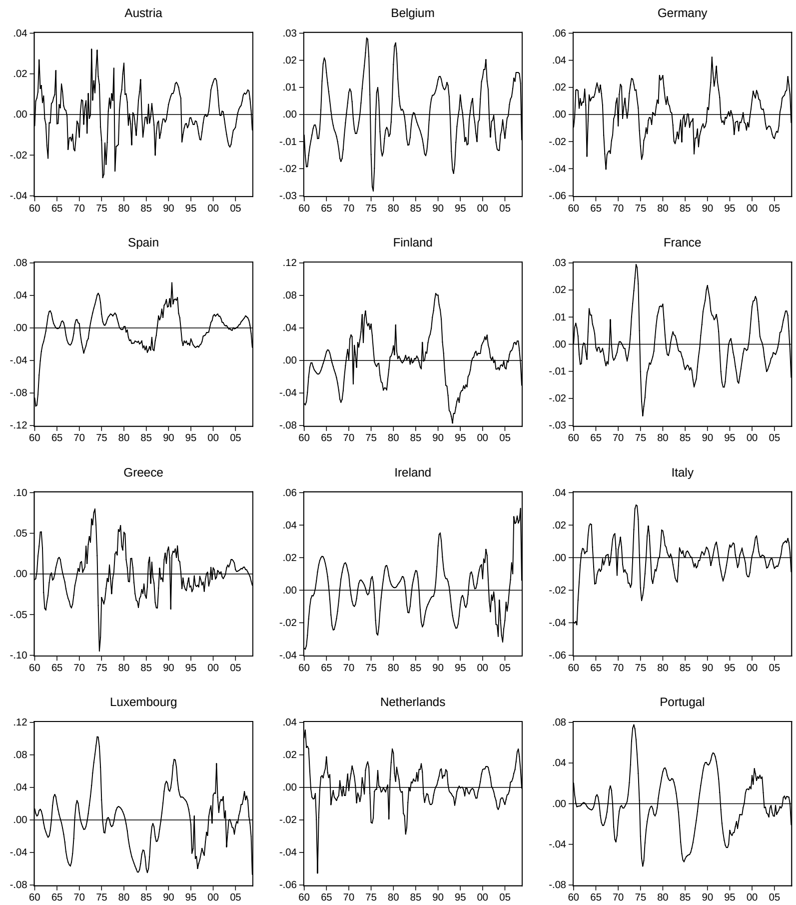


Figure 1: Cyclical component of (log) GDP: EMU countries

Table 2: **Unit root test results for weighted standard deviation series**

	Setting with intercept		Setting with intercept and linear trend	
	ADF test stat.	KPSS test stat.	ADF test stat.	KPSS test stat.
$emu-12$	-4.529***	0.988***	-4.905***	0.085
$oecd$	-3.586***	0.493**	-3.892**	0.155**
$global1$	-3.671***	0.768***	-4.476***	0.210**

Note: *, ** and *** stands for significance at the 10, 5 and 1% level, respectively.

Table 3: **AR(1) models with structural changes (SC): EMU-12**

		Partial-SC (intercept)	*Partial-SC (persistence)*	*Pure-SC*
Breaks (SSR)				
R=2		(1996/1)	(1996/1)	(1996/1)
R=3		(1974/3,1996/1)	(1974/3,1996/1)	(1974/4,1988/4)
R=4		(1974/3,1987/4,1996/1)	(1974/3,1987/4,1996/1)	(1974/4,1988/2,1996/1)
Sup-F test (ℓ)				
Sup-F test (1)		11.0786**	13.9340***	15.5172***
Sup-F test (2)		4.8264	6.4010*	10.2270**
Sup-F test (3)		3.7096	5.0635	10.7876***
UDmax		11.0786**	13.9340***	15.5172***
WDmax		11.0786**	13.9340***	15.5172**
Sup-F test (ℓ+1/ℓ)				
Sup-F test (2/1)		0.8343	1.5049	2.6119
Sup-F test (3/2)		4.4118	5.3994	10.4191
No. breaks selected				
Sequential		1**	1***	1***
BIC		0	0	0
LWZ		0	0	0
	No-SC	*Partial-SC (intercept)*	*Partial-SC (persistence)*	*Pure-SC*
$\hat{\alpha}_{0,1}$	0.0016*** (0.0004)	0.0026*** (0.0006)	0.0024*** (0.0005)	0.0026*** (0.0006)
$\hat{\alpha}_{1,1}$	0.8481*** (0.0336)	0.7906*** (0.0394)	0.8049*** (0.0370)	0.7931*** (0.0405)
break intercept	-	-0.0013*** (0.0005)	-	-0.0010 (0.0013)
break persistence	-	-	-0.1721*** (0.0663)	-0.0497 (0.1814)
Break		(1996/1)	(1996/1)	(1996/1)
95% Conf. Interval		(1994/3,2008/3)	(1994/3,1999/2)	(1994/4,2001/1)
90% Conf. Interval		(1995/2,2005/1)	(1995/1,1998/2)	(1995/2,1999/4)
Uncond. expect. ($R1$)	0.0107	0.0125	0.0123	0.0125
Uncond. expect. ($R2$)	-	0.0063	0.0066	0.0063
Variance ($R1$)	2.2943e-05	2.1131e-05	2.2507e-05	2.1354e-05
Variance ($R2$)	-	3.9863e-06	2.5575e-06	3.3215e-06
Q(1) test	0.3301	0.5307	0.5082	0.5344
Q(4) test	6.7083	8.1647*	8.0686*	8.1397*
JB test	55.3790***	65.2270***	61.3897***	64.4724***

Note: *, ** and *** stands for significance at the 10%, 5%, and 1% level. "Q(z) test" is the Ljung-Box test statistic (Ljung and Box, 1978) for autocorrelation up to zth order. "JB test" is the Jarque Bera test statistic (Jarque and Bera, 1987) for residual normality. LWZ is the modified Schwarz criterion of Liu *et al.*, 1997. The significance level of the sup-F tests were computed using the algorithm in Bai and Perron (1998 and 2003), using 1000 replications with Wiener processes of sample size 500.

Table 4: **AR(1) models with structural changes (SC): OECD**

		Partial-SC (intercept)	*Partial-SC (persistence)*	*Pure-SC*
Breaks (SSR)				
R=2		(1999/1)	(1999/1)	(1999/1)
R=3		(1977/2,1999/1)	(1977/2,1999/1)	(1980/3,1999/1)
R=4		(1977/2,1983/1,1999/1)	(1977/2,1983/1,1999/1)	(1977/2,1983/1,1999/1)
Sup-F test (ℓ)				
Sup-F test (1)		128.9633***	96.9283***	129.2726***
Sup-F test (2)		65.9577***	55.5108***	66.5164***
Sup-F test (3)		49.4858***	40.8158***	51.2707***
UDmax		128.9633***	96.9283***	129.2726***
WDmax		128.9633***	96.9283***	129.2726***
Sup-F test (ℓ+1/ℓ)				
Sup-F test (2/1)		11.0582**	7.0869*	9.6346
Sup-F test (3/2)		12.8591**	15.5393***	11.2795
No. breaks selected				
Sequential		1*** or 3**	1***	1***
BIC		3	3	3
LWZ		1	1	1
	No-SC	*Partial-SC (intercept)*	*Partial-SC (persistence)*	*Pure-SC*
$\hat{\alpha}_{0,1}$	0.0021*** (0.0006)	0.0034*** (0.0008)	0.0032*** (0.0007)	0.0033*** (0.0008)
$\hat{\alpha}_{1,1}$	0.8438*** (0.0436)	0.7724*** (0.0502)	0.7888*** (0.0472)	0.7801*** (0.0527)
break intercept	-	-0.0015*** (0.0006)	-	-0.0007 (0.0018)
break persistence	-	-	-0.1523*** (0.0560)	-0.0880 (0.1789)
Break		(1999/1)	(1999/1)	(1999/1)
95% Conf. Interval		(1998/4,2000/4)	(1998/3,2000/3)	(1998/4,2000/4)
90% Conf. Interval		(1998/4,2000/2)	(1998/3,2000/2)	(1998/4,2000/2)
Uncond. expect. ($R1$)	0.0133	0.0151	0.0150	0.0151
Uncond. expect. ($R2$)	-	0.0084	0.0087	0.0085
Variance ($R1$)	2.4521e-05	2.1058e-05	2.2483e-05	2.1692e-05
Variance ($R2$)	-	4.1839e-06	1.4590e-05	6.6922e-06
Q(1) test	0.0705	0.3400	0.2192	0.2788
Q(4) test	0.7262	1.0853	1.0616	1.0957
JB test	53.7529***	36.7712***	40.4554***	38.5142***

Note: *, ** and *** stands for significance at the 10%, 5%, and 1% level. "Q(z) test" is the Ljung-Box test statistic (Ljung and Box, 1978) for autocorrelation up to zth order. "JB test" is the Jarque Bera test statistic (Jarque and Bera, 1987) for residual normality. LWZ is the modified Schwarz criterion of Liu *et al.*, 1997. The significance level of the sup-F tests were computed using the algorithm in Bai and Perron (1998 and 2003), using 1000 replications with Wiener processes of sample size 500.

Table 5: **AR(1) models with structural changes (SC): Global1**

		Partial-SC (intercept)	*Partial-SC (persistence)*	*Pure-SC*
Breaks (SSR)				
R=2		(1998/3)	(1998/4)	(1998/3)
R=3		(1982/4,1998/3)	(1992/1,1998/4)	(1974/4,1998/4)
R=4		(1977/2,1983/1,1998/3)	(1977/1,1982/4,1998/4)	(1979/3,1992/1,1998/4)
Sup-F test (ℓ)				
Sup-F test (1)		18.4029***	20.6386***	22.8586***
Sup-F test (2)		9.3591***	11.0168***	15.7140***
Sup-F test (3)		7.7297***	9.0150***	12.2046***
UDmax		18.4029***	20.6386***	22.8586***
WDmax		18.4029***	20.6386***	22.8586***
Sup-F test (ℓ+1/ℓ)				
Sup-F test (2/1)		1.1243	2.3414	6.7042
Sup-F test (3/2)		1.7226	2.4158	4.5045
No. breaks selected				
Sequential		1***	1***	1***
BIC		1	1	0
LWZ		0	0	0
	No-SC	*Partial-SC (intercept)*	*Partial-SC (persistence)*	*Pure-SC*
$\hat{\alpha}_{0,1}$	0.0021*** (0.0006)	0.0042*** (0.0008)	0.0039*** (0.0008)	0.0043*** (0.0009)
$\hat{\alpha}_{1,1}$	0.8357*** (0.0448)	0.7080*** (0.0558)	0.7294*** (0.0518)	0.7020*** (0.0601)
break intercept	-	-0.0018*** (0.0005)	-	-0.0022 (0.0016)
break persistence	-	-	-0.1949*** (0.0528)	0.0456 (0.1659)
Break		(1998/3)	(1998/4)	(1998/3)
95% Conf. Interval		(1997/4,2003/1)	(1998/1,2000/3)	(1997/4,2002/2)
90% Conf. Interval		(1998/1,2001/4)	(1998/2,2000/1)	(1998/1,2001/2)
Uncond. expect. ($R1$)	0.0127	0.0144	0.0144	0.0144
Uncond. expect. ($R2$)	-	0.0083	0.0084	0.0082
Variance ($R1$)	1.6027e-05	1.1293e-05	1.1959e-05	1.1105e-05
Variance ($R2$)	-	2.5731e-06	1.6869e-06	2.8929e-06
Q(1) test	0.0316	0.1812	0.0916	0.2065
Q(4) test	1.9931	1.2093	0.9825	1.2471
JB test	46.1899***	31.3117***	36.9374***	30.2708***

Note: *, ** and *** stands for significance at the 10%, 5%, and 1% level. "Q(z) test" is the Ljung-Box test statistic (Ljung and Box, 1978) for autocorrelation up to zth order. "JB test" is the Jarque Bera test statistic (Jarque and Bera, 1987) for residual normality. LWZ is the modified Schwarz criterion of Liu *et al.*, 1997. The significance level of the sup-F tests were computed using the algorithm in Bai and Perron (1998 and 2003), using 1000 replications with Wiener processes of sample size 500.

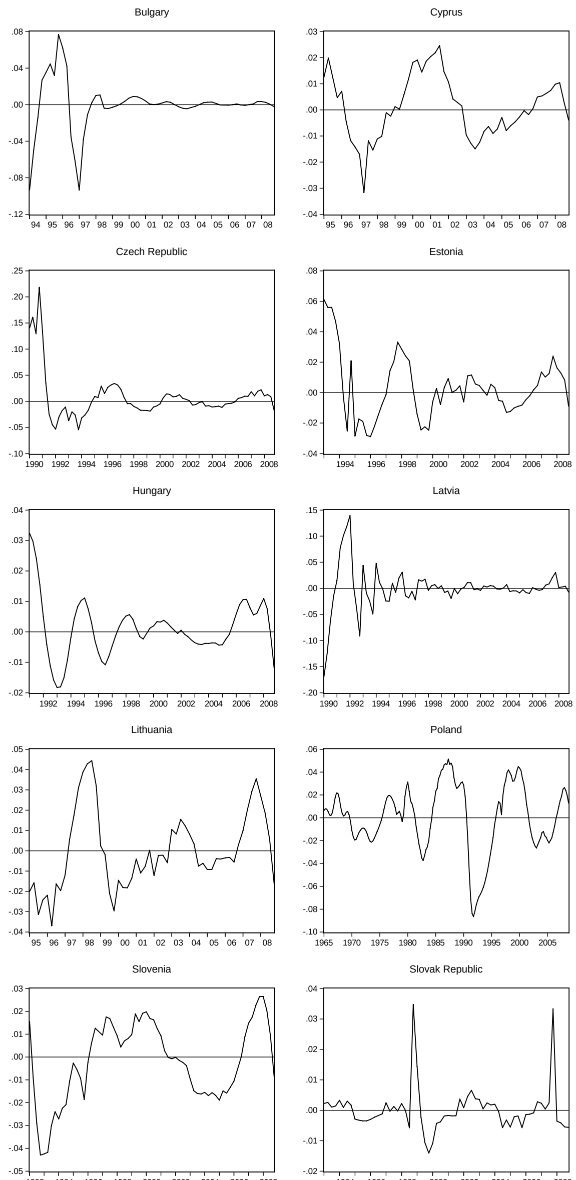


Figure 2: Cyclical component of (log) GDP: Enlargement countries

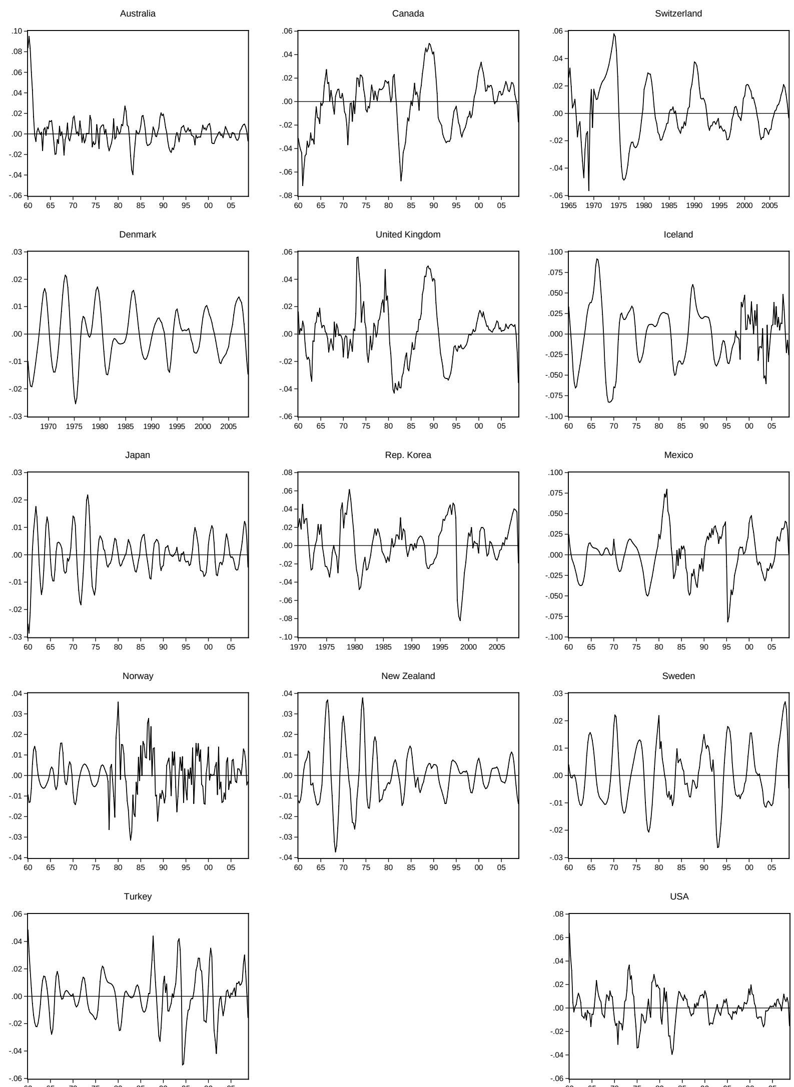


Figure 3: Cyclical component of (log) GDP: OECD countries

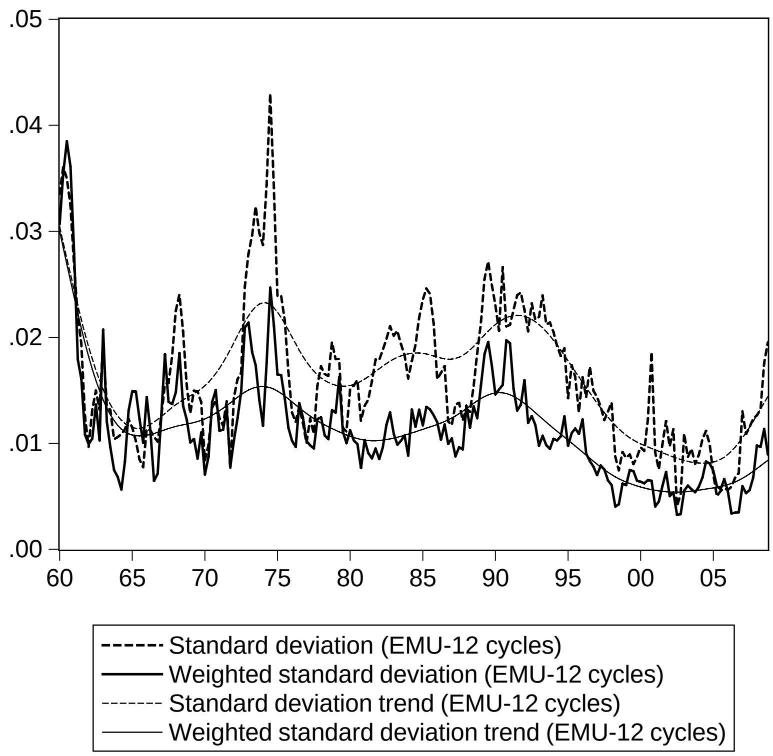


Figure 4: Dispersion of business cycles: EMU countries

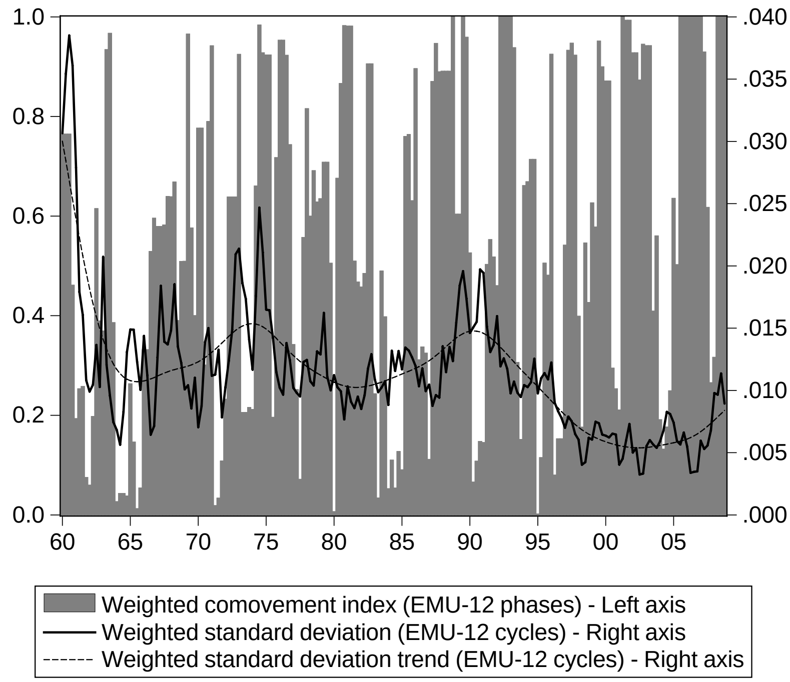


Figure 5: Dispersion and comovement of business cycles: EMU countries

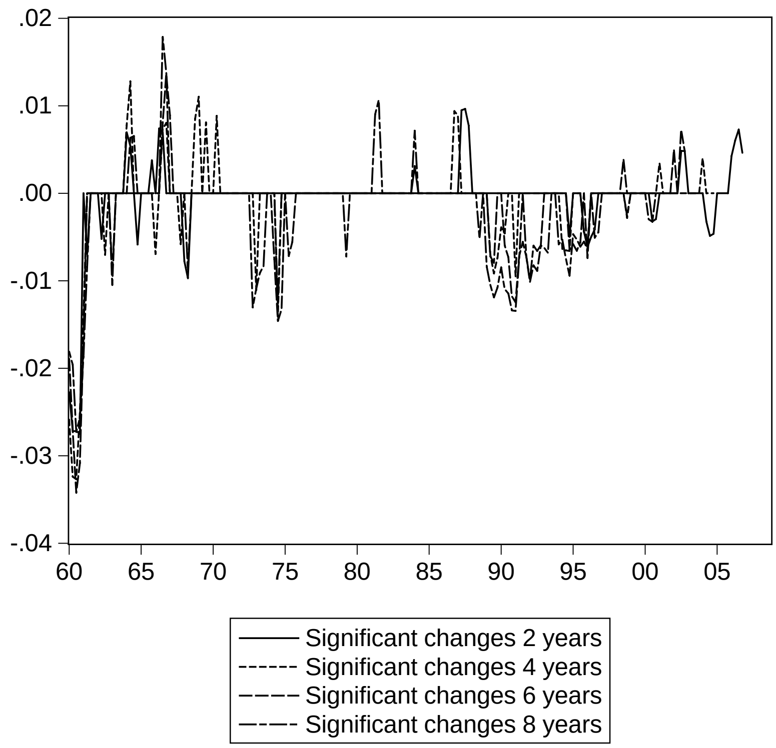


Figure 6: Significant dispersion changes: EMU

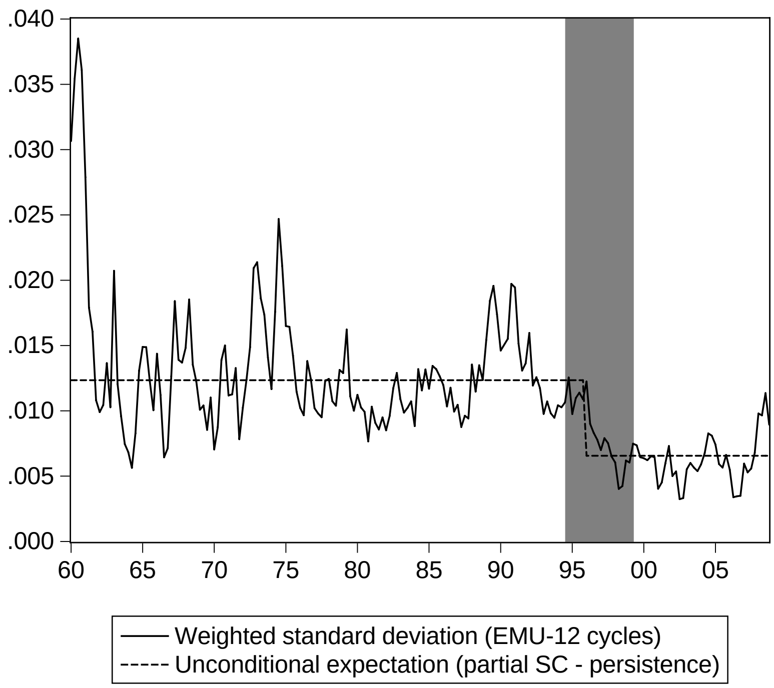


Figure 7: Business cycle dispersion regimes in EMU $\mathbf{E}[S_t|\hat{T}_1, R_j, j = 1, 2]$ and 95% Conf. interval

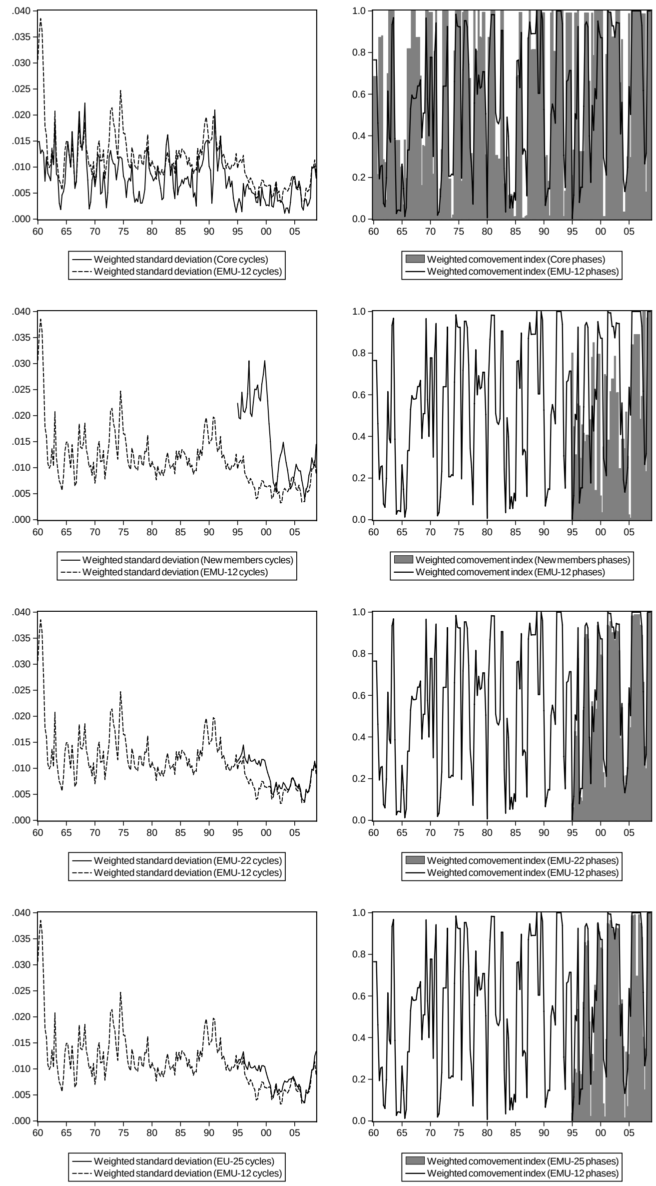


Figure 8: Business cycle dispersion: Core, Enlargement group, EMU-22, EU-25

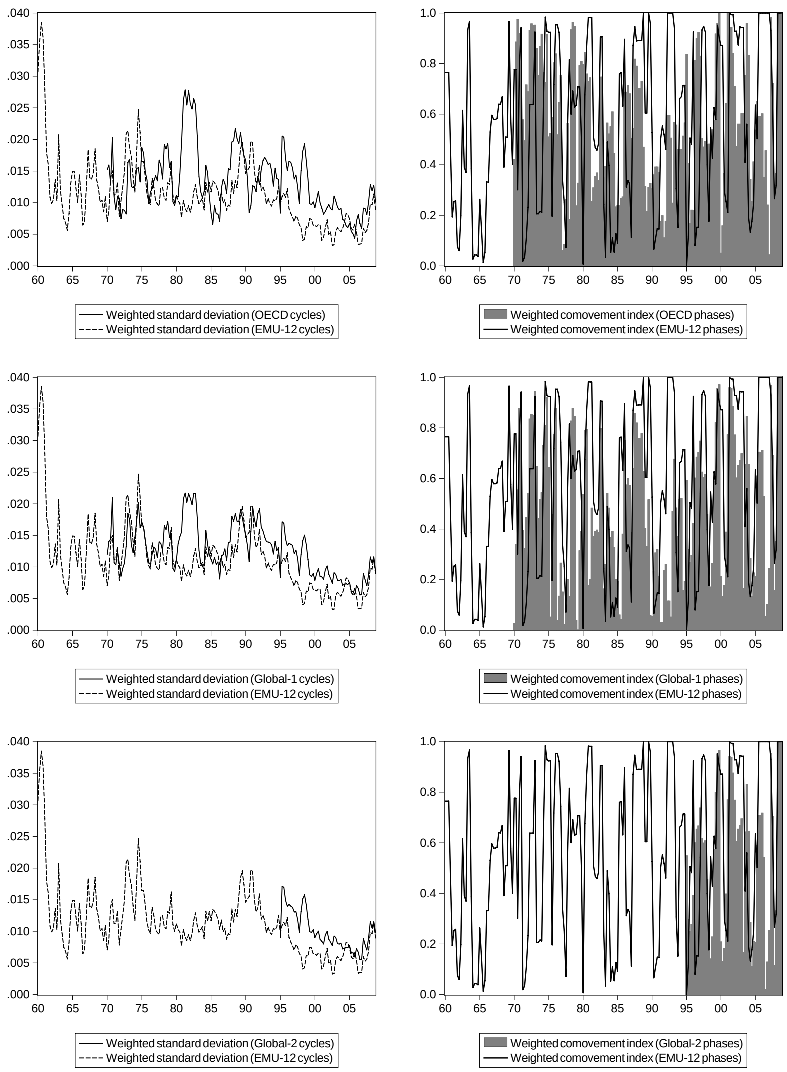
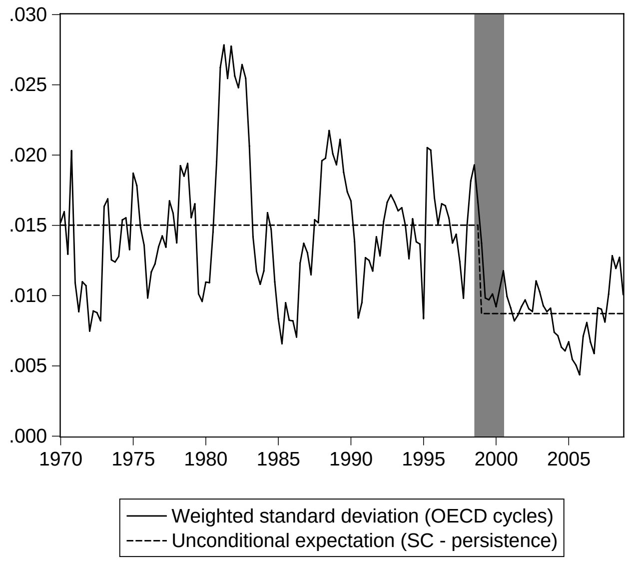


Figure 9: Business cycle dispersion: OECD, Global1, Global2



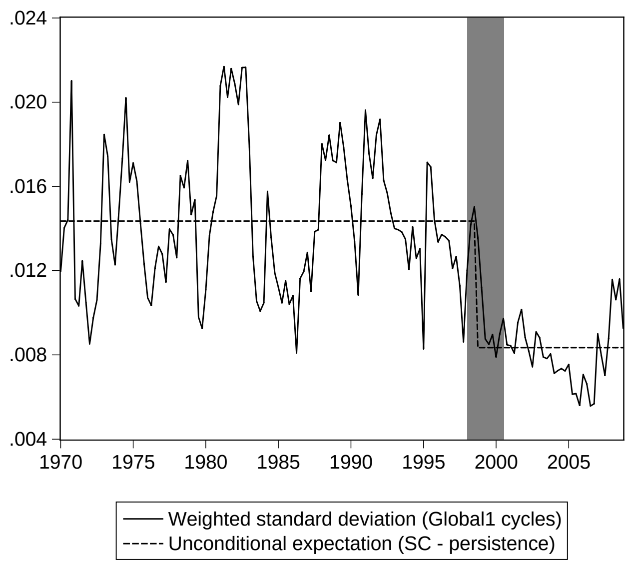


Figure 10: Business cycle dispersion regimes in OECD and Global1 $\mathbf{E}[S_t|\hat{T}_1, R_j, j = 1, 2]$ and 95% Conf. interval

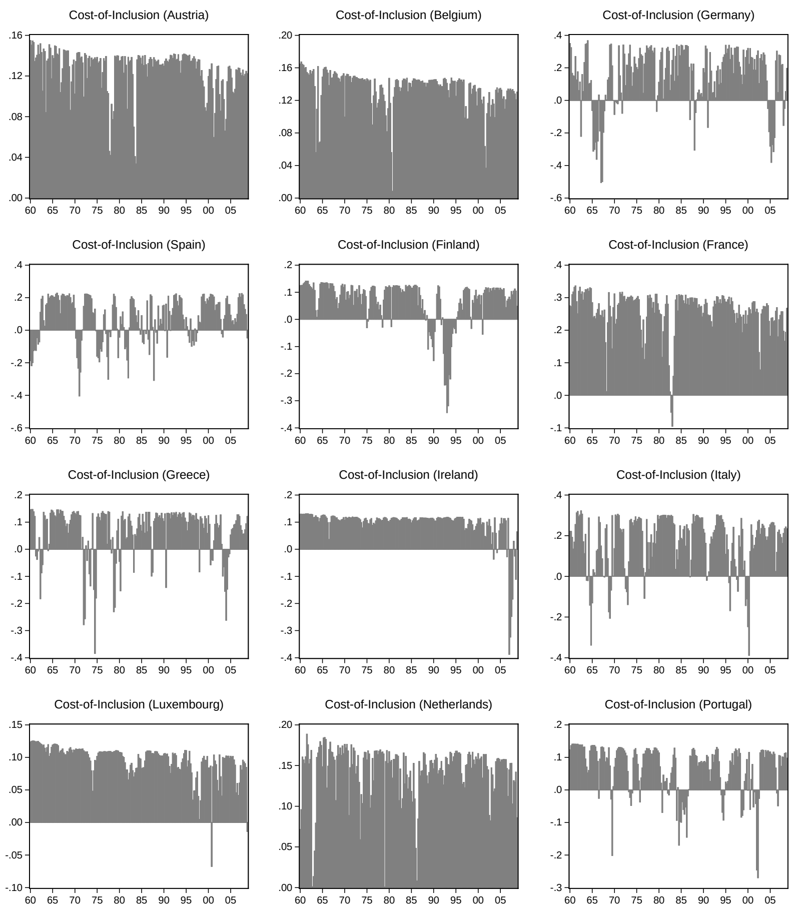


Figure 11: Cost of inclusion of a country: EMU (weighted)

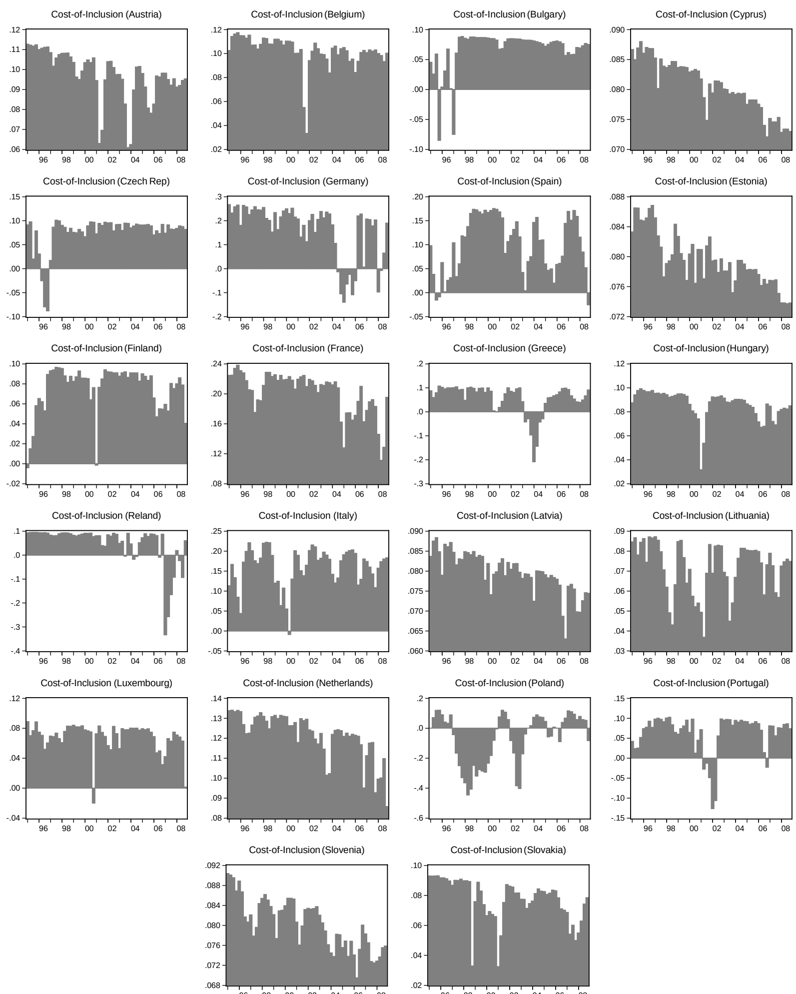


Figure 12: Cost of inclusion of a country: EMU-22 (weighted)

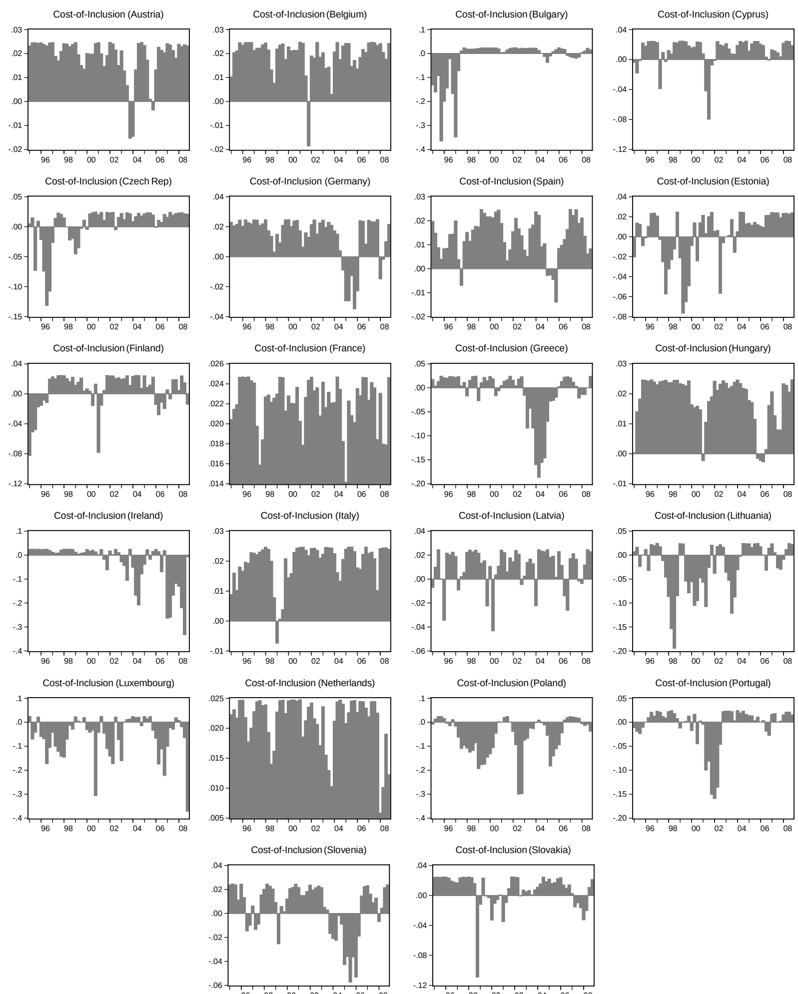


Figure 13: Cost of inclusion of a country: EMU-22 (unweighted)