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SUMMARY

This article studies business cycles links between the UK and the Euro zone. This question is interesting since it is directly linked to the debate about the optimality of the Euro zone as a currency area or the debate about the impact of potential entrants on this optimality. Business cycles 'coordination' can be seen as a necessary condition for having an Optimal Currency Area (OCA). This paper tries to see to what extent the entrance of the UK into the Euro zone would affect this coordination and therefore if it would decrease the probability of having an OCA.

In order to assess the coordination of business cycles, we evaluate common cycles for different groups of countries with a particular emphasis on the Euro group and on the Euro-plus-UK group. For this purpose, we use a structural model of the Harvey (1989) type, where each element of the dependent variable vector is decomposed into a trend and a cycle. These unobserved components are divided into an idiosyncratic, country specific part and a part common to the whole group. The model is estimated by the Kalman filter. We focus on the cyclical part, looking at the interactions between the common and the idiosyncratic part.

Three different measures are used in order to see how business cycles comovements and synchronization in the Euro zone are affected when the UK is added to this group. We look first at the variance of the cycles, in the same spirit as Kose et al. (2003). If the group is homogenous, the share of the common part in the total variance should be high for all of the countries of the group. It is found that the common cycle variance share of the UK is not systematically lower than the other Euro countries' one. A second measure is spectral density. If the cycles are homogenous within a group, they should be dominated by elements having the same frequencies. The shape of the UK cycle is not more different than other countries from the common cycle. Adding the UK would not necessarily affect the cohesion of the group. Finally, we use cross-correlation functions in order to capture lagged comovements. This allows to disentangle the comovements intensity (i.e. the maximum correlation) and the synchronisation (i.e. the lag at which this maximum correlation occurs). Then, we try to evaluate to what extent the inclusion of the UK modifies the correlations between the idiosyncratic and the common cycle. For GDP series, adding the UK has no effect on correlations of the other countries, which is not the case for other variables. In any case, the inclusion of the UK is not systematically associated with a lower level of correlation between the idiosyncratic and the common cycle.

To sum up, the results diverge between the type of variables used, which shows how useful it can be to look not only at output, but also at its components when studying business cycles. The results for GDP series show that there are many similarities between the UK cycle characteristics and the common cycle ones. At the same time, they suggest that the

UK cycle has only a marginal impact on the Euro common cycle. For three other macroeconomic series, adding the UK modifies the common cycle of the Euro group. However, this does not entail more heterogeneity in the group. In addition, the common cycle differs as much from the German or the Dutch cycle than from the UK cycle.

ABSTRACT

We use a structural model estimated by the Kalman filter in order to extract the common cycle for different groups of OECD countries. We try to evaluate to what extent the Euro zone common cycle is affected by the inclusion of the UK into the group. An important result of this work is that adding the UK to the Euro group does not lead to a greater heterogeneity of the group as a whole. Besides, the UK business cycle is not much different from Euro zone cycles. Another point is that the influence of the UK on the `Euro plus UK' common cycle is less obvious for output than for consumption, public expenditures or investment series. This suggests the importance of taking into account the components of output when analysing business cycles.

Classification JEL: E32, F02, F4.
Keywords: Common Business Cycles, UK/Euro zone, Optimal Currency Areas, Kalman Filter.

UNE ANALYSE DES CYCLES COMMUNS ENTRE LE ROYAUME-UNI ET LA ZONE EURO

RÉSUMÉ

Cet article étudie les liens existants entre les cycles économiques du Royaume-Uni et de la zone Euro. Cette question est liée au débat sur l'optimalité de l'Euro en tant que zone monétaire et sur celui de l'impact de nouveaux adhérents sur cette optimalité. La coordination des cycles économiques peut être vue comme une condition nécessaire à une zone monétaire optimale (ZMO). Ce travail essaie de voir à quel point l'entrée du Royaume-Uni dans la zone Euro modifierait cette coordination et ainsi si elle diminuerait la probabilité d'être en présence d'une ZMO.

Afin d'évaluer à quel point les cycles sont coordonnés, on estime les cycles communs pour différents groupes de pays avec une attention particulière pour les groupes Euro et 'Euro plus UK'. Pour ce faire, un modèle structurel *à la* Harvey (1989) est utilisé, où chaque élément du vecteur de variables dépendantes est décomposé en une tendance et un cycle. Ces composantes non observées sont elles-mêmes divisées en une partie individuelle et une partie commune au groupe entier. Le modèle est estimé par le filtre de Kalman. Nous nous intéressons à la partie cyclique, en observant les interactions entre les éléments propres à chaque pays et les éléments communs.

Trois mesures différentes sont utilisées afin de d'estimer à quel point les co-mouvements et la synchronisation des cycles économiques de la zone Euro sont modifiés lorsque l'on ajoute le Royaume-Uni à ce groupe. Nous nous penchons tout d'abord sur la variance des cycles en utilisant la mesure de Kose et al. (2003). Si le groupe est homogène, la part du cycle commun dans la variance totale du cycle doit être élevée pour tous les pays de ce groupe. Les résultats suggèrent que la part du cycle commun pour le Royaume-Uni n'est pas systématiquement plus basse que pour les pays du groupe Euro. Une deuxième mesure est la densité spectrale. Si les cycles d'un groupe sont homogènes, ils devraient être dominés par des éléments ayant les mêmes fréquences. La densité pour le Royaume-Uni ne diffère pas plus que certains pays de la densité du cycle commun. Ajouter ce pays au groupe Euro ne semble pas avoir d'impact sur la cohésion du groupe. En dernier lieu, nous utilisons les fonctions de corrélations-croisées afin de capturer les co-mouvements n'étant pas parfaitement synchrones. Cela nous permet de distinguer l'intensité des co-mouvements (i.e. la corrélation maximale) et la synchronisation (i.e. le retard après lequel cette corrélation maximale arrive). Il suffit alors de regarder à quel point l'entrée du Royaume-Uni modifie les corrélations entre les cycles individuels et le cycle commun. Pour les séries de PIB, l'ajout du Royaume-Uni n'a pas d'effet sur les corrélations des autres pays, ce qui n'est pas le cas pour les autres variables. Dans tous les cas, l'inclusion de ce pays n'est pas systématiquement associée avec un niveau inférieur de corrélations entre les parties individuelles et communes.

En résumé, les résultats sont différents selon les types de variables utilisés. Cela souligne l'utilité de ne pas étudier seulement les séries de PIB, mais aussi leurs composantes. Les résultats pour les séries de PIB montrent que les caractéristiques du cycle britannique et du cycle commun sont relativement semblables. En même temps, ils suggèrent que le cycle britannique n'a qu'un impact marginal sur le cycle commun du groupe Euro. Pour trois autres séries macroéconomiques, ajouter le Royaume-Uni modifie le cycle commun du groupe Euro. Mais cela n'entraîne pas une plus grande hétérogénéité du groupe. Par ailleurs, le cycle commun diffère plus des cycles allemands ou néerlandais que du cycle britannique.

RÉSUMÉ COURT

Cet article utilise un modèle structurel et le filtre de Kalman afin d'estimer les cycles économiques communs pour différents groupes de pays de l'OCDE. En particulier, l'étude essaye d'évaluer à quel point le cycle commun de la zone Euro est modifié lorsque l'on ajoute le Royaume-Uni à ce groupe. Un résultat important de ce travail est que l'inclusion du Royaume-Uni au groupe Euro n'entraîne pas une plus grande hétérogénéité du groupe dans son ensemble. Par ailleurs, le cycle britannique diffère peu des cycles de la zone Euro. Un autre élément est que l'influence du Royaume-Uni sur le cycle commun `Euro plus Royaume-Uni' est moins évident pour les données de PIB que pour celles de consommation, de dépenses publiques ou d'investissement. Cela souligne l'importance de prendre en compte les composantes du PIB pour l'analyse des cycles économiques.

Classement JEL : E32, F02, F42.
Mots Clés : Cycles Economiques Communs, Royaume-Uni/zone Euro, Zones Monétaires Optimales, Filtre de Kalman.

UK IN OR UK OUT? A COMMON CYCLE ANALYSIS BETWEEN THE UK AND THE EURO ZONE

Julien Garnier[1]

1. INTRODUCTION

The HM Treasury report published in June 2003 for the assessment of the *Five Economic Tests*, noticed that the UK business cycle was not coordinated enough with the Euro zone one. However, some authors –e.g. Massmann & Mitchell (2002), Hall & Yhap (2003)– have recently pointed out that the UK cycle was getting closer to continental Europe. Therefore, the question remains an open issue.

Apart from its political implications, the debate about UK/Euro zone business cycle relations is of importance for economists because it is directly linked to the theory of Optimal Currency Areas (henceforth OCA). Indeed, the ongoing debate about the optimality of the Euro zone goes hand in hand with such a question. The OCA theory tells that a monetary zone is optimal if the business cycles of its members are coordinated, if there is a high mobility of factors between these members and if they trade a lot with one another. The coordination of business cycles is therefore a necessary –although not sufficient– condition for optimality and the HM treasury did consider this issue with great care. The problem is that the theory is rather vague about the degree of business cycles coordination necessary in order to have an optimal zone. Concerning the UK/Euro case, one way could be to make –the rather strong– assumption that the EMU is an OCA. Then, it would suffice to compare the degree of business cycles coordination within the Euro zone with that between the UK and the Euro zone, in order to have an idea about the desirability of the UK to enter the EMU.

Many papers have addressed the issue of business cycles synchronisation within the European Union. A common finding is that the business cycles have become more similar with the European monetary integration process, e.g. Artis & Zhang (1997, 1999), Artis, Kontolemis & Osborn (1997)[2] . The results of Frankel & Rose (1997) go in the same way. At the same time, the UK is found to be more correlated with the US than with the other European countries. But this result appears for data starting in the 60s or 80s. Instead, the papers of Massmann & Mitchell (2002) and Hall & Yhap (2003) point out that larger business cycles co-movements between the UK and the other European countries have occurred during the past decade. More precisely, this phenomenon seems to happen after the German reunification and the European currency crisis periods.

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[1] European University Institute. julien.garnier@iue.it. This paper was started in July-August 2003 while I was doing an internship at the CEPII and for which I would like to thank Lionel Fontagné. I am particularly grateful to Paolo Zanghieri and Agnès Bénassy-Quéré for helpful comments. Of course, any error is mine.

[2] An exception can be found in Inklaar & Haan (2001).

Concerning methodology, we will use the Kalman filter and state-space modelling in order to detect common cycles for different groups of OECD countries. This approach can be directly linked to the litterature on dynamic factor analysis. See, e.g. the seminal article of Forni et al. (2000). However, our task is much more modest since we use a far smaller number of dependent variables and that we restrict the number of common factors to two.

Section 2 presents the model used and section 3 applies it to a group of OECD countries with a special attention to the UK and the Euro zone. The last part concludes.

2. MODELLING APPROACH

We will use in this study Kalman filtering techniques in order to extract common and idiosyncratic cycles from the series. The main idea behind this technique –and this is the case for other filters as well– is that a time series can be decomposed into a sum of elements that are not directly observed. Typically, for macroeconomic series, these elements are a trend and a cycle. When using *ad hoc* tools such as the Hodrick-Prescott filter, the trend will be the output of the filter and the cycle the difference between the series and its trend. The Kalman filter allows somehow a more subtle extraction of these elements. Assumptions about the behaviour of the unobserved components are made –i.e. about their ‘law of motion’– and the Kalman filter optimally extracts these components given these assumptions. This eases the interpretation of the filter output since a structure is put onto the model before extraction. Many different types of components other than the trend or the cycle can be extracted from the series. This structure can be built upon economic theory. See Laubach & Williams (2001) for an application to monetary policy.

We use the structural approach of Harvey (1989) and Harvey & Jaeger (1993), by decomposing the series into a so-called ‘local linear trend’ and a stochastic cycle. This model has received important attention in the recent years. Azevedo et al. (2003) propose an interesting development. They argue that leads and lags relationships are not adequately taken into account with this approach. They use a similar, but more general specification of the model, as in Harvey and Trimbur (2003), which allows to produce cyclical components that have the same properties as band-pass filters. Moreover, they modify the cycle in order to take phase-shifts into account as in Rünstler (2003).

Maravall (1995) shows that two main approaches are used in the unobserved component (UC) framework: in the model based approach, classical ARIMA models are rearranged into a state-space form and are estimated with the Kalman filter. In the structural time series (STS) approach, each state variable has a predefined structure. He points out the flexibility of the unobserved components as a tool and shows that stochastic trends and seasonal components can adequately be estimated. He shows that ad-hoc filtering may lead to spurious cycles, that is, their output may contain elements that do not exist in reality. Harvey & Jaeger (1993) show in a similar way that the Hodrick-Prescott filter can induce distortions in the filtered series.

The structural approach of common features diverges from the part of the literature which is explicitly built upon the cointegration framework. Cointegrated variables share common stochastic trends (King et al., 1991). But other forms exist such as 'serial correlation common features' (Engle & Kozicki, 1993, Vahid & Engle, 1993)[3]. Cubbada (1999) extends the concept of common cycles when the series exhibit unit roots at the zero and at seasonal frequencies. Breitung & Candelon (2000) propose a test for serial correlation common features in the frequency domain.

There seems to be no paper linking explicitly the two approaches. However, we can note that the Granger representation theorem –See Johansen (1995, theorem 4.2)– allows a mapping from the Beveridge-Nelson (BN) decomposition to the parameters of the vector error correction form (VECM)[4]. The paper of Morley et al. (2002) aims at linking the 'cointegration' and UC approaches. Their results suggests that if the assumption of no correlation between trend and cycles innovations is relaxed, the two approaches are identical for the quarterly US GDP.

We will use below a multivariate model with country-specific and common elements. Let $\boldsymbol{y}_t$ be a $k\times 1$ vector composed of macroeconomic series of a given group of countries, with $\mathbf{y}_t = (y_{1,t} \quad \cdots \quad y_{k,t})'$. The model for a given country *i* is assumed to be

$$y_{i,t} = \mu_{i,t} + \psi_{i,t} + \theta_i \mu_t + \omega_i \psi_t + \varepsilon_{i,t}, t = 1,...,T, i = 1,...,k \tag{1}$$

where $\mu_{i,t}$ and $\psi_{i,t}$ are the idiosyncratic trend and cycle, respectively, whereas μ_t and ψ_t are the common trend and common cycle. θ_i and ω_i are coefficients, since the common elements are unlikely to affect equally every country. $\varepsilon_{i,t}$ denotes *n.i.d* disturbances.

Heuristically, the trend is supposed to be a random walk with drift and the cycle is a sum of sine and cosine functions moving at a particular periodicity. See appendix 5 for a full description of the model. We focus essentially on the cyclical elements $\psi_{i,t}$ and ψ_t, which are extracted using the Kalman filter.

[3] Let y_t be I(1). Its elements are *cointegrated* if there exists a linear combination of them which is I(0). Δy_t exhibit a *serial correlation common feature* if there exists a linear combination of its elements that is an innovation with respect to past information, i.e. that is unpredictable.

[4] Since the coefficient associated with the random walk in BN has an exact expression in the Granger representation theorem, as it is a function of the parameters of the VAR equation.

3. UK/EURO BUSINESS CYCLES RELATIONS

We try to see in this empirical study whether the UK business cycle is getting closer to the Euro zone one. Recent papers have found results in this direction (Massman & Mitchell, 2002, Hall & Yhap, 2003). An experiment is conducted where the UK is included into the group of Euro countries[5]. We also examine how the characteristics of the cycles vary when the UK is included into or excluded from this group. Another question is to see whether the UK cycle is more correlated with the countries of the Euro zone or with the US.

Following Kose et al. (2003), we look first at the share of the variance of the common cycle in the total variance of the cycle for each country of a given group. In a second step, spectral densities are computed to see how similar the individual and common cycles are. Finally, correlation functions are used in order to see how the link between the UK, the Euro and the US cycles have evolved in the past two decades.

3.1. Data

The data comes from the *OECD statistical compendium*. We use a panel composed of Belgium, France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the United States for output and three of its expenditure components: consumption, public expenditures and gross fixed capital formation –we will simply refer to this variable as 'investment', below. Series are expressed in constant prices and are indexed with base 1995 Q1 = 100 and are quarterly. Whenever this was possible, no seasonal adjustment was used since Maravall (1995) has pointed out that this could bias the results of UC models. The sample goes from 1980 Q1 to 2002 Q4.

For Germany, some intrapolation was made from the series since it only started in 1991. The series for west-Germany only was available up to 1997 for GDP and 1998 for Consumption. By taking the index of the series for west-Germany it was possible to make a 'backward interpolation' of the series for Germany. This is not realistic at first sight but is not really problematic in our case since we are more interested in the variations of the series than in their levels and that we are looking for the cyclical link among EU/EEC members. Before 1991, it is therefore the behaviour of the Federal Republic of Germany that is relevant. Unfortunately, for public expenditures and investment the series for west-Germany were not available to the author so that this country has been dropped from the analysis in order not to limit too much the sample –which would have started in 1991 otherwise.

[5] By 'Euro zone', we consider in fact France, Germany, Italy, Belgium and the Netherlands, which could be seen as a 'core' group of the Eurozone. The reason is that the number of parameters to be estimated is equal to 8N+5 (N being the number of countries), which becomes untractable with maximum likelihood estimation if the number of countries is too large. Note that these five countries represent 80 to 85% (depending on the years) of the total GDP of the EMU, so we consider this group as an adequate proxy for the Euro zone.

3.2. How much are the cycles determined by the common factor?

3.2.1. Share of common cycle variance in the total cyclical variance

We use below the percentage shares of common cycle variance in the total cyclical variance, in the same spirit as Kose et al. (2003). The aim is to see how much the variability of the cycle is explained by the common part, setting aside the long run movements of the series. For country *i*, this is given by

$$S_i = 100 \frac{\omega_i^2 \sigma_{\tilde{\psi}}^2}{\sigma_{\psi i}^2 + \omega_i^2 \sigma_{\tilde{\psi}}^2 + 2\omega_i \ \mathrm{cov}(\psi_i, \tilde{\psi})}$$

where $\sigma_{\psi i}^2$ and $\sigma_{\tilde{\psi}}^2$ are the variance of the idiosyncratic part and the variance of the common part of the cycle, respectively, whereas ω_i is the loading factor for country *i*. We also use an alternative measure $S2_i$ that does not take the loading coefficient nor the covariance into account

$$S2_i = 100 \frac{\sigma_{\tilde{\psi}}^2}{\sigma_{\psi i}^2 + \sigma_{\tilde{\psi}}^2}$$

It is a simplified measure that aims at correcting for the biases that could happen in S_i. In particular, this could be the case if a low loading factor is induced by non-synchronisation between the idiosyncratic and the common cycle. Recall that this coefficient measures the contribution of the common cycle to the series at time *t* but does not take into account lagged comovements. The disadvantage of this measure is that its interpretation *per se* is less easy than for S_i. However, it eases cross-country comparisons.

Table 1 below compares S_i for three groups of countries –Euro, 'Euro plus UK', and UK/Japan/US – in order to see by how much it is affected by the inclusion of the UK into the Euro group. The third group is used as a control. Table 2 does the same for $S2_i$.

For output, the fact of including the UK into the Euro group does not modify dramatically the value S_i. If the UK was completely disconnected from the Euro zone, there should be a decrease in the share of the variance due to the common cycle, since the group would be more heterogeneous. On the contrary, the inclusion of the UK increases S_i for two countries of the group (Belgium and Germany) out of four. At the same time, the level of S_{UK} (20.28%) is higher than that of the Netherland, Italy and Belgium, and is just below the average of the group. This suggests that the UK plus Euro cycle reflects some homogeneity. The group composed of the UK, Japan and the US has been computed as a benchmark. It reveals that the average share of the cyclical variance explained by the common cycle is around 7%, which is below the figures for the Euro and Euro-plus-UK groups.

For consumption, the values of S_i for the Euro group are much lower than those for output, suggesting that the group is less determined by a common cycle. Besides, the inclusion of the UK induces a large increase in S_i for Italy but no similar variation for the other countries. This could be interpreted as an increase in the heterogeneity of the group. Similar observations could be made for public expenditures and investment.

For the UK/Japan/US group, the values of S_i are roughly in the same range for output – between 4.8 and 9%– whereas there is much more differences for the other macroeconomic aggregates, confirming the idea observed for the Euro and Euro-plus-UK groups that consumption, public expenditures and investment are less influenced by common cycles than output.

Table 1

Percentage share of common cycle variance.
***S* measure of Kose et al. (2003)**

	Output			*Consumption*			*Public Expenditures*			*GFCF*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	11.48	12.61		5.82	1.10		0.17	3.25		6.82	0.85	
France	61.85	59.29		1.68	2.96		7.43	40.83		9.85	34.49	
Germany	19.47	28.33		0.18	0.06							
Italy	20.96	16.90		0.10	37.16		32.20	69.19		9.98	25.07	
Netherlands	0.49	0.22		8.22	3.78		1.01	0.51		0.89	0.53	
UK		20.28	9.03		25.37	2.52		9.66	8.35		85.51	11.83
Japan			4.83			1.96			20.31			0.27
US			7.71			27.93			12.85			0.01
Average	22.85	22.94	7.19	3.20	11.74	10.80	10.20	24.69	13.84	6.88	29.29	4.04

A critic could be addressed to this technique in that the common cycle variance is a function of the loading factor ω_i, which measures the contribution of the common cycle to the series at time *t*. It might be that there is a phase lag between the cycle of the series and the common cycle, even though the series comove. This is the case in particular for the Dutch output series. One would expect the common Euro cycle to influence a lot the cycle of this country since it is quite small compared to its partners. However, S_{NL} is well below the average of the group. This can be explained by a small value of the loading factor (-0.05, see appendix 8.1), reflecting the fact that the common cycle and the Dutch cycle are not synchronised (see table 4 below) even though they comove (table 3).

Table 2 below measures the share of the common cycle variance without taking the loading factor into account. Consequently, the common cycle might be oversized for this measure, but is useful for cross-country comparison. The inclusion of the UK into the Euro group does not lower the share of the common cycle, suggesting that the 'Euro plus UK' group is not more heterogeneous than the Euro group. Note that the share of the common cycle for the Netherlands output series is above the average of the Euro group.

Table 2

Percentage share of common cycle variance.
***S2* measure: var(psi-common) / (var(psi-i)+ var(psi-common))**

	Output			*Consumption*			*Public Expenditures*			*GFCF*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	22.51	23.98		18.76	8.99		11.72	19.79		36.72	36.21	
France	89.94	86.01		45.43	45.37		64.74	86.14		92.82	95.49	
Germany	36.80	47.59		43.71	36.66							
Italy	47.20	38.99		7.94	69.70		88.12	97.71		54.31	69.28	
Netherlands	63.29	65.40		19.03	16.90		27.05	41.90		9.48	10.08	
UK		71.69	36.54		43.12	57.70		28.91	30.89		98.80	56.04
Japan			15.96			9.60			63.23			4.24
US			75.91			82.54			40.28			4.63
Average	51.95	55.61	42.80	26.97	36.79	49.94	47.91	54.89	44.80	48.33	61.97	21.64

If one looks at the ratio of common variance over idiosyncratic variance (appendix 8.1), the value for the Netherlands is in the same range as the other countries. This shows the importance of properly taking phase lags into account as is done in section 3.3.

3.2.2. Spectral densities

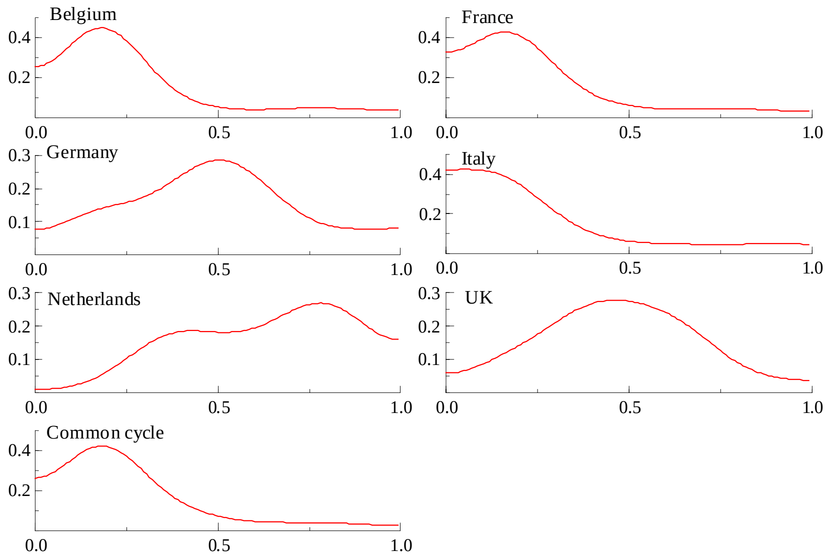
Another useful information is given by the spectral densities of the cycles. A spectral density can be regarded as a decomposition of a series into an infinite number of oscillating elements moving at different periodicities/frequencies. More precisely, almost any time series can be rewritten as an infinite sum of cosine and sine functions with different frequencies: each observation of the series in the time domain is a function of elements expressed in the frequency domain. By taking the inverse of this function, one gets an element –expressed in the frequency domain– which is a function of elements expressed in the time domain. Thus, the spectral density is more or less the expression of the time series (or more precisely, the autocovariance function of the series) in the frequency domain. Suppose that a spectral density has a single peak at one particular frequency ω. Then this series tends to be dominated by elements moving at this frequency and tends to come back at the same point every $p=2\pi/\omega$ periods.

By comparing the spectra of the idiosyncratic parts and of the common part of the cycles, one might get some insight about the homogeneity of the group, depending on whether the cycles are dominated by the same frequencies. By contrast, it could happen that the group is dominated by one country only. In that case the common cycle would be dominated by the frequencies at which this particular country oscillates.

The plots for the Euro-plus-UK group only have been represented below. See the appendix for the Euro and Japan/UK/US groups. The spectral densities were computed using a Parzen window and a truncation parameter of 10.[6]

[6] i.e. the periodogram was computed up to 10 lags/leads

Figure 1 - Spectral densities for `Euro plus UK' group – Output



For output, the spectrum of the common cycle is dominated by frequencies around 0.2.[7]. This shape is pretty similar to that of Belgium, France and to a lesser extent, Italy. The shape of the spectral densities is quite different for the UK, but this is the case for Germany, and the Netherlands as well. For consumption, the bulk of the common cycle is concentrated around the same frequencies as for output (around 0.2) and this is similar to Belgium and Italy –and maybe Germany, although the peak is at a slightly higher frequency. Another, smaller peak can be seen at higher frequencies, suggesting the influence of other countries dominated by higher frequencies: France, the Netherlands and the UK. The third macroeconomic aggregate is Public expenditures. The spectral shape is quite similar once again to that of Belgium, France and Italy. UK and the Netherlands show different behaviour. The similarity between the UK and the Euro group common cycle is higher for investment where the two shapes look quite similar. Recall that Germany has been dropped from public expenditures and investment databases.

In short, the Euro group common cycle spectral density exhibits a similar pattern as densities for Belgium, France and Italy. The UK has quite different shapes but they are not much more dissimilar to the common cycle than that of the Netherlands. Unfortunately, data for Germany was only available for output and consumption. But the estimated cycles for these two variables are dominated by different frequencies than the Euro group common cycle. This interval is higher for output than for consumption.

[7] For convenience, frequencies have been scaled to lie between 0 and 1. The representation between 0 and π is more common.

Figure 2 - Spectral densities for Euro plus UK group – Consumption

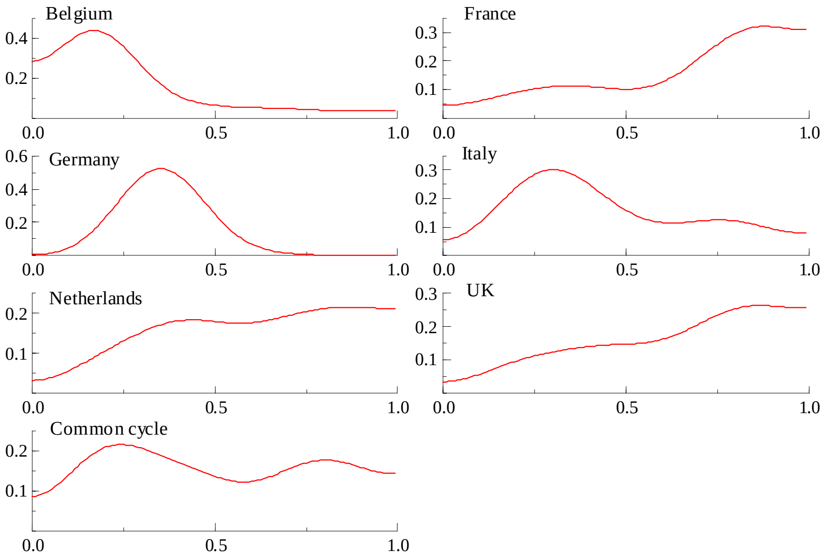


Figure 3 - Spectral densities for Euro plus UK group - Public expenditures

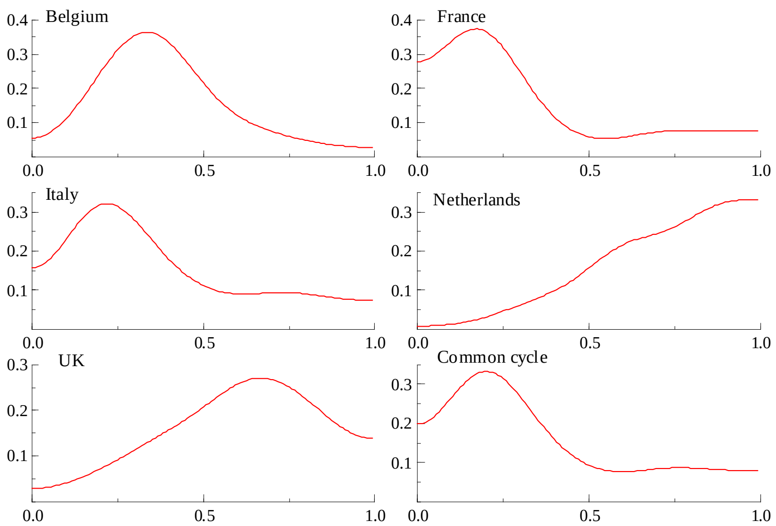
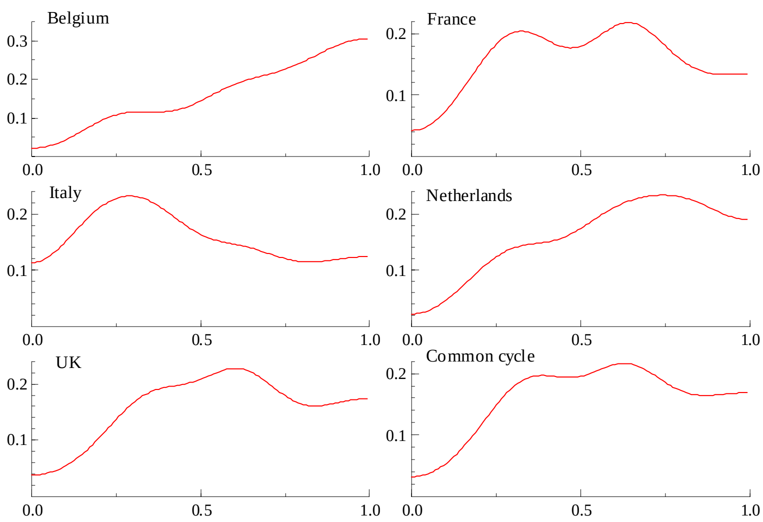


Figure 4 - Spectral densities for Euro plus UK group - Investment



For the Japan/UK/US group –appendix 9– the spectral density common cycle is very similar to that of the US for output, consumption and public expenditures, suggesting the dominating role of this country on the two others. However, for the two last variables, the influence of Japan and the UK on the common cycle is visible. For investment there is surprisingly an important difference between the US and the common cycle.

3.3. Correlation/synchronisation of the cycles

We use in this paragraph lagged *maximum* correlations in order to see how much the series comove and how much they are synchronised. It is clear that simple correlations are not sufficient from this point of view since they do not capture the lagged movements of the series. Using the above procedure, we estimate the cyclical part for each individual series and for several groups of countries. For each pair of series, correlations are computed at different lags[8], and the maximum correlation is stored, together with the corresponding lag ($max\ C_{xy}(\tau)$ and $argmax\ C_{xy}(\tau)$, respectively). The information contained in these two measures gives some insight about the way the series comove and about their synchronisation.

3.3.1. Correlation within groups

We examine here how the individual and common cycles are correlated within each group –Euro, Euro-plus-UK and Japan/UK/US. This will complement the information provided

[8] For two series x_t and y_t we compute the correlation function $C_{xy}(\tau) = E[(x_t - \bar{x})(y_{t+\tau} - \bar{y})] / \sigma_x \sigma_y$, τ = -*n*,...,*n*. Here we have set *n* = 6.

by the variance shares of the previous paragraph. Table 3 below measures maximum correlations between the individual cycles $(\psi_{i,t} + \omega_i \tilde{\psi}_t)$ and the common part $\tilde{\psi}_t$ of the cycles. See eq.(11). It shall be noted that $\tilde{\psi}_t$ is a part of the two variables. Therefore, instead of focusing on whether they are correlated or not, or on the level of this correlation, we will concentrate on the comparison of the correlations between groups. We look below at the effect of the inclusion of the UK into the Euro group and at the comparison Euro group, Japan/UK/US group.

Whole Sample

Table 3

Maximum correlations between univariate and common cycles

	Output			*Consumption*			*Public Expenditures*			*Investment*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	0.63	0.62		0.34	0.51		0.36	0.16		0.51	0.25	
France	0.79	0.79		0.23	0.19		0.40	0.32		0.20	0.50	
Germany	0.34	0.34		0.14	0.16							
Italy	0.56	0.54		0.34	0.57		0.31	0.66		0.67	0.23	
Netherlands	0.20	0.22		0.43	0.26		0.20	0.13		0.20	0.19	
UK		0.42	0.51		0.60	0.30		0.35	0.51		0.39	0.57
Japan			0.38			0.20			0.72			0.72
US			0.71			0.95			0.65			0.24
		(0.5)			(0.34)			(0.32)			(0.29)	
Average	0.50	0.49	0.53	0.30	0.38	0.48	0.32	0.32	0.63	0.39	0.31	0.51

nb: the average for Euro group only is in brackets

For output, the average correlation is higher for the group Japan/UK/US than for the Euro group (0.53 against 0.50), but the figures are in the same range. Besides, the three highest correlations (Belgium, France and Italy) are higher on average than that of Japan/UK/US. Turning now to the inclusion of the UK into the Euro group, we see that it does not modify much the figures. In addition, the correlation of the UK cycle with the common cycle is higher than that of Germany and the Netherlands. This suggests a similar observation as in the precedent paragraph. The UK business cycle exhibits some homogeneity with the Euro group, since its inclusion into the group does not modify much the structure of the relations of the individual cycles.

The inclusion of the UK modifies more the levels of the correlation for consumption than for output. However, correlation increases for three countries of the group, namely France, Germany and Italy. The UK cycle is more correlated with the common cycle than the other countries, suggesting that it has somehow ‘attracted’ the common cycle, thereby indicating an effect of the UK business cycle on the common cycle. However, the fact that the average correlation increases for the Euro group tends to show that including the UK does not entail more heterogeneity for this group. Similar remarks can be done for public expenditures and physical investment: the UK cycle is as much correlated with the common cycle as the average of the Euro group, but its inclusion leads to a modification of the correlations structure of this group.

An important fact to be noticed is that the average *within* correlation is higher for the Japan/UK/US group than for the Euro or Euro-plus-UK groups. An interpretation, in line with Kose et al. (2003), could be that the common component at the world level plays a larger role than at the continental level.

Table 11 in Appendix *10* also presents contemporaneous correlations for comparison.

The average lags are presented below. They measure the lag at which the first and the second series are mostly correlated. A negative value implies that the individual country leads the common cycle. For output, all the countries of the Euro group are in phase, at the exception of the Netherlands, and the inclusion of the UK into the Euro group does not affect this synchronicity. However, this is not the case for the components of output. The Euro-plus-UK group has a different lag structure than the Euro group, revealing once again how the UK modifies the common cycle for these variables. For instance, Belgium, France and Italy lead the common cycle for the consumption of the Euro group, whereas they are more or less in phase with for the Euro-plus-UK group. Inversely, the Netherlands are in phase with the common cycle in the first case, and lead it in the second case. A surprising result is that the German cycle lags the common cycle of the Euro zone for this variable, which seems counter-intuitive.

Note that the Japan/UK/US group is more synchronised. For all variables, the three countries seem to be in phase. The only minor exceptions being consumption where Japan leads by one quarter and investment where the US leads by 3 quarters.

Table 4

Average lags between univariate and common cycles

	Output			*Consumption*			*Public Expenditures*			*Investment*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	0	0		-4	0		6	0		0	5	
France	0	0		-2	1		0	4		2	0	
Germany	0	0		4	-2							
Italy	0	0		-4	0		-4	0		0	-1	
Netherlands	-1	-1		0	-3		-2	-3		-2	0	
UK		0	0		0	0		0	0		0	0
Japan			0			-1			0			0
US			0			0			0			-3

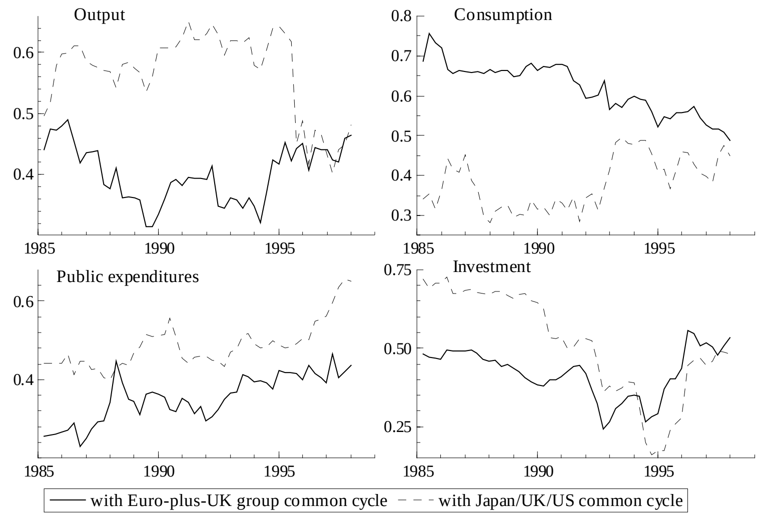
Rolling correlations

We use rolling correlations in order to see the evolution of the comovements and the synchronisation. A window equal to 40 observations (10 years) was selected[9]. We focus on

[9] The size of the window is constrained below by the number of lags taken into account in the correlation function. Indeed, the number of observations taken in the rolling correlation is equal to *n-r*, where *r* is the number of lags in the lagged correlation of the (mean-adjusted) variables x_t and y_t: $corr[x_t, y_{t+r}] = E[x_t y_{t+r}] / \sigma_x \sigma_y$, $r = -\tau,...,\tau$. At the same time, *n* is constrained above by the sample size, quite small here.

maximum correlations as explained above. Here the evolution of the correlation of the UK cycle with the common part of the group. The dates indicate the centre of the rolling window –i.e. the first date, 1985q1 indicates a correlations on the sample 1980q1-1990q1.

Figure 5 - Rolling correlation between UK cycle and Euro-plus-UK or Japan/UK/US common cycles



Four different patterns can be observed from the figure above. For output and public expenditures, the UK is more correlated with the Japan/UK/US common cycle than with the Euro group one. For the former series the difference disappears in the last years (from 1996 to 1998, i.e. over a period comprised between 1991 and 2003). For the latter series, the correlation of the UK cycle with both common cycles grows but is higher with the Japan/UK/US group. Inversely, the correlation with the Euro group common cycle is higher for consumption, although it tends to decrease. The difference between the two measures diminishes in the most recent years. Overall, it seems that there is an increasing similarity between the UK/Euro-plus-UK and UK/Japan-UK-US cyclical relations. The exception being public expenditures, for which both correlations tend to increase.

We now take the problem from another perspective and look at the correlations for the Euro group. How are they affected by the inclusion of the UK? Plots of the correlations between the idiosyncratic and the common cycle for the different countries of the Euro groups are displayed in appendix 10.2.1. They suggest that the effect of this inclusion is only marginal for output. See also appendix 10.2.2, which shows that the UK cycle is not modified by its inclusion into the Euro group nor is the Euro common cycle affected by the inclusion of the UK. This leads to two opposite interpretations. 1/ The UK cycle is either perfectly coordinated with the Euro zone common business cycle such that it does not modify it. 2/ Or the UK cycle is orthogonal to the common cycle of this group, such that they do not share any common cycle. The results obtained for variance shares (paragraph 3.2.1) and for spectral densities (3.2.2) would be more coherent with the first interpretation. However, this issue remains open.

On the contrary, the effect is quite important for consumption, public expenditures and investment. However, there is no systematic decrease in the correlation associated with the inclusion of the UK.

3.3.2. Correlations between cycles for different groups

We compare now the cycles across different groups or between groups and univariate series. In the latter case, we compare the common cycle of the group –as estimated in (12) and (13)– and the cycle obtained from the system (7)-(8). This will be the case for, e.g. the Euro zone and the UK.

Whole sample

Table 5 shows the effect of including the UK into the Euro group for correlations of the Euro zone with other countries[10]. The correlation Euro/US should increase when the UK is included in the former group. Surprisingly, this correlation increases only slightly for output and decreases for the components of output. Another thing is that the correlation with the group *Ja/UK/US* should be much higher for Euro-plus-UK than for Euro alone, since the UK is present on both sides. However, this is not the case and the increase is quite small for all variables. An explanation could be that the UK only accounts for a small share of the Japan-UK-US and Euro-plus-UK groups common cycles. This is plausible for output, since we have seen above that the common cycle of the Euro zone was not much affected by the UK, but it is a bit more striking for the other variables. Anyway, these remarks seem to weaken the view according to which the UK is closer to the US cycle than to the Euro one.

Table 5

Maximum Correlations between univariate or common cycles

	Output		*Consumption*		*Public expenditures*		*Investment*	
	Euro	*Euro+ UK*	*Euro*	*Euro+ UK*	*Euro*	*Euro+ UK*	*Euro*	*Euro+ UK*
Ja/ UK/ US	0.20	0.21	0.07	0.10	0.26	0.27	0.18	0.19
UK	0.28	0.42	0.16	0.60	0.22	0.35	0.19	0.39
US	0.15	0.19	0.13	0.10	0.32	0.24	0.18	0.13
Jap.	0.14	0.13	0.16	0.20	0.14	0.20	0.09	0.19

Table 6 is dedicated to the analysis of synchronisation between cycles. The US cycle is in phase with the Euro cycle for output but leads it for investment. Note that approximately the same structure is visible for row 1 (‘*Ja/UK/US*’) and for row 3 (US), which shows that

[10] The correlations where UK is present on both sides – *Ja/UK/US* with *Euro+UK* and *UK* with *Euro+UK* – are presented for control.

the common cycle of the *Ja/UK/US* group is pretty similar to the US cycle. Concerning the effect of including the UK, it does not modify the structure for output and modifies it slightly for investment. At the opposite, the time concordance between the Euro group and the US cycles is quite different from the relation between the US and the *Euro+UK* cycles for consumption and public expenditures. Therefore, the UK modifies the Euro group common cycles substantially.

Table 6

Average lags between univariate or common cycles

	Output		*Cons.*		*Public exp.*		*Invest.*	
	Euro	*Euro+UK*	*Euro*	*Euro+UK*	*Euro*	*Euro+UK*	*Euro*	*Euro+UK*
Ja/UK/US	-2	0	-3	1	6	-6	-4	-6
UK	0	0	3	0	6	0	1	0
US	0	0	-3	1	6	-6	-4	-6
Jap.	-1	-1	4	-1	-1	4	-2	-3

nb: a negative value means that the cycle in row leads the one in column

Table 7

Maximum Correlations - UK/partners

	Output	*Cons.*	*Public exp.*	*Invest.*
Euro	0.28	0.16	0.22	0.19
US	0.25	0.19	0.24	0.27
Jap.	0.10	0.23	0.21	0.11

Table 8

Average lags - UK/partners

	Output	*Cons.*	*Public exp.*	*Invest.*
Euro	0	-3	-6	-1
US	1	1	-6	-3
Jap.	-6	-1	3	-6

nb: a negative value means that the cycle in row leads the UK

Rolling correlations

Figure 6 - Maximum correlations between UK cycle and Euro common cycle or US cycle

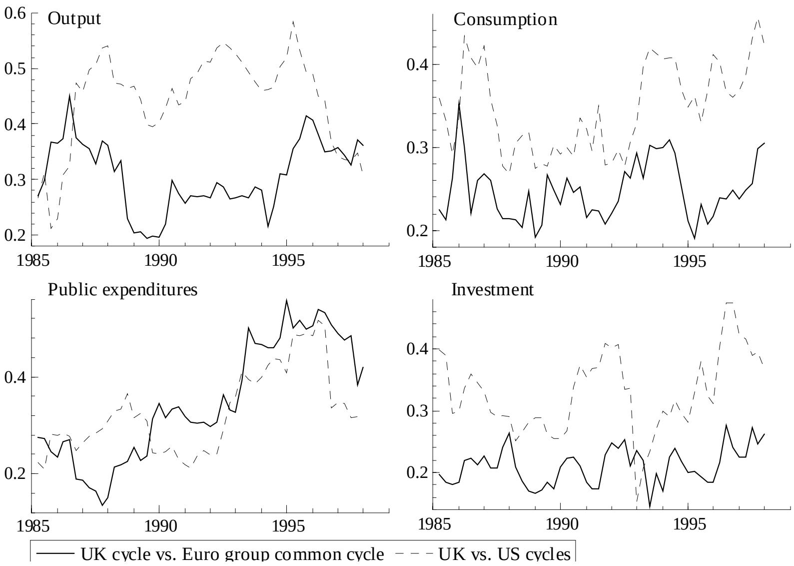


Figure 6 shows the rolling correlations between the UK and the Euro group common cycle and between the UK and the US cycles. For output, the average correlation is higher with the US than with the Euro group, confirming previous findings in the literature (e.g. Artis & Zhang, 1997). At the exception of public expenditures, the correlation for the other variables is higher for UK/US than for UK/Euro zone. A noticeable feature is that the correlation with the Euro group tend to increase in the last part of the sample, in particular after 1994 (i.e. correlations calculated over 1989-1999 and after), which is in line with Massmann & Mitchell (2002) and Hall & Yhap (2003).

If the UK is more correlated with the US than with the Euro group, one should normally find that including the UK into the Euro group lead to a higher correlation with the US. However, it is difficult to draw such a conclusion from figure 7, apart from output where there is only a slight increase and investment in the first part of the plot. This suggests that including the UK into the Euro group does lead to a modification of the common cycle but not necessarily in a way that makes it more correlated with the US cycle. The UK cycle is closer to the US cycle than the other EU countries, but only for output series. The components of output have different patterns.

Figure 7 - Maximum correlation of US cycle with the Euro or Euro-plus-UK common cycle

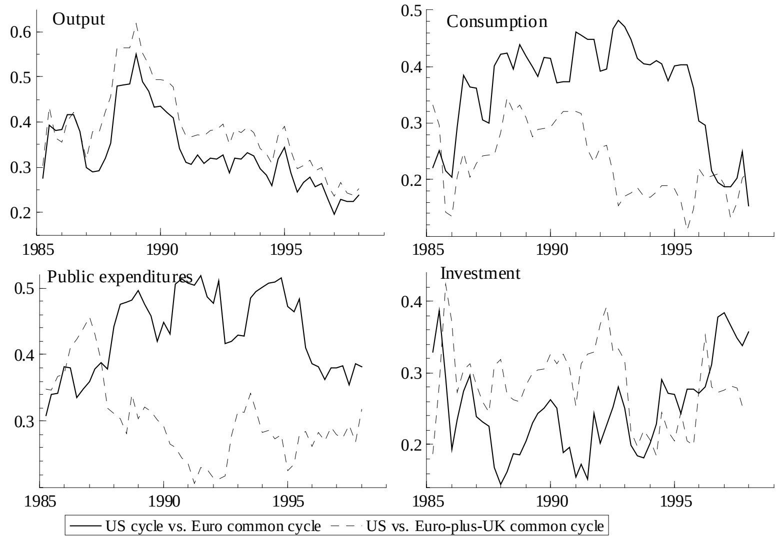
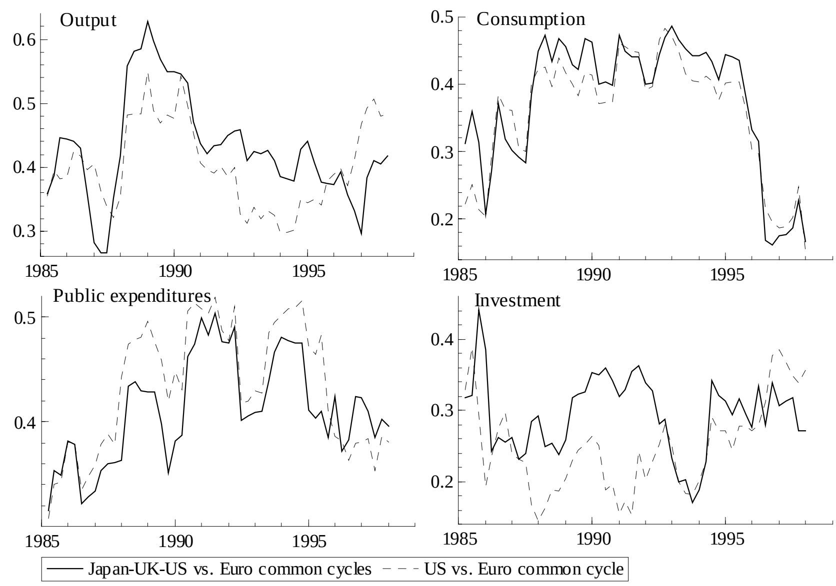


Figure 8 - Maximum correlation of Euro-group with the `rest of the world' common cycles



4. CONCLUSION

We have used in this study a structural time series estimated by the Kalman filter in order to extract idiosyncratic and common cycles for different groups of OECD countries. A particular attention was given to the relation between the UK and the Euro zone. Indeed, there is an ongoing debate about the business cycle links between the UK and continental Europe.

The results for GDP series are partly in line with the existing literature. On the one hand, it seems that the UK cycle is closer to the US cycle than to the Euro area one, which is in line with the findings of e.g. Artis et al. (1997). On the other hand, the correlation with the Euro common cycle has tended to increase since the beginning of the past decade as is the case for Massmann & Mitchell (2002) and Hall & Yhap (2003). At the same time, the UK output cycle does not modify much the common cycle of the Euro zone when it is incorporated into this group.

The results for the other macroeconomic series used here –consumption, public expenditures and physical investments– diverge from those of GDP in that the inclusion of the UK into the Euro group modifies the common cycle of the group. Besides, the share of the common cycle variance into the total cyclical variance is not lower for the UK than for the members of EMU, which tends to show that the UK cycle is not less determined by the common cycle than the Euro countries. Another argument is that the inclusion of the UK into the Euro-group does not lower the average correlations of the Euro countries with the common cycle, indicating that the modification of the common cycle induced by the inclusion of the UK does not mean that the group becomes more heterogenous. The spectral density of the UK cycle does not exhibit major differences in its shape from the common cycle, except for public expenditures. In any case, it does not depart more from the common cycle than the Dutch cycle or -to a lesser extent given data availability- to the German one. These results depart from existing literature.

For synchronisation, the GDP cycles of the Euro countries are in phase with the common cycle on average, except the Netherlands. Adding the UK to the Euro group does not modify this fact. However, the addition of the UK modifies the common cycle for variables other than output. Consequently, the synchronisation between Euro countries idiosyncratic cycles and the common cycle is affected for these variables. At the same time, for all of the variables the UK is synchronised with the common cycle. This suggests that the UK cycle is not completely disconnected from the Euro zone business cycle.

The general result of this work is that the UK business cycle is not much different from the Euro zone cycles. Moreover, adding the UK to the Euro group does not lead to a greater heterogeneity of the group as a whole. A second important point is that weaker results are found for output series than for consumption, public expenditures or investment series. This suggests the importance of taking the components of output into account when looking at international business cycles. One might also conclude that the business cycles links between the UK and continental Europe have been underestimated in the literature since much emphasis was put onto output series.

Business cycle coordination can be seen as a necessary condition for having an OCA. In that case –and provided that the Euro zone is an OCA itself– the policy implication of this paper is that it is not possible to reject the hypothesis according to which the 'Euro-plus-UK' zone would be an OCA. In other words, under the assumption that the Euro zone is optimal, one cannot tell *a priori* that the 'business cycles condition' is not fulfilled for the Euro-plus-UK zone. Of course, postulating that the Euro zone is an OCA is quite strong. But one could make a weaker statement and see the Euro area as a 'workable' monetary zone. The results of this paper would then suggest that the Euro-plus-UK zone could be a workable monetary zone as well.

APPENDICES

5. MODEL

5.1. Baseline model

We use the structural decomposition of the Harvey type (Harvey, 1989). Each observed variable *i* is determined by two unobserved components, a trend $\mu_{i,t}$ and a cycle $\psi_{i,t}$.

$$y_{i,t} = \alpha_i^{'}\mathbf{x}_{i,t} + \mu_{i,t} + \psi_{i,t} + \varepsilon_{i,t},\ t = 1,...,T,\ i = 1,...,k \tag{2}$$

$\mathbf{x}_{i,t}$ corresponds to external variables –seasonal dummies and information variables for outliers and structural breaks. See the description of the procedure in appendix 7. α_i denotes the corresponding coefficients. Note that in order to ease the presentation, we drop this term below.

Suppose also that $\varepsilon_{i,t} \sim NID(0, \sigma^2_{\varepsilon i})$. In addition, suppose that the trend has the 'local linear' form –i.e. it is a random walk with a drift that is itself a random walk.

$$\mu_{i,t} = \mu_{i,t-1} + \beta_{i,t-1} + u_{i,t},\ u_{i,t} \sim NID(0, \sigma^2_{i,u}) \tag{3}$$

$$\beta_{i,t} = \beta_{i,t-1} + v_{i,t}, v_{i,t} \sim NID(0, \sigma^2_{i,v}) \tag{4}$$

The cycle $\psi_{i,t}$ is part of the process generated by

$$\begin{pmatrix} \psi_{i,t} \\ \psi^*_{i,t} \end{pmatrix} = \rho_i \begin{pmatrix} \cos\omega_i & \sin\omega_i \\ -\sin\omega_i & \cos\omega_i \end{pmatrix} \begin{pmatrix} \psi_{i,t} \\ \psi^*_{i,t} \end{pmatrix} + \begin{pmatrix} \kappa_{i,t} \\ \kappa^*_{i,t} \end{pmatrix} \tag{5}$$

ρ is the so-called 'damping factor'. It belongs to the interval [0,1]. Note that (5) is simply a way to put in a state space form the oscillating process $\psi_{i,t} = \rho_i cos\omega_i t + \rho_i sin\omega_i t + \kappa_{i,t}$. Besides, as shown by Harvey (1989), the cyclical process can be rewritten as an ARMA(2,1) and $0 \leq \rho \leq 1$ is a requirement for the roots to lie outside the unit circle. At the limit, when $\rho = 0$, the cycle becomes purely white noise. When $\rho = 1$, the process exhibits a unit root. The error terms $\kappa_{i,t}$ and $\kappa^*_{i,t}$ are supposed to be *NID* with mean zero and variances $\sigma^2_{i,\kappa}$ and $\sigma^2_{i,\kappa*}$, respectively.

Note that it is also assumed that the error terms are uncorrelated, such that

$$\Omega_i = \begin{pmatrix} \sigma^2_{\varepsilon_i} & 0 \\ 0 & \mathbf{P}_i \end{pmatrix} \text{ where } \mathbf{P}_i = diag(\sigma^2_{i,u} \quad \sigma^2_{i,v} \quad \sigma^2_{i,\kappa} \quad \sigma^2_{i,\kappa*}) \tag{6}$$

We will see below that a restriction is imposed in that $\sigma^2_{i,\kappa} = \sigma^2_{i,\kappa*}$.

Putting this univariate model into a state space form gives,

$$y_{i,t} = \mathbf{z}\zeta_{i,t} + \varepsilon_{i,t} \tag{7}$$

$$\zeta_{i,t+1} = \tau_i \zeta_{i,t} + \eta_{i,t} \tag{8}$$

with $\zeta'_{i,t} = \begin{pmatrix} \mu_{i,t} & \beta_{i,t} & \psi_{i,t} & \psi^*_{i,t} \end{pmatrix}$ and $\eta'_{i,t} = \begin{pmatrix} u_{i,t} & v_{i,t} & \kappa_{i,t} & \kappa^*_{i,t} \end{pmatrix}$. Besides, $\mathbf{z} = \begin{pmatrix} 1 & 0 & 1 & 0 \end{pmatrix}$ and τ_i a (4×4) matrix:

$$\tau_i = \begin{pmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \alpha_i & \beta_i \\ 0 & 0 & \gamma_i & \delta_i \end{pmatrix}$$

where the sub-matrix $\begin{pmatrix} \alpha_i & \beta_i \\ \gamma_i & \delta_i \end{pmatrix}$ is the coefficient matrix of the cyclical component defined in (5). (7) is the measurement equation and (8) is the state equation. $\mathbf{z}\zeta_{i,t} = y_{i,t} - \varepsilon_{i,t}$ is the signal.

5.2. Multivariate setting

Leaving apart any common component consideration, the multivariate specification of the model is straightforward. We get

$$\underset{k\times 1}{\mathbf{y}_t} = \mathbf{Z}\zeta_t + \varepsilon_t \tag{9}$$

$$\underset{km\times 1}{\zeta_{t+1}} = \mathbf{T}\zeta_t + \eta_t \tag{10}$$

with y_t being a vector of observed variables, $\zeta_t^{'} = \left(\zeta_{1,t}^{'} \quad \ldots \quad \zeta_{k,t}^{'}\right)$, $\mathbf{Z} = I_k \otimes \mathbf{z}$ and $\mathbf{T} = diag\left(\tau_1 \quad \ldots \quad \tau_k\right)$. *m* is the number of state variables and *k* is the number of countries. In the present case, *m* = 4. However, this is no longer the case when additional state variables are added to the model[11] .

5.2.1. Common components

Assume now that each observed series is not only determined by the idiosyncratic unobserved variables of (2), but also by components common to all the other series. Common elements are treated as principal factors. The task of this paper is much more modest than in the often cited article of Forni et al. (2000). First because we have far less variables and second because we make the assumption that there is just one common cycle. This assumption obliges us to include idiosyncratic elements as well for each of the variables. Otherwise, this would come down to assuming that every element of the dependent vector is entirely determined by the common element, while the remaining part is white noise. This would certainly be a too strong assumption. Thus there are two common factors, one common trend and one common cycle. The assumption that there is only one common factor of each type is relatively strong, but simplifies the interpretation in terms of a *European cycle* or any other common cycle, and is necessary for our task.

$$y_{i,t} = \mu_{i,t} + \psi_{i,t} + \theta_i \mu_t + \omega_i \psi_t + \varepsilon_{i,t},\ t = 1,\ldots,T,\ i = 1,\ldots,k \tag{11}$$

where μ_t and ψ_t are the common trend and common cycle, respectively, and θ_i and ω_i the corresponding loading coefficients for country *i*. The assumption is made that both (absolute values of the) coefficients belong to the interval [0,1], which is equivalent to assuming that the common elements do not determine the series as much as the idiosyncratic part. The multivariate model becomes

$$\underset{k\times 1}{\mathbf{y}_t} = \mathbf{Z}^* \zeta_t^* + \varepsilon_t \tag{12}$$

$$\underset{(km+m)\times 1}{\zeta_{t+1}^*} = \mathbf{T}^* \zeta_t^* + \eta_t \tag{13}$$

where

$$Z^* = \begin{pmatrix} Z & \Theta & 0_{k\times 1} & \Omega & 0_{k\times 1} \end{pmatrix}$$

[11] Namely, seasonal dummies and information variables for outliers and structural breaks. Typically, the number of information variables will vary from one country to the other, depending on the tests implemented -see below- so that *m* is not known in advance.

with **Θ** and **Ω** being $k\times1$ vectors containing the loading coefficients and $\mathbf{0}_{k\times1}$ being vectors of zeros. Also

$$\underset{(4k+4)\times(4k+4)}{\mathbf{T}^{*}} = diag(\mathbf{T} \quad \tau) = diag\left(\tau_1 \quad \ldots \quad \tau_k \quad \tau\right)$$

$$\zeta_t^{*'} = (\zeta_t^{'} \quad \zeta_t^{'}) = \left(\zeta_{1,t}^{'} \quad \ldots \quad \zeta_{k,t}^{'} \quad \zeta_t^{'}\right)$$

5.3. Estimation

The idiosyncratic and common cycles are estimated by the Kalman smoother. A presentation of the Kalman filter and smoother goes well beyond the scope of this paper. See Harvey (1989 chap.3) for an extensive treatment of the topic. See also Proietti (2002, appendix C). All computations were performed with the library SsfPack version 2.2 of Koopman, Shephard and Doornik[12]. For an extensive documentation on this library, see Koopman et al. (1999). Codes and data are available upon request.

5.3.1. *Maximum Likelihood estimation and identifiability*

The parameters are estimated first by maximum likelihood. See appendix 6. The procedure used here for MLE is the one of Koopman et al. (1999, p.140), based upon the BFGS numerical optimisation method. Some restrictions must be imposed on the parameters of the model in order to get full identification, in the sense that one cannot find two different sets of parameters that produce the same joint density function. We impose first positive definiteness of the variances. Harvey (1989) shows that the local linear trend model is identified, provided that the disturbances are normally distributed and mutually uncorrelated. He shows also that the conditions $\rho > 0$, $\omega \in [0,\pi]$ and $E[\kappa_t \kappa_t^*] = 0$ in the stochastic cycle model are sufficient to insure identifiability. Note that $\sigma_{i,\kappa}^2 = \sigma_{i,\kappa*}^2$ is not required. However, this restriction has been imposed on the model as it is a common practice in the literature (e.g. Harvey & Jaeger, 1993 or Proietti, 2002) and as the estimations seemed more stable with this additional restriction. To sum up, the main restrictions are given by (6) and by ρ .and ω ($\omega \in [0,\pi]$ and $\rho \in [0,1]$, $\forall i$),

Additional restrictions are placed upon the common components. It is common in dynamic factor analysis to set the covariance matrix of the error terms of the common factors equal to an identity matrix. However, since we do want to compare the share of the variance due to the common cycle, we have to be a bit more careful in the selection, in order to have variances in the same range. The variance of the error term of the common part was set equal to the mean of the error terms of the idiosyncratic parts, such that $\sigma_e^2 = \frac{1}{k}\sum_i \sigma_{i,e}^2$,

[12] Available at www.ssfpack.com

$e=\{u,v,\kappa\}$. For some reasons that remain obscure to the author, ρ, the damping factor of the common cycle, tends to increase with the number of countries in the group under consideration. To avoid this problem, we set $\rho = \frac{1}{k}\sum_i \rho_i$.

5.3.2. Setting starting values for the Kalman filter

The Kalman filter estimates optimally the value of the state vector at time *t*. But this optimal estimation requires that the system matrices, as well as the initial state vector $\zeta^{*,0}$ and covariance matrix of the initial state vector, $\boldsymbol{P}_0$, are known. Usually, $\zeta^{*,0}$ and $\boldsymbol{P}_0$ are set such that they are the mean and covariance matrix of the unconditional distribution of $\zeta^{*,t}$. Harvey (1989, p.121) shows that for the stochastic cycle model, the initial conditions are a zero mean and a covariance matrix $\mathbf{P}_0 = \left[\sigma_\kappa^2/(1-\rho^2)\right]\mathbf{I}_2$, where $\sigma^{2,\kappa}$ and ρ^2 are the same as above and $\boldsymbol{I}_2$ is a (2×2) identity matrix. Given the values of $\sigma^{2,\kappa}$ and ρ^2 found in the ML estimations, $\boldsymbol{P}_0$ will oscillate in general between 10^{-2} and 10^{-3}. In order to simplify the calculations, we have taken an arbitrarily small value and set $\boldsymbol{P}_0=10^{-8}$ here. The results should not be too much affected by this choice.

When the state equation is not stationary, which is the case for the local linear trend, the unconditional distribution of the state vector is not available. One must therefore use a non-informative initial condition. This is best achieved by using a diffuse prior such that $\mathbf{P}_0 = v\mathbf{I}$, where $v \to \infty$. In practice, we follow Koopman et al. (1999) who use $v=10^6$.

6. ALGORITHM USED:

1. Put model into state space form.

2. Estimate the parameters by maximum likelihood (ML).

3. Compute de Jong and Penzer outliers and structural break tests and create dummies accordingly.

4. Incorporate dummies into the state space model.

5. Re-estimate the parameters by ML.

6. Compute the Kalman smoother and extract relevant smoothed state variables (here idiosyncratic and common cycles).

7. DE JONG & PENZER (1998)' OUTLIERS AND STRUCTURAL BREAKS TESTS

An important question which is often underestimated in the empirical business cycles literature, is the one of outliers and structural breaks. Indeed, abnormal movements in the data due to measurement errors or extreme shocks affecting the economy should be excluded from the analysis. If this is not the case, the estimated model may be biased.

Tests for structural breaks and outliers in a state-space framework[13] were presented by DeJong and Penzer (1998). See also Koopman et al. (1999). Thanks to the relative flexibility of the SsfPack library, the implementation of such tests is relatively simple. The test is based on the residuals associated with the state space model, estimated via the Kalman filter. Harvey and Koopman (1992) show that these so-called auxiliary residuals can be used to detect outliers and structural breaks.

The idea behind the test is that the system is driven by some unobserved components (UC, or state variables) which capture its true behaviour –recall that the Kalman filter optimally extracts state variables. If the model is chosen adequately, the observed series –or measurement equation– is then the sum of a signal and a white noise. However, some shocks to the system cannot be taken into account properly by the model, i.e. outliers and structural breaks. If the disturbance term exhibit aberrant behaviour at some point and cannot be considered as white noise, there must be such a shock at this point. Of course, these tests work under the assumption that the model is the true one, i.e. that the state equations are chosen adequately.

Once the tests have been conducted and that the outliers and structural breaks have been detected, the corresponding information vectors are added to the model. For outliers, they consist in dummy variables equal to one at the time of the outlier and zero elsewhere. For structural breaks, the variable is equal to zero before the date of the break and equal to one after.

Consider the state space system of (9) and (10) and modify the notation slightly such that:

$$\underset{k\times 1}{\mathbf{y}_t} = \mathbf{Z}\zeta_t + \mathbf{G}_t\varepsilon_t \tag{14}$$

$$\underset{m\times 1}{\zeta_{t+1}} = \mathbf{T}\zeta_t + \mathbf{H}_t\varepsilon_t \tag{15}$$

Suppose one believes there is an outlier or a level shift at time *t*. The traditional way to test for this is to include an explanatory variable that takes such a shock into account – e.g. a dummy equal to one at the time of the sock and zero elsewhere. It is sufficient to regress

[13] Note that the tests proposed by the authors can be seen more generally as tests for unusual behaviour of the state variables. One could test as well for abnormal cycles or even abnormal moving average terms –in the VAR state-space framework.

this variable onto the dependent variables and to test if the coefficient is different from zero or not. Let δ be this coefficient, D an explanatory variable and $\sigma^2\Sigma$ the covariance matrix of y_t. Using GLS, we get

$$\hat{\delta} = (D'\Sigma^{-1}D)^{-1}D'\Sigma^{-1}y = S^{-1}s$$

The test of H_0:δ=0 uses the statistic

$$\tau^2 = \hat{\sigma}^{2} s' S^{-1} s$$

which has an approximate χ_p^2 distribution where p is the number of linearly independent columns of D. de Jong & Penzer show[14] that the maximum ρ^{*2} of $\rho^2 = \tau^2 / \hat{\sigma}^2$ is

$$\rho_t^{*2} = \mathbf{v}_t'\mathbf{F}_t^{-1}\mathbf{v}_t + \mathbf{r}_t'\mathbf{N}_t^{-1}\mathbf{r}_t \tag{16}$$

where $\mathbf{v}_t = \mathbf{G}_t\varepsilon_t$ is the prediction error and $\boldsymbol{F}_t$ is the prediction variance of $\boldsymbol{y}_t$. $\boldsymbol{v}_t$ and $\boldsymbol{F}_t$ are estimated by the Kalman filter. $\boldsymbol{r}_t$ is the backward prediction error and $\boldsymbol{N}_t$ is the backward prediction variance of ζ_t. $\boldsymbol{r}_t$ and $\boldsymbol{N}_t$ are estimated by the Kalman smoother. Therefore, the first term in the RHS of (16) corresponds to the observation equation and the second term corresponds to the state equation. It is not difficult to see from (14) and (15) that the former indicates abnormal shocks that affect y_t for one period only (i.e. outliers) whereas the latter indicates shocks that affect the level of y_t permanently (i.e. structural breaks). Two important results of de Jong & Penzer are that the maximum (16) is also attained when the shocks are uncorrelated and that $\rho_t^{*2} = \mathbf{r}_t'\mathbf{N}_t^{-1}\mathbf{r}_t$ when there is no outlier and $\rho_t^{*2} = \mathbf{u}_t'\mathbf{M}_t^{-1}\mathbf{u}_t$ when there is no shock to the trend. $\boldsymbol{u}_t$ is the backward prediction error and $\boldsymbol{M}_t$ is the backward prediction variance of y_t, obtained from the Kalman smoother. This implies that it is possible to test separately for the different types of abnormal shocks. The authors note that both terms of the RHS of (16) follow chi-squared distributions with degrees of freedom equal to the number of components in the measurement and the state equation, respectively. Therefore, ρ_t^{*2} follows a chi-squared distribution as well.

[14] Theorem 3, p801.

8. DECOMPOSITION OF S_I

8.1. Variances ratio

Table 9

Common cycle variance to idiosyncratic cycle variance ratio

	Output			*Consumption*			*Public Expenditures*			*GFCF*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	0.29	0.32		0.23	0.13		0.13	0.25		0.58	0.57	
France	8.94	6.15		0.83	0.57		1.84	6.22		12.93	21.19	
Germany	0.58	0.91		0.78	0.48							
Italy	0.89	0.64		0.09	6.20		7.42	42.69		1.19	2.25	
Netherlands	1.72	1.89		0.24	0.15		0.37	0.72		0.10	0.11	
UK		2.53	0.62		1.70	0.79		0.41	0.45		82.34	1.28
Japan			0.42			0.13			1.72			0.04
US			0.92			5.23			0.67			0.05
Average	2.49	2.07	0.65	0.43	1.54	2.05	2.44	10.06	0.95	3.70	21.29	0.46

8.2. Loading coefficients

Table 10

Loading coefficients

	Output			*Consumption*			*Public Expenditures*			*GFCF*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	0.79	0.80		-0.61	0.31		0.11	0.38		0.40	-0.12	
France	0.75	0.78		0.15	-0.24		0.22	-0.53		-0.10	0.23	
Germany	0.67	0.70		0.05	-0.04							
Italy	0.67	0.65		-0.11	0.40		-0.44	0.49		0.37	-0.58	
Netherlands	-0.05	-0.03		0.69	-0.55		0.17	-0.08		-0.30	0.22	
UK		0.34	0.49		0.59	0.18		0.54	0.50		0.48	0.39
Japan			0.38			0.40			0.51			0.26
US			0.37			0.44			0.56			-0.05

9. SPECTRAL DENSITIES

9.1. Euro group

Figure 9 - Spectral densities for Euro group – Output

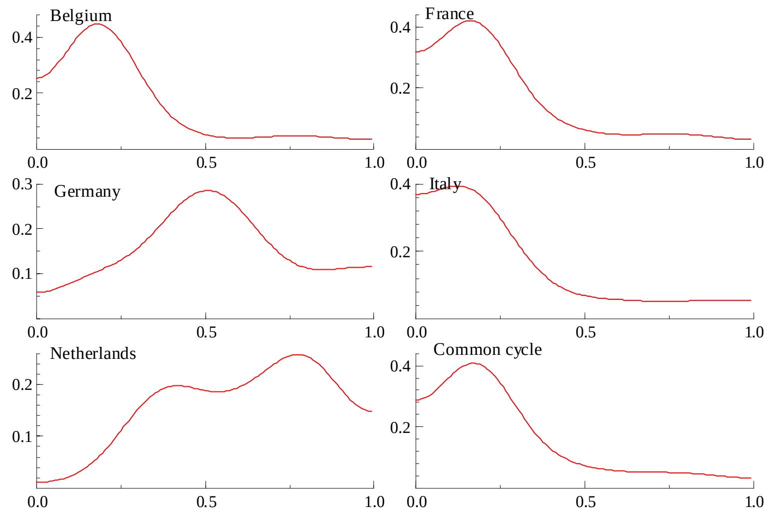


Figure 10 - Spectral densities for Euro group – Consumption

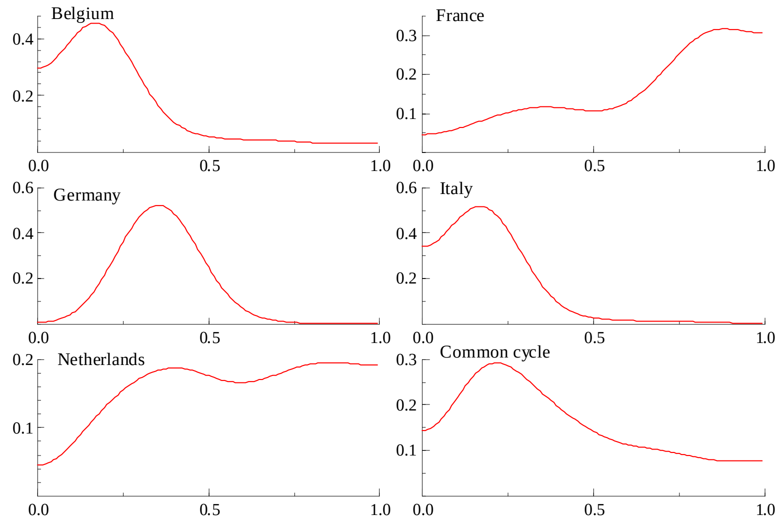


Figure 11 - Spectral densities for Euro group - Public expenditures

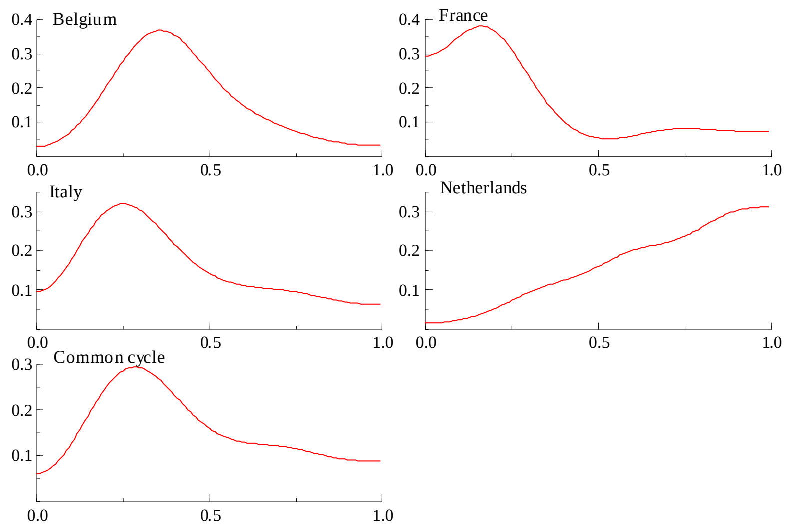
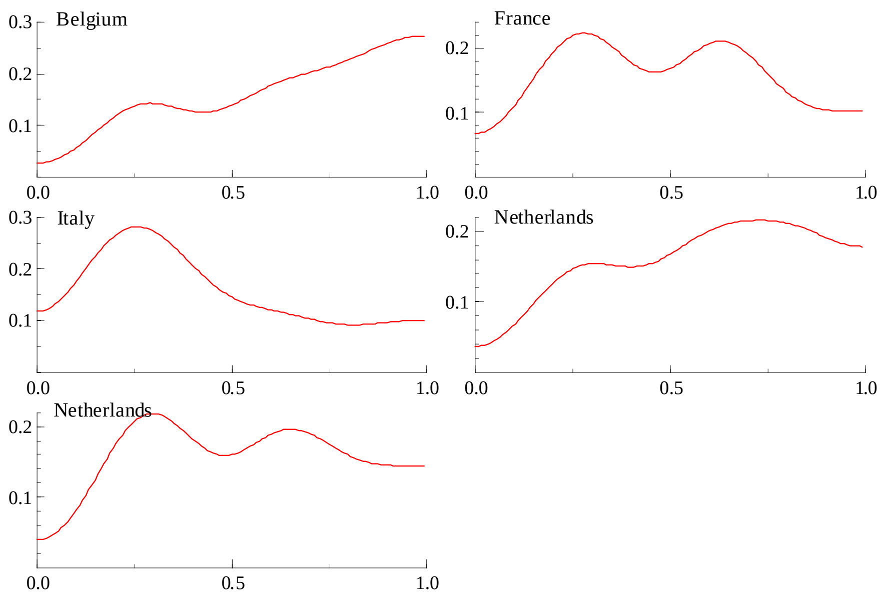


Figure 12 - Spectral densities for Euro group – Investment



9.2. Japan/UK/US

Figure 13 - Spectral densities for Japan/UK/US group- Output

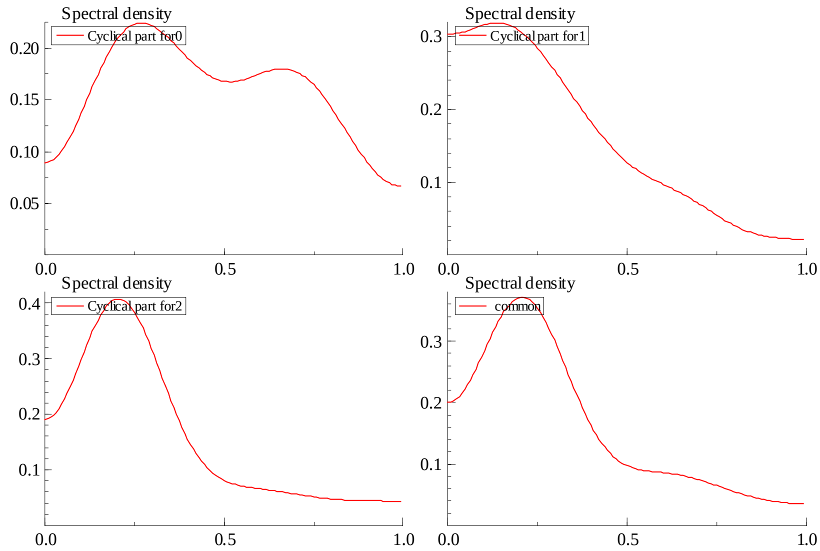


Figure 14 - Spectral densities for Japan/UK/US group- Consumption

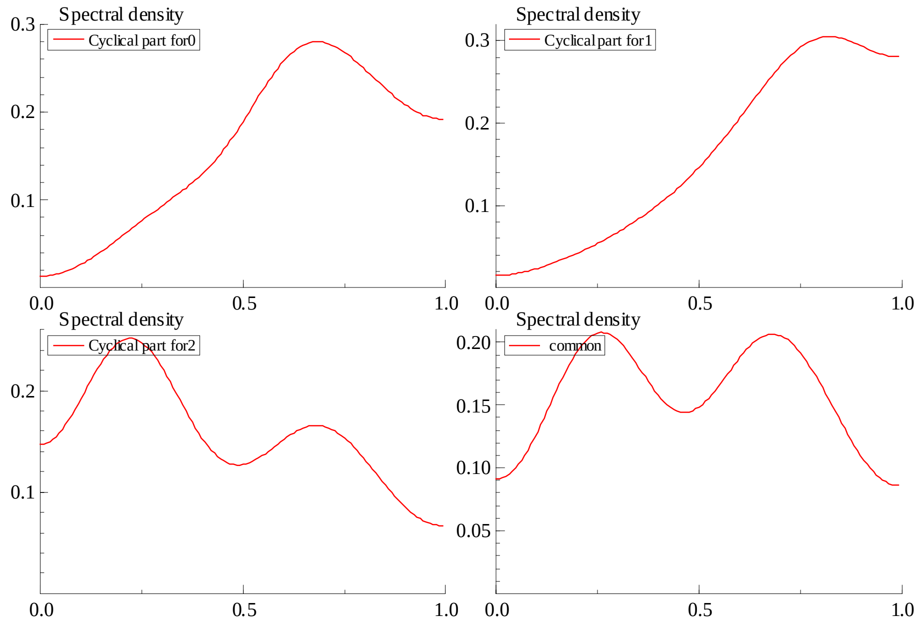


Figure 15 - Spectral densities for Japan/UK/US group- Public expenditures

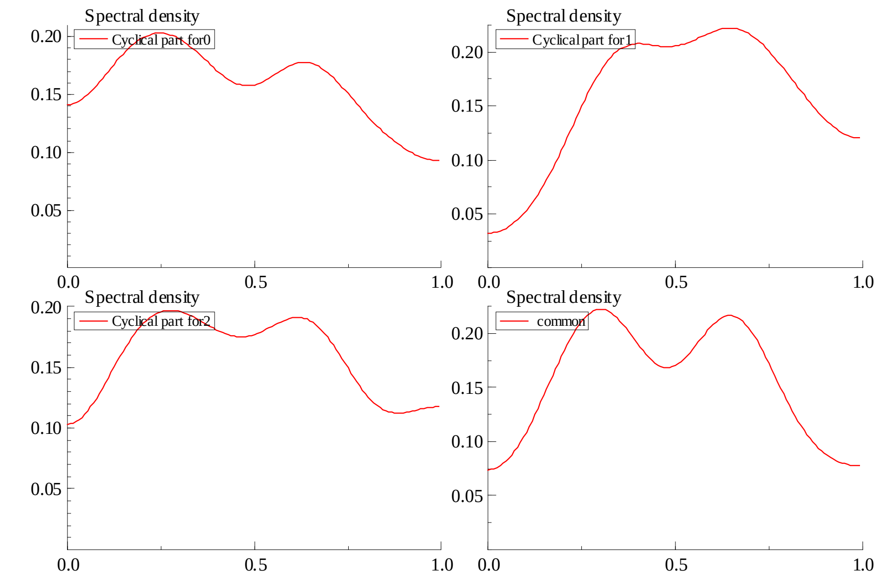
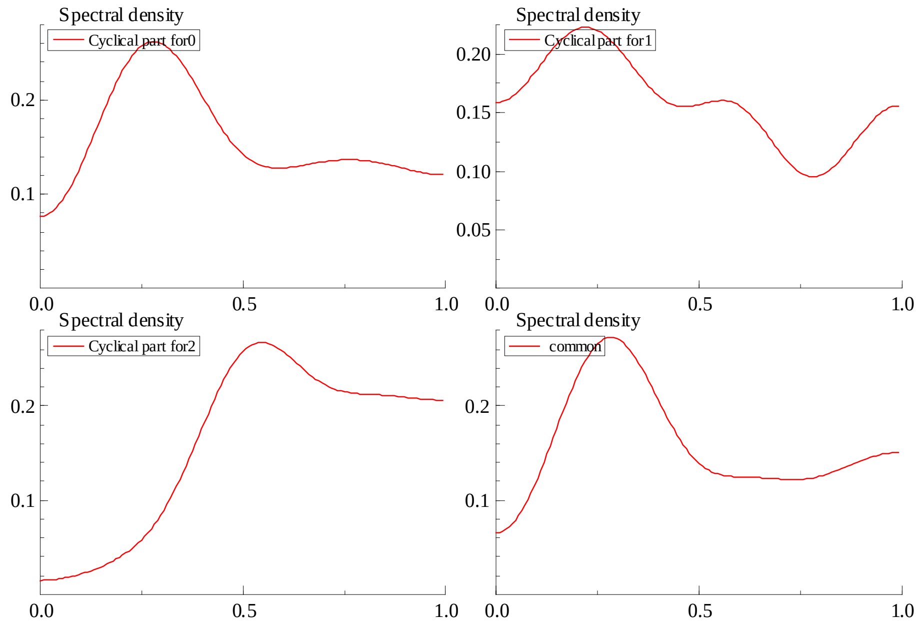


Figure 16 - Spectral densities for Japan/UK/US group- Investment



10. CORRELATIONS

10.1. Whole sample

Table 11

Correlations between univariate and common cycles

	Output			*Consumption*			*Public Expenditures*			*Investment*		
	Euro	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*	*Euro*	*Euro-UK*	*UK-Jp-US*
Belgium	0.63	0.62		-0.81	0.51		0.08	0.16		0.51	-0.10	
France	0.79	0.79		0.12	-0.22		0.40	-0.68		-0.33	0.50	
Germany	0.34	0.34		0.05	-0.12							
Italy	0.56	0.54		-0.30	0.57		-0.93	0.66		0.67	-0.74	
Netherlands	0.04	0.06		0.43	-0.40		0.05	-0.02		-0.28	0.19	
UK		0.42	0.51		0.60	0.30		0.35	0.51		0.39	0.57
Japan			0.38			0.11			0.72			0.72
US			0.71			0.95			0.65			-0.17
		(0.47	)		(0.07	)		(0.03	)		(-0.04	)
Average	0.47	0.46	0.53	-0.10	0.16	0.45	-0.10	0.09	0.63	0.14	0.05	0.37

Table 12

Correlations between univariate or common cycles

	Output		*Consumption*		*Public expenditures*		*Investment*	
	Euro	*Euro+ UK*	*Euro*	*Euro+ UK*	*Euro*	*Euro+ UK*	*Euro*	*Euro+ UK*
Ja/UK/US	0.17	0.21	-0.02	0.05	0.10	-0.09	0.08	-0.10
UK	0.28	0.42	-0.11	0.60	-0.07	0.35	-0.17	0.39
US	0.15	0.19	-0.06	0.08	0.09	-0.03	0.03	-0.07
Jap.	-0.02	0.00	0.03	-0.16	0.13	-0.05	-0.05	0.06

Table 13

Correlations - UK/ partners

	Output	*Cons.*	*Public exp.*	*Invest.*
Euro	0.28	-0.11	-0.07	-0.17
US	0.20	0.12	0.12	0.05
Jap.	0.03	-0.25	0.13	0.07

10.2. Rolling maximum correlations

10.2.1. Effects of including the UK into the Euro group: 'within' correlations

Figure 17 - Rolling correlations of individual cycles with common cycles – Output

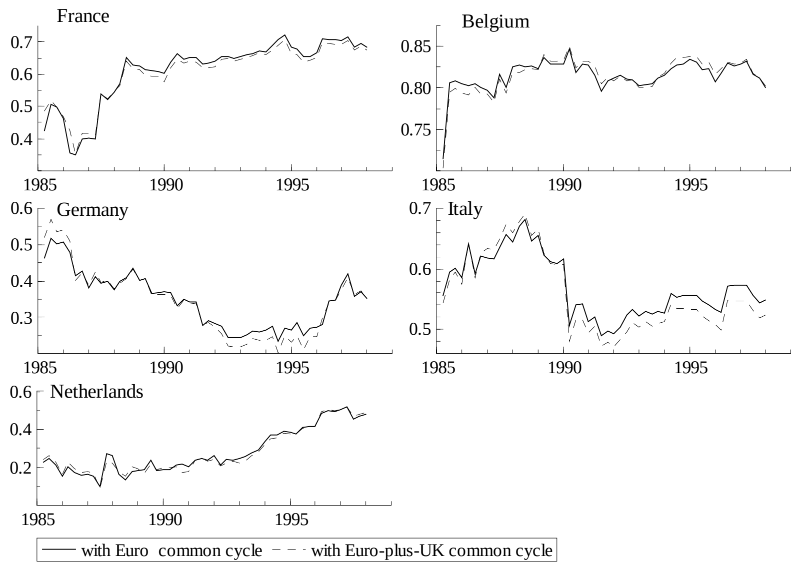


Figure 18 - Rolling correlations of individual cycles with common cycles – Consumption

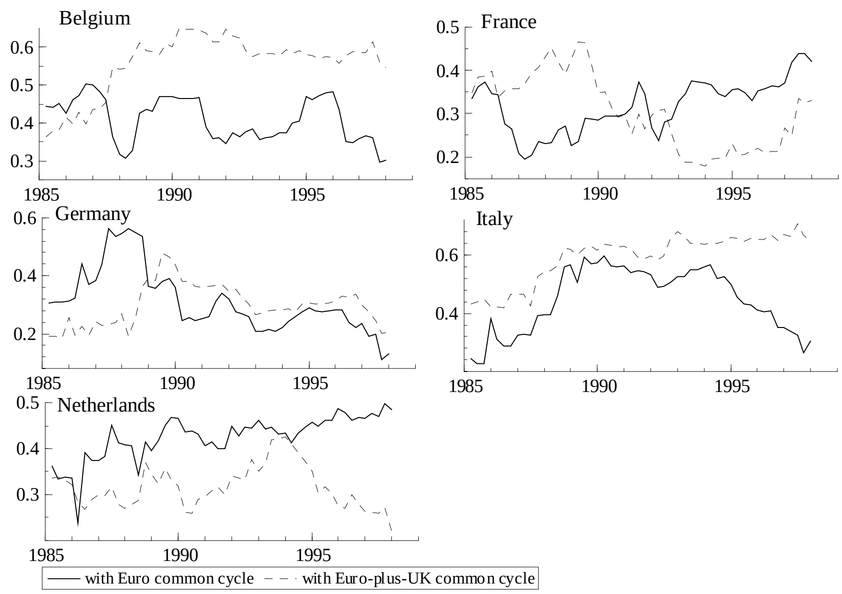


Figure 19 - Rolling correlations of individual cycles with common cycles – Public expenditures

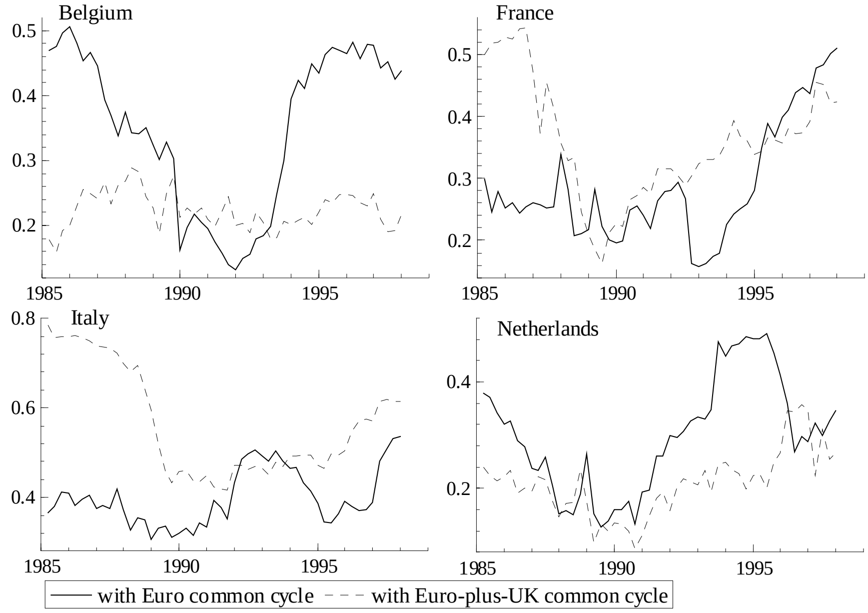
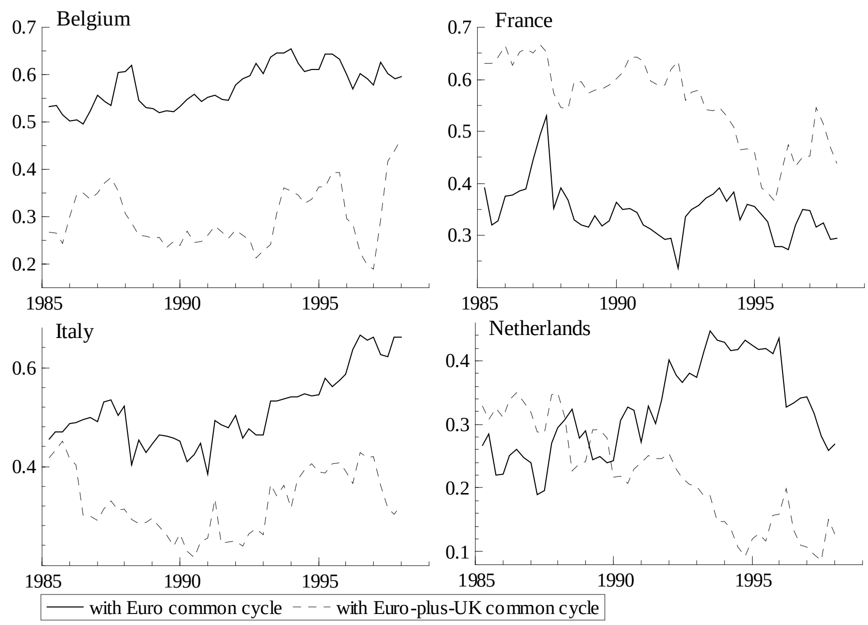
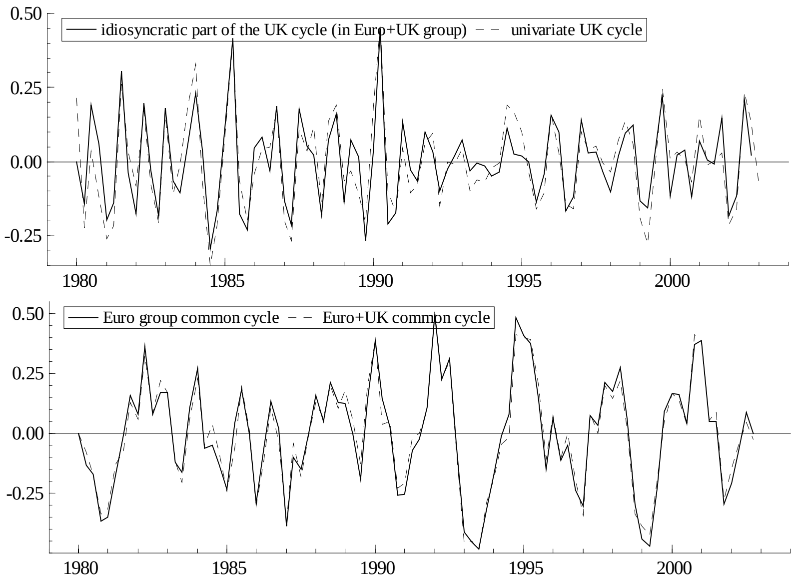


Figure 20 - Rolling correlations of individual cycles with common cycles – Investment



10.2.2. UK cycles when included into the Euro group

Figure 21 - Modifications of the common cycle and the UK individual cycle induced by the inclusion of the UK into the Euro group



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