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Is There a Common European Business Cycle?

New Insights from a Frequency Domain Analysis

By Jörg Breitung* and Bertrand Candelon**

Summary

To assess the synchronization of business cycles in Europe we extract the cyclical component of industrial production in five European countries using the filter of Baxter and King (1999). The hypothesis of a joint business cycle is tested by using the frequency domain common cycle test suggested by Breitung and Candelon (2000). The common cycle hypothesis is clearly rejected for U.K. data whereas some weak evidence for a joint cyclical pattern is found for France, The Netherlands, Austria and Germany.

1. Introduction

Since January 1999, European countries entered the third stage of the Economic and Monetary Union (EMU) adopting the Euro as the single currency for twelve participating countries.[1] The success of such a monetary union depends on the stabilization costs induced by abandoning nominal exchange rates as a stabilization instrument. If stabilization costs exceed the benefits, which are mainly due to microeconomic efficiency gains (see, e.g., de Grauwe, 1994), then countries have no interest in joining the EMU. Mundell's (1961) theory of optimum currency area has coped with such situations. A set of criteria based on the labor mobility, wages and prices flexibility (Blanchard and Muet, 1993), industrial diversification and trade openness (Gros, 1996; Pisani-Ferry, 1997) was adopted to assess the real consequences of a monetary integration.[2] However, such criteria are difficult to operationalize in an empirical analysis.

As an alternative, many empirical studies analyse the importance of asymmetric shocks. Since shocks are not observed, econometric methods are used to identify them. For example, Helg et al. (1995) and Bayoumi and Eichengreen (1993) adopted a structural VAR approach, whereas Artis and Zhang (1995) developed an identification scheme based on cyclical components. Rubin and Thygesen (1996), Beine and Hecq (1997) and Beine, Candelon and Hecq (2000) employ a codependence framework and a Markov Switching VAR model is used by Filardo and Gordon (1994), Beine, Candelon and Sekkat (1999) and Krolzig (2001). This empirical work demonstrates that it is important to distinguish short and long-run effects. Bayoumi and Eichengreen (1993), Helg et al. (1995) and Rubin and Thygesen (1996) use differenced variables in the VAR representation. However, such a specification neglects the effects on the long-run relationship between the variables. Beine and al. (2000) overcome this problem by investigating simultaneously the common trends and common cycles. The presence of a common cycle among European countries is an indication of perfect synchronisation of shocks so that Europe may constitute an optimal currency area.

In this paper, we use descriptive techniques based on the Baxter-King filter (see Baxter and King, 1999) and the frequency domain approach of Breitung and Candelon (2000) to investigate the presence of common cycles in European production data. This framework allows us to study comovement at different frequencies so that it is possible to distinguish short-run from long-run comovement between the variables. Therefore, synchronization between different European countries can be studied in the short as well as in the long-run.

The plan of the paper is as follows. In section 2 the filter of Baxter and King (1999) is adapted to extract the cyclical component of industrial production series and some preliminary conclusions are drawn from a comparison with the German reference cycle. Section 3 introduces the

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[1] Greece has recently joined the first group of eleven countries.

[2] See Lafrance and St-Amand (1999) for a more detailed presentation of these criteria.

common cycle framework, and section 4 presents the empirical results for five EU countries. Section 5 offers some conclusions.

2. The Cyclical Components

In our empirical study we consider five European countries: Germany, Austria, the United Kingdom, France and the Netherlands. Austria is closely related to Germany and is therefore expected to exhibit strong common fluctuations. France and the Netherlands are also neighbours of Germany and initial members of the European Union. Therefore, we also expect some comovement with Germany, although the economic links between these countries are weaker than the relationship between Austria and Germany. Finally, output fluctuations of the United Kingdom is known to be loosely linked to Germany (e. g. Krolzig, 2001). We focus on seasonally unadjusted industrial production (IP) indices for the period ranging from 1975m1 – 1997m4 which were extracted from the Datastream database. These indices are also used by Rubin and Thygesen (1997), Beine et al. (2000).

In the first step of our analysis we extract the cyclical components of the industrial production series by using the linear filter proposed by Baxter and King (1999). Let y_t be the time series observed for $t = 1,\dots,T$. The filtered series results as

$$c_t = \sum_{j=-k}^{k} \quad b_j y_{t+j},$$

where the filter weights are symmetric with $b_j = b_{-j}$ and $\Sigma\, b_j = 0$. These conditions imply that the filter reduces the order of integration by two, that is, if y_t is integrated of order $I(2)$, then c_t is $I(0)$ in the terminology of Box and Jenkins (1976).

The filter is constructed by minimizing the distance of the frequency response function $\varphi(\omega)$

$$\varphi(\omega) = \Sigma_{j=\,k}^{k} b_j e^{-i\omega j}$$

and the "ideal" frequency response function

$$\varphi^*(\omega) = \begin{cases} 1 & for \quad a \le \omega \le b \\ 0 & otherwise \end{cases}$$

and $k \to \infty$. For finite k, the filter is adjusted to account for truncation effects (see Baxter and King, 1999). For our analysis, we define the range of business cycle frequencies as $\omega \in [0.049, 0.26]$, which corresponds to cycle length between 24 and 128 months. The truncation lag is set to $k = 25$.

The resulting cyclical components of the monthly indices of industrial production (IP) for four countries are shown in figure 1, where the cyclical component of the German IP series are also shown for reference purpose. It turns out that the cyclical components of Germany and Austria are very similar, whereas the cyclical components of Germany and the UK are quite different. The cycles of France and the Netherlands are less synchronized than Germany/Austria but still move ogether closely. These first results suggest that the business cycle pattern of Germany, France, Netherlands and Austria are similar, whereas the U.K. data tell quite a different story. In the remaining steps of the analysis we study the cyclical comovement of the series in more detail by applying the test for common cycles suggested by Breitung and Candelon (2000).

3. Common Cycles in the Frequency Domain

In the previous section, a filter was used to extract the cyclical component of the time series. To investigate whether the observed similarities of the cyclical components are due to a common cycle, we test whether there exist a linear combination of the series that eliminates the cyclical pattern of the time series. It is important to note that our test procedure is applied to the original data and does not involve the application of linear filters as in the previous section.

To illustrate the main ideas, it is useful to consider a simple example. Let x_t and y_t be two cyclical time series which can be decomposed as

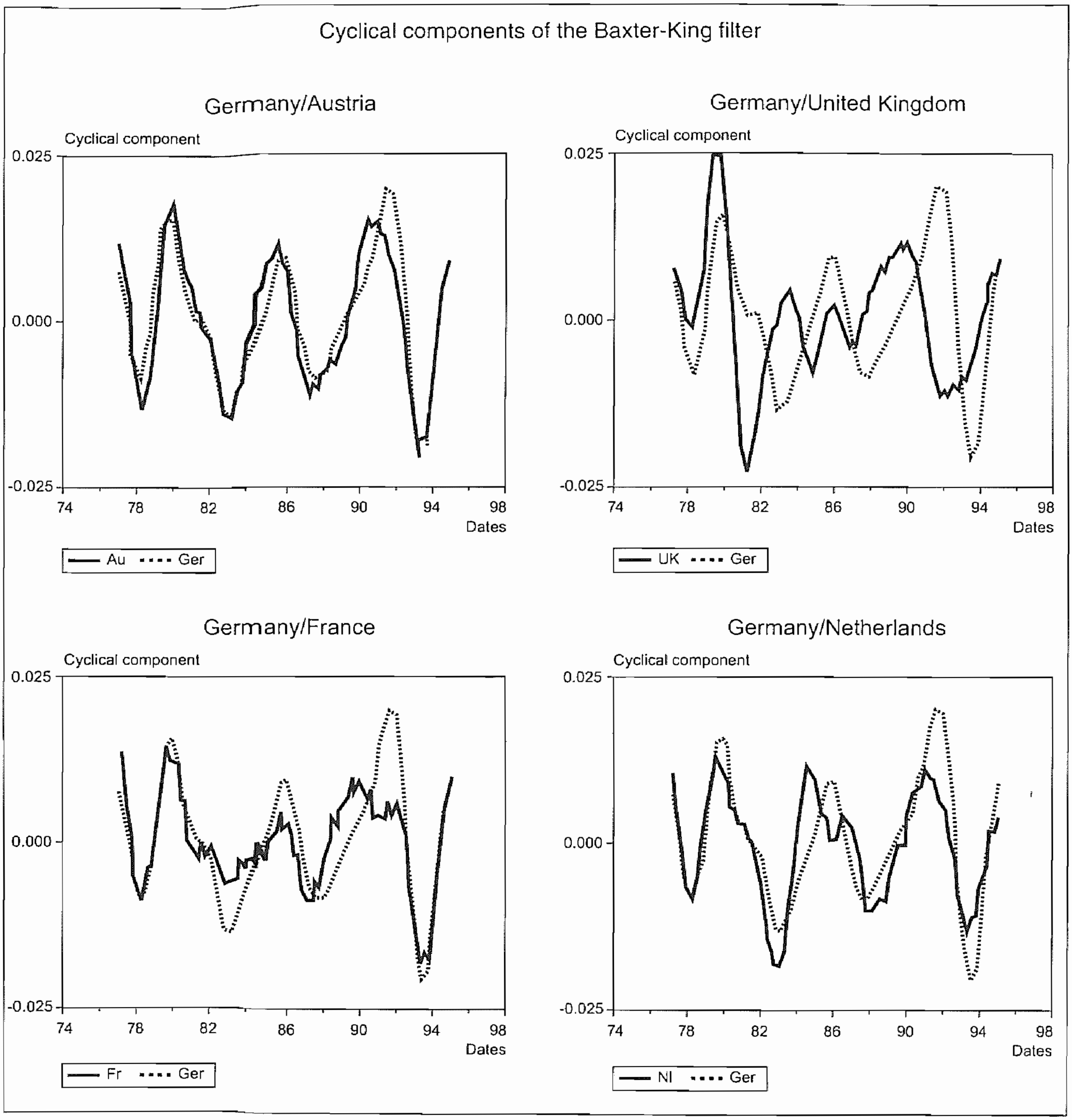
$$x_t = c_t + u_t \qquad (1)$$

$$y_t = \gamma c_t + v_t, \qquad (2)$$

where c_t is a common cyclical component and u_t and v_t are uncorrelated white noise series. By construction it is assumed that the processes have a peak in the spectrum at the same frequency. According to the definition of Engle and Kozicki (1993) the series have a *serial correlation common feature* (SCCF) if x_t and y_t are serially correlated and there exists a linear combination $z_t = y_t - \gamma x_t$ that is white noise. In other words, whereas both time series have a spectral peak at some frequency, the spectrum of the linear combination z_t is flat. It follows that the cyclical pattern of the series is lost if a particular linear combination of the series is considered.

A serious problem with this approach is that it seems overly restrictive as it is assumed that the errors u_t and v_t are white noise. Thus, recent work extends the original SCCF concept in various directions. The framework of Breitung and Candelon (2000) is based on a decomposition of the forecast error variance in the frequency domain. Let $I_{t-1} = \{x_{t-1}, y_{t-1}, x_{t-2}, y_{t-2}, \dots\}$ denote the information set defined by the past of the processes. Then the forecast of z_t is given by $\xi_t = E(z_t \mid I_{t-1})$. The SCCF concept suggested by Engle and Kozicki (1993) implies that z_t is unpredictable so that the conditional variance of the one-

Figure 1


Cyclical components of the Baxter-King filter

step prediction error $var(z_t | I_{t-1})$ is identical to the unconditional variance $var(z_t)$. It follows that $\xi_t = E(z_t)$ and $var(\xi_t) = 0$. The concept of Breitung and Candelon (2000) is based on the fact that

$$\text{var}(\xi_t) = \frac{1}{2\pi} \int_{-\pi}^{\pi} f_\xi(\omega) d\omega,$$

where $f_\xi(\omega)$ denotes the spectrum of the prediction ξ_t. The decomposition of the forecast error variance in the frequency domain (3) allows us to define predictability at frequency ω. If z_t is predictable at frequency ω, then the forecast ξ_t should have a nonzero spectral density at ω. In fact, if ξ_t has a zero spectral density at ω, then the forecasted series cannot explain the behaviour of the observed time series at frequency ω.

We are now in the position to define the concept of a *common cycle at frequency* ω^*. Assume that x_t and y_t are predictable at frequency ω^* in the sense that the spectral density of the predicted series is positive. Then, there exists a common cycle at frequency ω^*, if there exists a linear combination z_t and a forecast $\xi_t = E(z_t | I_{t-1})$ with spectral density $f_\xi(\omega^*) = 0$.

An important advantage of this concept is that it focusses on a particular frequency rather than restricting the whole spectrum of the linear combination. Therefore, predictability at low frequencies (the trend behaviour) and high frequencies do not affect the concept of a common business cycle component. Furthermore, the concept of Engle and Kozicki (1993) implies that the time series have common cycles at *all* frequencies $\omega^* \in [0, \pi]$.

For a practical application of this concept, a test procedure is required that allows us to test the hypothesis that a series is unpredictable at some pre-specified frequency. Following Engle and Kozicki (1993) and Vahid and Engle (1993), it is possible to use test procedures based on instrumental variables (IV) or a canonical correlation analysis (CCA). If it is assumed that the vector $w_t = [x_t, y_t]'$ admits the VAR(p) representation

$$w_t = A_1 w_{t-1} + \ldots + A_p w_{t-p} + \varepsilon_t, \qquad (4)$$

where ε_t is white noise with $E(\varepsilon_t \varepsilon_t') = \Sigma$, then the prediction of the linear combination can be written as

$$\xi_t = E(y_t - \gamma x_t | I_{t-1}) = a_1 x_{t-1} + \ldots + a_p x_{t-p} \\ + b_1 y_{t-1} + \ldots + b_p y_{t-p} = a(L) x_{t-1} + b(L) y_{t-1},$$

where L is the lag-operator and $a(L) = a_1 + a_2 + \ldots + a_p L^{p-1}$ and $b(L) = b_1 + b_2 L + \ldots + b_p L^{p-1}$.

If z_t is unpredictable at frequency ω^*, then $|a(e^{i\omega^*})| = 0$ and $|b(e^{i\omega^*})| = 0$. Following Breitung and Candelon (2000), these restrictions imply the following set of hypotheses:

$$\begin{aligned} &\sum_{s=1}^{p} a_s cos(\omega^* s) = 0 \qquad &&\sum_{s=1}^{p} a_s sin(\omega^* s = 0) \\ &\sum_{s=1}^{p} b_s cos(\omega^* s) = 0 \qquad &&\sum_{s=1}^{p} b_s sin(\omega^* s = 0) \end{aligned} \qquad (5)$$

Therefore, the hypothesis that z_t is unpredictable at frequency ω^* leads to a set of linear restrictions in the model

$$y_t = \gamma x_t + \theta_0' \eta_t + \upsilon_{2t},$$

where $\theta_0 = [a_1, \ldots, a_p, b_1, \ldots b_p]'$, $\eta_t = [x_{t-1}, \ldots, x_{t-p}, y_{t-1}, \ldots y_{t-p}]'$ and υ_{2t} is a white noise error. The null hypothesis of a common cycle can be written as:

$$H_0 : R(\omega^*)\, \theta_0 = 0\,, \qquad (6)$$

where

$$R(\omega^*) = \begin{bmatrix} \cos(\omega^*) & \cdots & \cos(\omega^* p) & 0 & \cdots & 0 \\ \sin(\omega^*) & \cdots & \sin(\omega^* p) & 0 & \cdots & 0 \\ 0 & \cdots & 0 & \cos(\omega^*) & \cdots & \cos(\omega^* p) \\ 0 & \cdots & 0 & \sin(\omega^*) & \cdots & \sin(\omega^* p) \end{bmatrix}$$

Notice that $sin(j\omega^*) = 0$ *for* $\omega^* = 0$ and $\omega^* = \pi$ $(j = 1, \ldots, q)$ and, therefore, the respective rows are dropped in these cases.

Let us consider the IV approach of the test. Under the null hypothesis theVAR model (4) can be written as a system of simultaneous equations:

$$x_t = \theta_1' \eta_t + \upsilon_{1t} \qquad (7)$$
$$y_t = \gamma x_t + \theta_0' \eta_t + \upsilon_{2t} \qquad (8)$$

where equation (7) is identical to the first equation of the VAR given in (4). This equation is therefore just-identified, whereas under the null hypothesis the equation (8) gives rise to 3 over-identifying restrictions.

The set of simultaneous equations can be estimated by using a two-stage least-squares approach with η_t as the vector of instrumental variables. The hypothesis that there exists a linear combination which is unpredictable at frequency ω^* can be tested by running the auxiliary regression

$$\upsilon_{2t} = \delta' \eta_t + e_t, \qquad (9)$$

where υ_{2t} denotes the residuals from a two-stage least-squares estimation of (8). If the null hypothesis is correct, then υ_{2t} is white noise and, therefore, the lagged variables in η_t have no explanatory power in (9). Sargan's (1958) test of the over-identifying restrictions is equivalent to T times the (uncentered) R^2 from the regression (9). This test statistic is asymptotically χ^2 distributed with three degrees of freedom (cf. Breitung and Candelon, 2000) and is denoted as IV test statistic.

4. Empirical Results

In this section the common cycle framework introduced in section 3 is applied to annual differences of the monthly IP series used in section 2. The original series show a pronounced seasonal pattern and the application of unit roots tests (see Hylleberg et al., 1990) indicate that the series possess unit roots at some seasonal frequencies. We therefore use annual differences of the logged time series. Four bivariate VAR models are estimated by using Germany as the reference country. The lag order of the systems is determined by the Akaike information criterion (see table 2, second row for the results).

Table 1

Cointegration tests

Countries		λ – max	critical value	trace	critical value
Germany/UK	r = 0	29.00	14.1	39.68	15.4
	r ≤ 1	10.69	3.8	10.69	3.8
Germany/Austria	r = 0	15.45	14.1	27.93	15.4
	r ≤ 1	12.48	3.8	12.48	3.8
Germany/France	r = 0	26.25	14.1	35.58	15.4
	r ≤ 1	9.36	3.8	9.36	3.8
Germany/NL	r = 0	15.86	14.1	29.99	15.4
	r ≤ 1	14.13	3.8	14.13	3.8

Note: The entries represent the test statistics for the Johansen-Juselius cointegration test. The lag orders for the test can be found in Table 2.

For the methodology of section 3 we have assumed that the vector of times series is stationary. To test this hypothesis, the trace statistic for cointegration (cf. Johansen, 1991) is applied to the annual differences. Since both hypotheses $r = 1$ and $r = 0$ are rejected at the 0.05 significance level, we conclude that the cointegration rank is two, that is, both series are stationary.

Table 2 reports the SCCF statistics based on the IV approach suggested by Engle and Kozicki (1993) and the canonical correlation statistics due to Vahid and Engle (1993) denoted by CCA. It turns out that the presence of a common cycle (at all frequencies) is rejected in each of the four cases. This suggests that the degree of synchronization among European countries is quite low. Similar findings were obtained by Beine et al. (2000).

If the procedures of section 3 are used to test for common cycles in the frequency domain, a much more informative picture emerges. These test use the same data series (the annual differences) but test for a common cycle at particular frequencies. To this end, the test statistic is computed for a grid of frequencies ranging from $\omega^* = 0$ to $\omega^* = \pi$. The results are depicted in figure 2, where the values of the test statistic at every frequency is reported along with the 0.05 critical value. It turns out that the comovement between Germany and Austria is accepted in a frequency range $\omega \in [0.35, 0.7]$ corresponding to a cycle length between 8 and 22 months. This frequency range is somewhat higher than the typical business cycle frequencies. Nevertheless, for typical business cycle frequencies the test statistics is close to the 0.01 critical value. Concerning France and the Netherlands, the test statistic accepts for frequencies around $\omega = 0.6$, which corresponds to a cycle length of about one year. On the other hand, for typical business cycle frequencies the test statistic rejects the common cycle hypothesis. This suggests that the comovement between France and the Netherlands relatively to Germany is high at seasonal frequencies but fairly limited at typical business cycle frequencies. For the United Kingdom, the tests clearly reject the common cycle hypothesis for all frequencies $\omega \leq \pi/2$.

This analysis corresponds roughly to the preliminary finding of section 2. Compared to Germany, Austria shares the closest cyclical dynamics. This suggests that the stabilization costs due to a single currency between

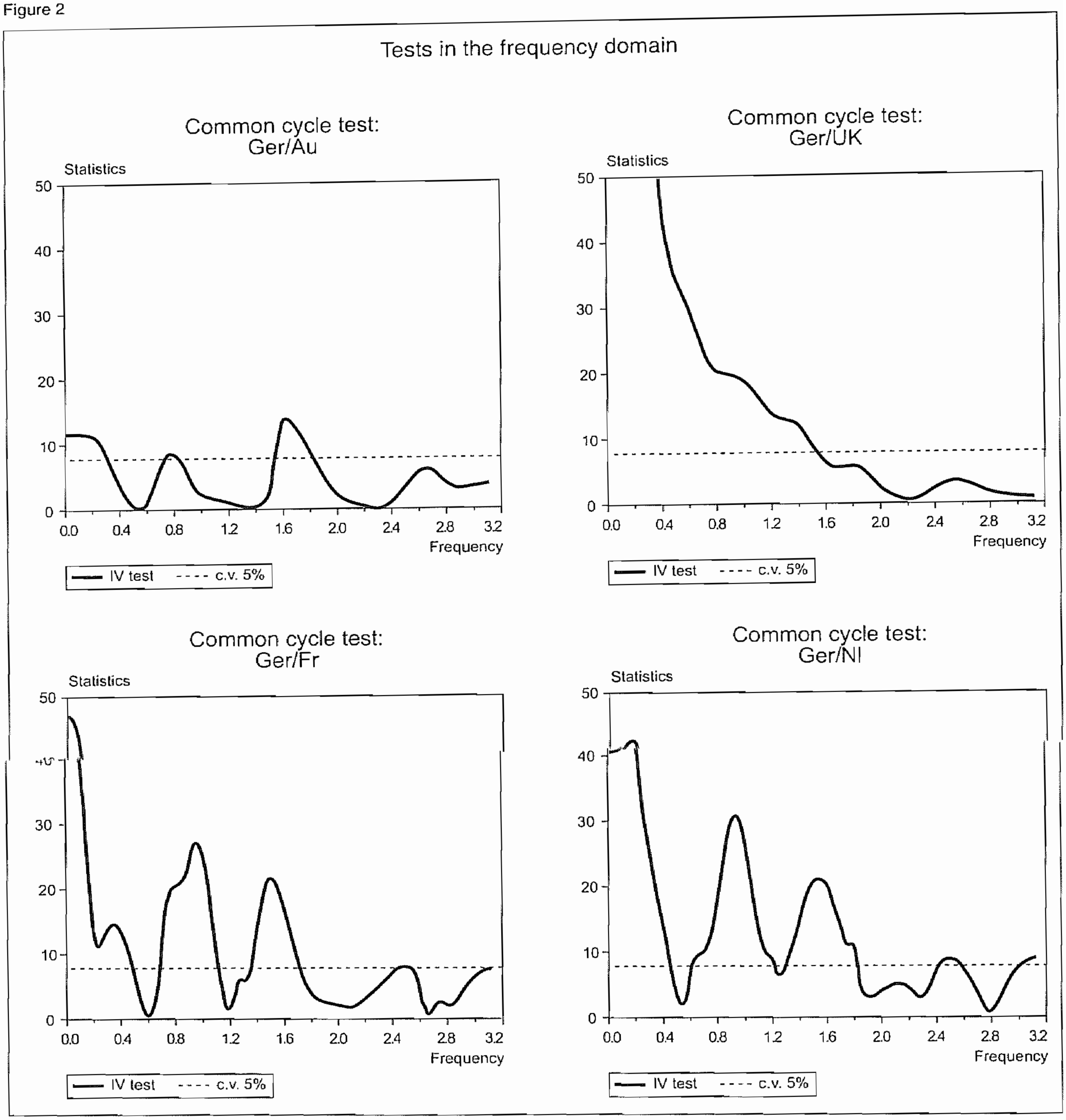
Table 2

Test of SCCF

	Germany/ UK	Germany/ Austria	Germany/ France	Germany/ NL
Lag length	11	9	15	13
CCA	188.627*	59.480*	106.769*	104.633*
IV	148.800*	42.926*	92.075*	85.929*

Note: The entries report the test statistics of the "IV" (cf. Engle and Kozicki, 1993) and "CCA" (cf. Vahid and Engle, 1993) approaches. — * Indicates a rejection with respect to the 5% critical value.

Figure 2



Tests in the frequency domain

these two countries is low. France and the Netherlands reveal a low level of synchronization at business cycle frequencies and the business cycle of the U.K. seems to be rather independent from the continental business cycle. This suggests that it is favorable for the U.K. to stay outside the EMU, since a European monetary stabilization policy may have adverse effects on the British economy. On the other hand, one might argue that joining the EMU may help to synchronize the business cycle of the U.K. Once a sufficient level of synchronization is achieved, the U.K. as well as all other members of the EMU could benefit from a larger currency area.

5. Conclusion

In this paper new techniques are applied to analyse the synchronization of European business cycles. The test procedure is based on the fact that if there is a common cycle at some business cycle frequency, then there exist a linear combination which eliminates the cyclical behaviour in the time series. This technique resembles the well-known cointegration approach of Engle and Granger (1987). Indeed, the cointegration hypothesis can be seen as a test of a common "cycle" at frequency zero (i. e. the trend).

Using the frequency domain common cycle tests it turns out that the business cycle of the U.K. is largely independent of the business cycles of other continental European countries. Therefore, the U.K. will face the highest stabilization costs in joining the EMU. On the other hand, Austria appears to be highly synchronized with Germany, whereas France and the Netherlands have an intermediate position. Regarding the close comovement of the cyclical components extracted from the Baxter-King filter, the rejection of a common cycle with Germany at typical business cycle frequencies is rather surprising. The alternative of the common cycle test is that there exist separate business cycles that may nevertheless be highly correlated. Therefore, it may be difficult to distinguish highly correlated cycles from a joint cycle by a mere graphical inspection.

Moreover, it is well known that a rejection of the test does not imply that the alternative (separate cycles) is true. It may be that structural changes, outliers or other anomalies are responsible for the rejection of the test statistics. Indeed, the introduction of the European Monetary Union may have produced some structural breaks that possibly spoiled the outcomes of our test. In our forthcoming work we will therefore consider generalizations of the common cycle test that allow for structural breaks.

Finally, it is important to note that our approach follows a somewhat descriptive tradition as we do not try to *explain* the mechanism behind the common cyclical movement. Of course, it would be desirable to identify the sources of the joint cyclical behaviour like common shocks or identical impulse responses. To this end, a *structural* model must be specified instead of a reduced form VAR model we have used in our analysis.

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Zusammenfassung

Gibt es einen gemeinsamen europäischen Konjunkturzyklus? Neue Erkenntnisse durch eine Spektralanalyse

Um die Synchronität der Konjunkturzyklen in Europa zu bewerten, wird die Zykluskomponente der Industrieproduktion in fünf europäischen Ländern identifiziert, indem der Baxter-King-Filter (1999) angewendet wird. Die Hypothese eines gemeinsamen Konjunkturzyklus wird durch einen Test auf einen gemeinsamen Zyklus im Frequenzbereich nach Breitung und Candelon (2000) überprüft. Ein gemeinsamer Konjunkturzyklus muss demnach für Großbritannien klar zurückgewiesen werden, wohingegen einige schwache Anzeichen für ein gemeinsames Konjunkturmuster für Frankreich, die Niederlande, Österreich und Deutschland gefunden werden konnten.