ABSTRACT

This paper tests for asymmetries in the European Monetary System (EMS). The analysis indicates that any asymmetric movements between German and other EMS interest rates originating from changes in the US rate are temporary and tend to be eliminated during subsequent periods through offsetting interest rate adjustments. Furthermore, the trivariate error correction vector autoregression analysis of interest rate relationships among the US, Germany and each of the other EMS countries suggests that German leadership is not an EMS-wide phenomenon, since it is confirmed only with respect to Belgium and France.
CONTENTS

I. INTRODUCTION

II. THE RELATIONSHIP BETWEEN ERM INTEREST RATES AND THE US RATE

III. INTEREST RATE INTERACTIONS IN THE EMS AND THE GERMAN LEADERSHIP HYPOTHESIS

IV. CONCLUSIONS

NOTES

REFERENCES
1. INTRODUCTION

The objective behind the foundation of the European Monetary System (EMS) in March 1979 was the creation of a zone of monetary (exchange rate and price) stability in Europe. It is generally accepted that the adoption of the exchange rate mechanism (ERM) of the EMS has contributed to the reduction in the intra-EMS nominal and real (bilateral and effective) exchange rate volatility relative to the pre-EMS period (Rogoff, 1985; Artis 1987; Taylor and Artis, 1988). However, it is not clear how much of this reduction is the result of increased policy coordination. It has been argued that the maintenance of capital controls by the majority of the EMS countries has been a crucial element of the function of the system, despite the fact that, due to “leakages”, their effectiveness is only temporary (Wyplosz, 1980; Steinberr and De Schrevel, 1988). The existence of capital controls, by limiting the mobility of assets, seems to have contributed to asymmetric movements in the D-mark (DM) cross rates associated with changes in the sentiment against the US dollar (Giavazzi and Giovannini, 1986, 1989; Taylor and Artis, 1988). Moreover, asymmetries in the EMS are also associated with the dominant role of Germany in setting its monetary policy independently and thus in providing the system with a monetary standard, while the other ERM members bear the burden of adjustment by gradually accommodating the policies pursued by the German authorities (Giavazzi and Giovannini, 1987, 1989).

Three approaches have been used in the literature in order to document the asymmetric nature of the EMS. The first
approach concentrates on the response of the DM cross rates to changes in the effective dollar rate (Artis, 1987; Glavazzi and Giovannini, 1986, 1989). It also tests the hypothesis of uncovered interest rate parity between the DM bilateral rates as well as between the DM and the dollar (Taylor and Artis, 1988). The second approach is based on the investigation of the predictive power of the German interest rate and monetary growth rate for the path of the same variables in other ERM members and vice versa (Mastrocasqua et al., 1988; Fratianni and von Hagen, 1989; Karfakis and Moschos, 1990). The third approach addresses the issue of the effectiveness of sterilization policy in the EMS by estimating central bank reaction functions relating changes in reserves with changes in the domestic component of monetary base (Gasos and Maenning, 1987; Mastrocasqua et al., 1988).

The aim of this paper is twofold. First, it examines the relationship between ERM interest rate differentials and the US rate, as an alternative way of testing EMS asymmetries in the context of the first approach. Second, it reconsiders the second approach by applying the Johansen (1988) procedure for testing for cointegration, and then using trivariate error correction vector autoregressive specifications to detect causality patterns.

2. THE RELATIONSHIP BETWEEN RELATIVE ERM INTEREST RATES AND THE US RATE

It is an empirical fact that fluctuations in the US dollar are associated with financial tensions in the EMS. Artis (1986), and Glavazzi and Giovannini (1986, 1989) have shown that movements in the effective dollar rate are associated with fluctuations in the DM bilateral rates. These cross rate asymmetries, however, were less pronounced during the EMS period relative to the pre-EMS period. Furthermore, the results of Taylor and Artis (1988) have rejected the hypothesis of uncovered interest rate parity between the DM and the other ERM currencies, but supported the zero risk premium hypothesis between the DM and the dollar, indicating the failure of the EMS to render member currencies perfect substitutes.

In this context, an alternative approach to testing for asymmetries in the EMS would be the examination of the response of ERM interest rate differentials, defined as deviations of the German interest rate from each of the other ERM member rates, to US monetary shocks.

Suppose that the EMS, due to the presence of capital controls, is characterized by asymmetric investor preferences which are biased towards the centre country (Germany). In this system, mark denominated assets would be very close substitutes in investors' portfolios with assets denominated in an outside reserve currency (US dollar), while assets denominated in any other member currency, say j, would be less
close substitutes with dollar assets. An exogenous monetary shock initiated from, a fall (rise) in the US interest rate, would affect the relative prices of assets and give rise to portfolio reallocations. Thus, the demand for mark denominated assets would increase (decrease) relative to the demand for assets denominated in currency j, resulting in relative interest rates movements within the system. Accordingly, a relationship between the ERM interest rate differential and the US rate would exist as:

\[ r_{jt} - r_{st} = b r_{ust} + \epsilon_t \]  

(1)

where \( r_{jt} \), \( r_{st} \), and \( r_{ust} \) denote the interest rates in country j, Germany, and US respectively, and \( \epsilon_t \) is an error term.

A negative sign of \( b < 0 \) is consistent with asymmetric portfolio reallocations biased towards Germany. On the other hand, a positive sign of \( b > 0 \) could indicate that Germany is more successful relative to the other ERM members in sterilizing capital flows associated with these portfolio reallocations.

The approach adopted in this section concentrates on equation (1). The empirical analysis is carried out using OECD monthly data on short run domestic nominal interest rates for Belgium (B), France (F), Germany (G), Ireland (IR), Italy (IT), the Netherlands (NL) and the US over the period April 1979 to September 1989. With respect to the univariate time series properties of the data, there is evidence (Karfakis and Moschos, 1990) that the generating mechanism of the ERM interest rates are well approximated by a random walk. Furthermore, unit root tests (Fuller, 1976; Dickey and Fuller, 1981) reported in Table 1 show that interest rate differentials are also characterized by non-stationarities, with the exception of the differential between the Dutch and the German rate which is stationary. The presence of unit roots in interest rate differentials is consistent with the results of Karfakis and Moschos (1990) who could not reject the null hypothesis of non-cointegration (Engle and Granger, 1987) between the German and the other ERM rates. Finally, the results of Table 1 also suggest the presence of a unit root in the US series.

Given the evidence that the series concerned are integrated of order one (I(1)), equation (1) should be estimated in first-difference form to achieve stationarity, unless the variables are cointegrated in which case an error correction (EC) specification would be appropriate (Engle and Granger, 1987). The test results for cointegration reported in Table 2 suggest the lack of cointegrating relationships. In view of these findings, the investigation of asymmetries in the EMS is based on equation (1) estimated in first-difference form. The regression results are reported in Table 3. In most cases, the estimates show a positive coefficient implying a smaller response of the German interest rate relative to the other ERM rates. This form of asymmetry could be taken as evidence that German authorities are more successful relative to other ERM members in shielding domestic interest rates from US monetary policy shocks through sterilization of short run
capital flows. In the regression involving the French interest rate, the coefficient is negative but statistically insignificant. This result could be attributed to the temporary effectiveness of capital controls which have been used by the French authorities as an instrument of short run monetary policy autonomy over most of the sample period. In the regressions for Italy and Ireland, the findings that the coefficients are significant only at the 0.10 level could also be associated with the use of capital controls in these two countries.

In order to investigate the dynamic effect of US interest rate changes on ERM rate differentials, an autoregressive distributed lag (ADL) model is also considered:

$$\Delta(r_{jt}-r_{gt}) = a + A(L)\Delta (r_{jt}-r_{gt}) + \Gamma(L)\Delta x_{p_{jt}} + \epsilon_{jt}$$  \hspace{1cm} (2)

where $j=B, F, IR, IT, NL$; $A(L) = a_0 + a_1 L + \ldots + a_p L^p$ and $\Gamma(L) = 1 + \gamma_1 L + \ldots + \gamma_q L^q$ are polynomials in lag operator of order $p$ and $q$ respectively, and $\epsilon_{jt} \sim N(0, \sigma^2)$.

In the context of equation (2), the following hypotheses are examined:

a) strong form of symmetry:
   $H_0$: $\gamma_k = 0$, with $k = 0, 1, 2, \ldots, q$

b) weak form of symmetry:
   $H_0'$: $\sum \gamma_k = 0$, with $k = 0, 1, 2, \ldots, q$

The weak form of the hypothesis is less restrictive and hence it constitutes a more realistic view of the symmetry hypothesis, since it allows for temporary responses of ERM interest rates to US rate shocks, but restricts the total effect of these shocks to be zero.

The selection of the lag order of equation (2) is based on the Akaike (1969) and the Schwarz (1978) information criteria. In applying these criteria, the monthly frequency of the data favoured the selection of 12 as the maximum lag length. Whenever the 12 lags were selected, the maximum lag was extended.

The test results obtained from equation (2) are given in Table 4. When lagged values of the independent variable appear among the regressors, the strong form of the symmetry hypothesis is rejected regardless of the lag selection criterion used. However, the weak form of the symmetry hypothesis is strongly supported by the data for all countries. This finding is not sensitive to the lag selection procedure, except for Belgium where only the Akaike criterion does not reject the weak form of the symmetry hypothesis.

Overall, the results suggest the following. First, the EMS does not seem to be characterized by long run comovements of its relative interest rates with the US rate. Second, any asymmetric movements between German and other ERM interest rates emanating from changes in the US rate are temporary and tend to be eliminated during subsequent periods through offsetting interest rate adjustments.
This section addresses the question of EMS asymmetries in the context of GLH by allowing for US interest rate effects. The variables $r_j$, $r_n$, and $r_m$, entering equation (1) are treated as endogenous and their data generation mechanisms are modelled as trivariate VAR systems. The presence of unit roots in the levels of the series concerned implies that a VAR specification in first-difference form would be an appropriate characterization of the data generation process, only if the series are not cointegrated. Engle and Granger (1987) have shown that if a set of variables are cointegrated, then there exists an EC representation and vice versa. In the EC model there are two sources of causality (Granger, 1969), either through the EC term or through the lagged first-difference terms. It follows that VAR models in first-differences lead to misspecification, since the source of causation associated with the EC term is omitted (Granger, 1988). Tests for cointegration among $r_j$, $r_n$, and $r_m$ are therefore required before deciding about the appropriate specification of the VAR models. Given that the number of variables to be tested for cointegration is greater than two, the testing procedure developed by Engle and Granger (1987) is not applicable, since it does not address the possibility that more than one cointegrating vectors may be present.

Recent advances in cointegration theory (Johansen, 1988; Johansen and Juselius, 1990) have developed tests regarding both the number of cointegrating vectors and hypotheses with respect to the elements of these vectors. The procedure is based on regressing the n-element vectors $\Delta X_t$ and $X_{t-m}$ on $\Delta X_{t-1}$.

3. INTEREST RATE INTERACTIONS IN THE EMS AND THE GERMAN LEADERSHIP HYPOTHESIS

The issue of asymmetries in the EMS associated with the dominant role of Germany could be also addressed by investigating whether or not German interest rate movements convey information about future changes of other ERM member rates and vice versa. In this context, the German leadership hypothesis (GLH) would imply that movements in the German interest rates are indicators of future changes of the other ERM rates and not visa versa.

Fratanni and von Hagen (1989), have tested GLH by analyzing multivariate time series models of EMS central bank reactions to both domestic variables and to monetary policy developments inside and outside the EMS. The results indicated that monetary policy within the system was interactive in the sense that ERM interest rates responded to the German rate, but the opposite was also true. Karfakis and Moschos (1990) on the other hand, have examined GLH in the context of the uncovered interest rate parity using bivariate vector autoregressive (VAR) analysis. An interesting aspect of their results is the evidence of unidirectional interest rate linkages from Germany to other ERM members, a finding which is consistent with GLH. However, the bivariate analysis of GLH does not allow for any possible effect of interest rate changes originating from the rest of the world, thus implicitly assuming that the EMS is a closed system.
i=1, ..., m-1, and possibly a constant, and obtaining the associated n-element residual vectors \(R_t\) and \(R_{xt}\), where \(n\) is the number of variables tested for cointegration. The test statistic for the number of cointegrating vectors is obtained by solving the eigenvalue problem

\[
\lambda S_m - S_0^2 S_0^{-1} S_m = 0
\]

where \(S_{nm} = T^{-1} E_t R_t R_t'\), \(i, l = 0, m\), and \(T\) denotes the number of observations.

The likelihood ratio (LR) statistic

\[
-2\ln Q = -T \sum_{i=1}^{n} \ln(1-\lambda_i)
\]

is a test that there are at most \(r\) cointegrating vectors versus the general alternative (trace), where \(\lambda_i\) corresponds to the \(n-r\) smaller eigenvalues. The nxr matrix of cointegrating vectors \(\beta\) can be obtained as the \(r\) n-element eigenvectors corresponding to \(\lambda_i\).

The LR statistic for testing that there are \(r\) versus \(r+1\) cointegrating vectors is based on the maximum eigenvalue and given by:

\[
-2\ln Q(r!r+1) = -T \ln(1-\lambda_{r+1})
\]

The LR statistics (3) and (4) based on the trace and the maximal eigenvalue respectively, have non-standard distributions. Johansen (1988), and Johansen and Juselius (1990) have derived appropriate critical values. Tests of hypotheses regarding individual elements of the eigenvectors are also developed in Johansen and Juselius (1990). The LR test statistic for the hypothesis \(H_0: \beta = 0\), where \(H\) is a \(n\times n\) matrix of known restrictions and \(\Theta\) is an \(n\times r\) matrix of parameters which incorporate the restrictions on the individual values of the eigenvectors, is given by:

\[
-2\ln Q = T \sum_{i=1}^{n} \frac{(1-\lambda_i^*)}{1-\lambda_i^*}
\]

where \(\lambda_i^*\) corresponds to the \(r\) largest eigenvalues of the matrix \(H' S_0 S_0^{-1} S_0 H\) with respect to \(H' S_m H\). The asymptotic distribution of this statistic is \(\chi^2\) with \(r(n-r)\) degrees of freedom (Johansen and Juselius, 1990).

The results of the tests for cointegration among \(r_t\), \(r_f\), and \(r_{us}\), for \(j=\text{B,F,IT,IR,ND}\), given in Table 5 reject the hypothesis of zero cointegrating vectors in all cases, with the exception of Ireland. The hypotheses that there are at most 1 or 2 cointegrating vectors are not rejected, at the 0.05 level, for the equations concerning Belgium, France and Italy. The test for the maximal eigenvalue however suggests that only one cointegrating vector is present in all these cases. Finally, in the equation for the Netherlands, the LR test based on the trace suggests that there are two cointegrating vectors.

The test results for cointegration among the interest
rate series, suggest that the data generation mechanisms of all the trivariate systems, with the exception of that for Ireland, should be modelled as error correction vector autoregressive (ECVAR) specifications. A trivariate ECVAR model with two cointegrating vectors is specified as:

\[
\Delta y(t) = a_0 + \Lambda(L) \Delta y_{t-1} + \sum_{i=1}^{2} \alpha_{ni} Z_{t-1,i} + \psi_t
\]

where \( y \) is a 3x1 vector of endogenous variables \( \{r_1, r_2, r_{us}\} \); \( a_0 \) is a fixed intercept vector; \( \Lambda(L) = [\Lambda_1(L) \ A_2(L) \ A_{us}(L)] \) is a 3x3 polynomial matrix in the lag operator, with \( \Lambda_1(L) = \{\phi_1(L) \ \psi_1(L) \ \omega_1(L)\} \); \( h=j, k, US \); \( \alpha_{ni} = \{\alpha_{ni} \ \alpha_{ni} \ \alpha_{ni}\} \); \( i=1,2 \), is a 3x1 vector of parameters; \( Z_{t-1,i} \) are the elements of a 2x1 vector \( Z_{t-1} \) of EC terms, with \( Z_{t-1} = [\beta_1' \ y_{t-1}'] \), and \( \beta = [\beta_1 \ \beta_2 \ \beta_{us}]' \) is a 3x2 matrix of cointegrating vectors; \( w \) is a 3x1 vector of white noise errors with properties: \( E(w_t) = 0 \), \( E(w_t w_{t+1}') = \Omega \), when \( t \neq \xi \) and zero otherwise, with \( \Omega \) denoting the variance-covariance matrix of residuals.

In the context of equation (6), the following hypotheses are tested:

a) independence of country \( j \) from German monetary policy:

\[ H_0^j: \phi_1(L) = 0 \quad \text{and} \quad H_1^j: \alpha_{nj} = 0, \quad \text{when} \ \beta_n=0 \]

or

\[ H_2^j: \phi_1(L) = 0, \quad \text{when} \ \beta_n=0 \]

Rejection of either \( H_0^j \) or \( H_1^j \) would imply that country \( j \) depends on German monetary policy.

b) German monetary policy independence in the EMS:

\[ H_0^j: \psi_1(L) = 0 \quad \text{and} \quad H_1^j: a_{nj} = 0, \quad \text{when} \ \beta_n=0 \]

or

\[ H_2^j: \psi_1(L) = 0, \quad \text{when} \ \beta_n=0 \]

Rejection of either \( H_1^j \) or \( H_2^j \) would imply that German monetary policy is not independent in the EMS.

c) independence of country \( j \) from the US monetary policy:

\[ H_0^j: \phi_{us}(L) = 0 \quad \text{and} \quad H_1^j: \alpha_{us} = 0, \quad \text{when} \ \beta_{us}=0 \]

or

\[ H_2^j: \phi_{us}(L) = 0, \quad \text{when} \ \beta_{us}=0 \]

d) German monetary policy independence from the US:

\[ H_0^j: \psi_{us}(L) = 0 \quad \text{and} \quad H_1^j: a_{us} = 0, \quad \text{when} \ \beta_{us}=0 \]

or

\[ H_2^j: \psi_{us}(L) = 0, \quad \text{when} \ \beta_{us}=0 \]

In this framework, the hypothesis of German leadership is consistent with rejection of country \( j \) independence from German monetary policy and non-rejection of German monetary policy independence.

It should be noted that the presence of an EC term in a particular equation, say \( j \), of model (6) implies that \( \Delta r_{1j} \) is caused by both \( r_{col} \) and \( r_{pol1} \) unless one of the cointegrating parameters associated with these two lagged variables is zero. Therefore, LR tests for zero restrictions on individual elements of the eigenvectors were performed, before estimating the ECVAR systems. The results are reported in Table 6, for the cointegrating vectors associated with France, Italy and the Netherlands, all three single hypotheses, \( \beta_n=0 \), \( \beta_n=0 \) and \( a_{nj}=0 \) are rejected at the 0.05 significance level. In the case
for Belgium, the hypotheses $\beta_1=0$ and $\beta_4=0$ are rejected, but $\beta_2=0$ can not be rejected, indicating the existence of a cointegrating relationship only between the Belgian and the US interest rate.

The results of the ECVAR systems are given in Table 7. The strategy adopted in specifying the number of lagged $\Delta y$ terms in equation (6), was based on Sims’ (1980) likelihood ratio test. A maximum number of 12 lags was considered, in order to preserve a reasonable number of degrees of freedom. The selected lag length was also checked for the presence of serial correlation associated with the truncation of the lag structure.

Regarding the question of independence from German monetary policy, the hypothesis $H^2_a$, associated with the impact of lagged $\Delta r_a$ in each $\Delta r_i$ equation, is not rejected for France, Italy and Ireland, but it is rejected for Belgium and the Netherlands. Furthermore, the hypothesis $H^2_g$ associated with the significance of the EC terms, is rejected in the equations for Belgium, France and the Netherlands. Since the restriction $\beta_4=0$, corresponding to the coefficient of the German interest rate in the cointegrating relationship for Belgium is not rejected, the hypothesis that the Belgian interest rate is independent from German monetary policy developments is supported by the results. Thus, the evidence suggests that only the Italian and the Irish interest rate are independent from movements in the German rate.

With respect to German monetary policy independence, the results indicate that the hypotheses $H^1_i$ and $H^2_i$, testing the impacts of lagged $\Delta r_i$ and EC terms on $\Delta r_a$, are both rejected only for the Netherlands, suggesting that the stance of German monetary policy is not influenced from monetary developments in Belgium, France, Italy and Ireland.

Turning to the effects of the US interest rate on ERM rates, the hypothesis $H^1_y$ and $H^2_y$ are rejected at the 0.05 level, only for Belgium and France. Furthermore, the significance of the EC terms in the equations for Belgium, France and the Netherlands suggest that the hypothesis of independence from US monetary policy is rejected for these countries. Finally, the hypothesis of independence of the German interest rate from the US rate is rejected, indicating the high degree of financial integration between German and US money markets.

Overall, the German interest rate does not appear to have information content in predicting future movements of the Italian and the Irish rate and vice versa. Moreover, changes in the German rate have predictive power with respect to movements in the Dutch rate but the opposite is also true, suggesting that interest rate adjustments are shared between the two countries. Thus, the results support the hypothesis of German leadership only with respect to Belgium and France.

As noted by Granger (1988), the misspecification of VAR models associated with the improper omission of EC terms, results in missing forecastability, and hence reaching incorrect conclusions about non-causality. It is of interest therefore, to highlight the validity of this argument, by considering GLM using causality tests by means of traditional
VAR models estimated in first-difference form. Thus, model (6) was reestimated, after omitting the EC terms. The results for three alternative lag structures in $\Delta y$ are reported in Table 9. The evidence shows that movements in the German interest rate do not have information content for the French rate, when the EC term is omitted from the system. Furthermore, the predictive power of the Dutch interest rate for the path of the German rate is also lost. These findings show the pitfalls of ignoring the long run properties of the data and using traditional VAR analysis in first-difference form to detect causality patterns.

It is worth noting that the results obtained by means of trivariate ECVAR systems suggest that Germany carries out an independent monetary policy with respect to most ERM countries, but it exerts a limited leadership (with respect to Belgium and France). This is contrary to the evidence obtained from bivariate VAR analysis in Karfakis and Moschos (1990), who rejected GLH only in the case of Ireland. Thus the findings of this paper indicate that GLH is not an EMS-wide phenomenon, and this bears similarity with the conclusions of Fratianni and von Hagen (1989). 19

4. CONCLUSIONS
This paper has dealt with testing for asymmetries between Germany and other EMS countries. The first important aspect of the results is that changes in the US interest rate have a significant current period effect on the interest rate differentials between Germany and other ERM members. However, the contemporaneous effect tends to be offset during subsequent periods and the total effect is zero. The implication is that asymmetries of this type exist but are short-lived.

An interesting feature of the empirical analysis is the existence of cointegrating trivariate interest rate relationships among US, Germany and each of the other ERM countries, with the exception of Ireland, thus indicating the pitfalls of using traditional VAR analysis in first-difference form to infer causality. Furthermore, our findings based on trivariate ECVAR models suggest that movements in the German interest rate are independent from changes in interest rates of other EMS countries, with the exception of the Netherlands. On the other hand, the German interest rate conveys information about future movements of the interest rate in Belgium, and the Netherlands. The conclusion is that GLH is not a rule which characterizes the functioning of the EMS as a whole. Instead, asymmetries associated with GLH are a limited phenomenon present in the case of Belgium and France. Finally, the US interest rate policy has predictive power for interest rate policies in the majority of the EMS countries, suggesting that interest rate adjustments to US monetary shocks are shared by Germany and other EMS countries.
Notes

1. Denmark, France, Ireland, and Italy have been using capital controls of various degrees of severity, whereas Belgium has adopted a dual exchange rate as a substitute for controls (Steinherr and De Schrevel, 1988).

2. As Giavazzi and Giovannini (1986) have argued, the presence of capital controls renders assets less substitutable, since it increases transaction costs.

3. The data have been obtained from OECD, Main Economic Indicators. These are yields on three-month (B, I, US) or six-month (I) Treasury bills and on three-month loans (F, G, NL). Due to data limitations, the series for France cover the period 1981:1-1989:9, and Denmark has not been included into the analysis.

4. The stationarity of the Dutch-German interest rate differential could reflect the existence of close monetary links between the two countries.

5. The results of Gasos and Menzinger (1987), and Mastropolous et al. (1988) indicated that the sterilization policy of Germany was more effective relative to other ERM members.

6. The calculation of the eigenvectors of $S_{0}^{-1}S_{m}$ with respect to $S_{m}$ can be transformed into a standard eigenvalue problem by using the Choleski decomposition $S_{m}=CC'$, since the eigenvalues that solve $|\lambda S_{m} - S_{m}S_{0}^{-1}S_{m}|$ also solve $|\lambda I - S_{m}S_{0}^{-1}S_{m}C^{-1}|=0$. Premultiplying the eigenvectors of the standardized problem by $C^{-1}$, one can obtain the original eigenvectors normalized such that $E'_{S_{m}S_{0}^{-1}S_{m}}=I$. The calculations of the eigenvectors reported in Table 5 below, have been performed using the computer package RATS 3.0, VAR Econometrics, Inc/Doan Associates.

7. A constant term is included in the set of regressors in the calculation of $R_{m}$ and $R_{m}^{*}$. This is equivalent to the presence of a linear trend component in the non-stationary $X_{t}$.

8. The hypotheses $H_{0}$ and $H_{1}$ are identical, since they refer to the same EC term.

9. When the null hypothesis of smaller than 12 lags was rejected, the structure of 12 lags was tested against alternatives with higher number of lags, unless it passed the serial correlation test.

10. It should be noted that the analysis of Fratianni and von Hagen (1989), is carried out in a multivariate framework and thus no strict comparisons can be made. One qualitative difference in their results is that the German interest rate seems to be jointly affected by a weighted average of interest rates in small EMS countries, as well as by the French and the
REFERENCES


TABLE 1. Unit root tests for short term domestic interest rate differentials \(R_d-R_{d'}\) and the US rate \(R_{us}\)

<table>
<thead>
<tr>
<th>Country</th>
<th>Statistic</th>
<th>B</th>
<th>F</th>
<th>IR</th>
<th>IT</th>
<th>NL</th>
<th>(R_{us})</th>
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<td>Levels</td>
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<td>DF-test</td>
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<tr>
<td>(\tau_d)</td>
<td>-2.62</td>
<td>-1.73</td>
<td>-2.26</td>
<td>-1.64</td>
<td>-3.11</td>
<td>-2.04</td>
<td></td>
</tr>
<tr>
<td>(\Phi_1)</td>
<td>3.95</td>
<td>2.02</td>
<td>3.06</td>
<td>1.85</td>
<td>5.37</td>
<td>2.59</td>
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<td>ADF(4)-test</td>
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<tr>
<td>(\tau_d)</td>
<td>-1.87</td>
<td>-0.85</td>
<td>-2.54</td>
<td>-1.92</td>
<td>-2.92</td>
<td>-1.64</td>
<td></td>
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<tr>
<td>(\Phi_1)</td>
<td>1.87</td>
<td>0.64</td>
<td>3.29</td>
<td>1.85</td>
<td>4.41</td>
<td>1.37</td>
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<tr>
<td>(\tau_d)</td>
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<td>-11.12</td>
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<td>(\Phi_1)</td>
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<td>62.88</td>
<td>55.64</td>
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<tr>
<td>(\tau_d)</td>
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<td>-5.06</td>
<td>-4.88</td>
<td>-5.93</td>
<td>-5.55</td>
<td></td>
</tr>
<tr>
<td>(\Phi_1)</td>
<td>17.27</td>
<td>11.13</td>
<td>12.81</td>
<td>11.86</td>
<td>17.58</td>
<td>15.42</td>
<td></td>
</tr>
</tbody>
</table>

NOTES: DF and ADF(4) denote the Dickey-Fuller(1981), and the augmented(4lags) DF tests respectively. The statistics \(\tau_d\) and \(\Phi_1\), which refer to the single hypothesis of a unit root, and the joint hypothesis of a unit root and a zero mean respectively, have critical values of \(-2.89\) (Fuller, 1976), and \(4.71\) (Dickey and Fuller, 1981) at the 0.05 level for \(T=100\).
### TABLE 2. Tests of cointegration between EMS interest rate differentials \((r_j - r_u)\) and the US rate \((r_{us})\)

<table>
<thead>
<tr>
<th>Country j</th>
<th>DF</th>
<th>ADF(4)</th>
<th>CIRDW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>-2.60</td>
<td>-2.07</td>
<td>0.21</td>
</tr>
<tr>
<td>France</td>
<td>-2.58</td>
<td>-1.01</td>
<td>0.18</td>
</tr>
<tr>
<td>Ireland</td>
<td>-2.37</td>
<td>-2.48</td>
<td>0.20</td>
</tr>
<tr>
<td>Italy</td>
<td>-1.65</td>
<td>-1.98</td>
<td>0.09</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-3.30</td>
<td>-3.14</td>
<td>0.30</td>
</tr>
</tbody>
</table>

NOTE: The critical values of DF, ADF(4) and the cointegrating regression DW (CIRDW) tests are -3.37, -3.17 and 0.39 respectively at the 0.05 level for T=100 (Engle and Yoo, 1987).

### TABLE 3. Interest rate asymmetries in the EMS:

\[
\Delta(r_j - r_u) = a + b\Delta r_{us} + \nu_j
\]

<table>
<thead>
<tr>
<th>Country j</th>
<th>Estimate of b</th>
<th>t-ratio of b</th>
<th>LM(1)</th>
<th>LM(12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0.235</td>
<td>4.35*</td>
<td>1.18</td>
<td>9.69</td>
</tr>
<tr>
<td>France</td>
<td>-0.107</td>
<td>1.51</td>
<td>0.01</td>
<td>10.39</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.149</td>
<td>1.85**</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Italy</td>
<td>0.107</td>
<td>1.83**</td>
<td>0.36</td>
<td>12.27</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.092</td>
<td>1.98*</td>
<td>0.04</td>
<td>16.65</td>
</tr>
</tbody>
</table>

Notes: The estimates have been obtained by OLS, except in the case of Ireland where CORC(2) has been used due to the presence of second order serial correlation. LM(\(\xi\)) refers to the Lagrange multiplier test statistic for up to \(\xi\) order residual correlation which has a \(X^2(\xi)\) distribution. * and ** indicate significance at the 0.05 and the 0.1 levels respectively.
TABLE 4. Interest rate asymmetries in the EMS:

\[ \Delta(r_1 - r_2) = a + A(L)\Delta(r_1 - r_2)_{t-1} + \Gamma(L)\Delta r_{2x} + \epsilon_{t} \]

<table>
<thead>
<tr>
<th>Country j</th>
<th>Akaike criterion</th>
<th>Schwarz criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(p,q)</td>
<td>F-test of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( H_0^1 )</td>
</tr>
<tr>
<td>Belgium</td>
<td>(14,1)</td>
<td>0.00'</td>
</tr>
<tr>
<td>France</td>
<td>(11,5)</td>
<td>0.00'</td>
</tr>
<tr>
<td>Ireland</td>
<td>(2,1)</td>
<td>0.06</td>
</tr>
<tr>
<td>Italy</td>
<td>(10,0)</td>
<td>0.29</td>
</tr>
<tr>
<td>Netherlands</td>
<td>(11,1)</td>
<td>0.05'</td>
</tr>
</tbody>
</table>

Notes: \((p,q)\) denotes the selected values of \(A(L)\) and \(\Gamma(L)\) respectively. The test results refer to the marginal significance levels of the F-tests for the hypotheses \(H_0^1: \gamma_k = 0\), \(k=0, \ldots, q\) and \(H_0^2: \Sigma \gamma_k = 0\), \(k=0, \ldots, q\), respectively. ' indicates significance at the 0.05 level.

TABLE 5. Tests of cointegration among interest rates in Germany, the US and country j.

<table>
<thead>
<tr>
<th>Country j</th>
<th>rs2</th>
<th>rs1</th>
<th>rs0</th>
<th>rs2</th>
<th>rs1</th>
<th>rs0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>4.01</td>
<td>9.95</td>
<td>37.71</td>
<td>4.01</td>
<td>5.94</td>
<td>27.76</td>
</tr>
<tr>
<td>France</td>
<td>2.43</td>
<td>12.8</td>
<td>52.4</td>
<td>2.43</td>
<td>10.37</td>
<td>39.59</td>
</tr>
<tr>
<td>Ireland</td>
<td>4.33</td>
<td>12.97</td>
<td>25.34</td>
<td>4.33</td>
<td>8.64</td>
<td>12.37</td>
</tr>
<tr>
<td>Italy</td>
<td>4.90</td>
<td>17.15</td>
<td>45.1</td>
<td>4.90</td>
<td>12.25</td>
<td>27.86</td>
</tr>
<tr>
<td>Netherlands</td>
<td>7.09</td>
<td>19.05</td>
<td>55.14</td>
<td>7.09</td>
<td>11.96</td>
<td>36.09</td>
</tr>
</tbody>
</table>

Critical value (95%) 8.083 17.844 31.256 8.083 14.595 21.279

Notes: Critical values are taken from Johansen and Jusolius (1990, Table A.2).
### TABLE 6. Tests of zero-restrictions on the elements of cointegrating vectors $\beta$

<table>
<thead>
<tr>
<th>Restrictions</th>
<th>Country 1</th>
<th>B</th>
<th>F</th>
<th>IT</th>
<th>NL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_1=0$</td>
<td></td>
<td>21.35</td>
<td>25.03</td>
<td>12.77</td>
<td>26.13</td>
</tr>
<tr>
<td>$\beta_2=0$</td>
<td></td>
<td>0.03*</td>
<td>10.44</td>
<td>5.97</td>
<td>22.74</td>
</tr>
<tr>
<td>$\beta_3=0$</td>
<td></td>
<td>12.32</td>
<td>26.25</td>
<td>13.67</td>
<td>10.66</td>
</tr>
</tbody>
</table>

Notes: $\beta=[\beta_1 \beta_2 \beta_3]'$. * indicates significance at the 0.05 level.

### TABLE 7. Error correction VAR systems: Causality tests.

<table>
<thead>
<tr>
<th>System</th>
<th>Dep. V/b/e</th>
<th>Lags/Q(30)</th>
<th>$H_0$</th>
<th>$H_1$</th>
<th>$H_1^+$</th>
<th>$t_1$</th>
<th>$t_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B,G,US</td>
<td>B</td>
<td>12/0.49</td>
<td>0.00*</td>
<td>-</td>
<td>0.03*</td>
<td>-3.47*</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>12/0.86</td>
<td>-</td>
<td>0.21</td>
<td>-0.01*</td>
<td>-0.31</td>
<td>-</td>
</tr>
<tr>
<td>F,G,US</td>
<td>F</td>
<td>12/0.32</td>
<td>0.27</td>
<td>-</td>
<td>0.04*</td>
<td>3.36*</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>12/0.99</td>
<td>-</td>
<td>0.21</td>
<td>0.1</td>
<td>-1.07</td>
<td>-</td>
</tr>
<tr>
<td>IR,G,US</td>
<td>IR</td>
<td>12/0.84</td>
<td>0.79</td>
<td>-</td>
<td>0.61</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>12/0.92</td>
<td>-</td>
<td>0.76</td>
<td>0.00*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IT,G,US</td>
<td>IT</td>
<td>12/0.98</td>
<td>0.96</td>
<td>-</td>
<td>0.48</td>
<td>-0.7</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>12/0.82</td>
<td>-</td>
<td>0.8</td>
<td>0.04*</td>
<td>-1.45</td>
<td>-</td>
</tr>
<tr>
<td>NL,G,US</td>
<td>NL</td>
<td>12/0.57</td>
<td>0.04*</td>
<td>-</td>
<td>0.71</td>
<td>-2.07*</td>
<td>-1.91*</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>12/0.79</td>
<td>-</td>
<td>0.02*</td>
<td>0.04*</td>
<td>0.57</td>
<td>-3.08*</td>
</tr>
</tbody>
</table>

Notes: The F-tests are calculated for the joint hypothesis that the coefficients of the lags of each independent variable are zero. Q(30) refers to the MSL of the Ljung-Box Q statistic for serial correlation at 30 degrees of freedom. The values of t-ratio refer to $H_2$, $H_3$, $H_4$ and $H_5$. * indicates significance at the 0.05 level.
<table>
<thead>
<tr>
<th>System</th>
<th>Dep. 12 Lags</th>
<th>V-bio</th>
<th>H_{inf}</th>
<th>H_{q}</th>
<th>H_{infq}</th>
<th>H_{uu}</th>
<th>H_{infuu}</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11,12,4)</td>
<td>(2,4,1), G(2,1,11)/(1,1,4), US(21,5,9)/(5,1,21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.00*</td>
<td>0.05*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.01*</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.15</td>
<td>0.00*</td>
<td>0.08</td>
<td>0.00*</td>
<td>0.88</td>
<td>0.00*</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>(14,11)/(14,11), G(1,11)/(1,1,2), US(1,2,15)/(1,1,15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.76</td>
<td>0.43</td>
<td>0.42</td>
<td>0.00*</td>
<td>0.14</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.19</td>
<td>0.00*</td>
<td>0.51</td>
<td>0.00*</td>
<td>0.64</td>
<td>0.00*</td>
<td></td>
</tr>
<tr>
<td>IR</td>
<td>(1,1,1)/(1,1,1), G(1,11,1)/(1,4,1), US(21,10,3)/(21,3,2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR</td>
<td>0.79</td>
<td>0.61</td>
<td>0.12</td>
<td>0.58</td>
<td>0.12</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.76</td>
<td>0.00*</td>
<td>0.91</td>
<td>0.00*</td>
<td>0.64</td>
<td>0.00*</td>
<td></td>
</tr>
<tr>
<td>IT</td>
<td>(10,4,1)/(10,4,1), G(1,11,1)/(1,4,1), US(21,10,1)/(21,2,1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT</td>
<td>0.79</td>
<td>0.34</td>
<td>0.26</td>
<td>0.00*</td>
<td>0.27</td>
<td>0.00*</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.43</td>
<td>0.00*</td>
<td>0.16</td>
<td>0.00*</td>
<td>0.19</td>
<td>0.00*</td>
<td></td>
</tr>
<tr>
<td>NL</td>
<td>(9,5,6)/(9,2,1), G(1,11,2)/(1,4,1), US(21,3,11)/(21,3,11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NL</td>
<td>0.01*</td>
<td>0.12</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.09</td>
<td>0.00*</td>
<td>0.93</td>
<td>0.00*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: $H_{inf}$ tests the hypothesis that the German lagged interest rates are jointly insignificant in the equation for country $j$. $H_{inf}$ tests the hypotheses that the US lagged interest rates are jointly insignificant. Figures in parentheses refer to the lags obtained from Akaikeschwarz criteria respectively. * indicates significance at the 0.05 level.
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