Cointegration analysis of the intensity of the ERM currencies under the European Monetary System

Kai-Yin Woo *

Department of Economics, Hong Kong Shue Yan College, Wai Tsui Crescent, Braemar Hill Rd., North Point, Hong Kong

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Abstract

This paper examines the (long-run) intra-zonal elasticities between the spot exchange rates of the deutschemark and other major ERM currencies (French franc, Belgian franc, Dutch guilder, Danish krone, Italian lira and British pound) under the EMS. The findings show that under the fixed-but-adjustable rate system, the hypothesis of no cointegration can be rejected for all chosen ERM currency pairs and unit restriction on zonal elasticities can be accepted for almost all cointegrated currency pairs. On the other hand, under the fixed-rate system, Danish krone, Italian lira and British pound fail the cointegration test and the zonal elasticities for all cointegrated currency pairs are rejected to be unity. The study signifies less intense linkages of the ERM currencies without parity realignments. Finally, the deutschemark took the role of error-correcting process for one cointegrated currency pair under the fixed-but-adjustable-rate system, and it performed the same role for two pairs under the fixed-rate system. Hence, deutschemark should not be assumed a priori statistically exogenous under the EMS © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Intra-zonal elasticity; Multivariate cointegration; Partial vector error correction

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* Tel.: + 852-25707110; fax: + 852-28068044.
E-mail address: kywoo@yahoo.com (K.-Y. Woo)
1. Introduction

The European Monetary System (EMS) started its operation in March 1979 with the aim of creating a zone of intra-European exchange rates and monetary stability. The distinguished feature of the EMS is the Exchange Rate Mechanism (ERM). The initial ERM participants in 1979 included Belgium, Denmark, France, Germany, Italy, Ireland and the Netherlands. Spain joined in 1989, followed by Britain in October 1990 and Portugal in 1992. The participants in the ERM are required to establish a bilateral exchange rate grid, which is a set of bilateral central parity rates of the ERM currencies. The margin of fluctuations of a central rate was initially set at $\pm 2.25\%$ for most ERM currencies, with the exception of the Italian lira, Spanish peseta and British pound ($\pm 6\%$).\(^1\)

I divide the whole period of the EMS into two: the par-value flexibility period (fixed-but-adjustable rate system) and the par-value rigidity period (fixed-rate system).\(^2\) At the beginning, the central parity rates in the ERM were not firmly fixed but allowed to realign so as to maintain the intra-zonal competitiveness. Frequent parity realignments occurred until January 1987. From January 1987 to September 1992, no parity realignments were found except for the devaluation of the Italian lira in January 1990.

In August and September 1992, there were continual speculative attacks against many ERM currencies. On September 17, the Italian lira and British pound left the ERM, and the Spanish peseta was devaluated. Nonetheless, speculative pressures against the ERM currencies continued. In late July 1993, speculative transactions pushed several ERM currencies, such as the French franc and the Belgian franc, near or below their respective ERM floors. On August 1, the EC finance ministers and central governors decided to widen the margins for all ERM currencies, except the Dutch guilder, to $\pm 15\%$.\(^3\) From then on, the tension against the ERM diminished gradually when economic recovery spread across Europe. On November 26, 1996, the lira re-joined the ERM at the parity of L 1000 per deutschmark.

In fact, the EMS is not the final stage of the European union. The Maastricht Treaty of 1991 marked the transition to the European Monetary Union (EMU) in three stages by 1999 at the latest. The Euro, coming in 1999, will then become the official currency for member countries of the Euro zone.\(^4\) The conversion rate between the Euro and each member’s national currency will be fixed and irrevocable. The stability of the ERM of the EMS can guarantee the stability of the Euro.

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\(^1\) As from July 1990, the margin for the Italian lira was narrowed down to be $\pm 2.25\%$ until the lira left the ERM in September 1992.

\(^2\) This way of division can be referred to Corden (1994) and Fratianni and Artis (1996).

\(^3\) For further details, see the October 1993 *World Economic Outlook*, IMF (International Monetary Fund, 1993).

\(^4\) There are 11 member countries of the Euro zone in 1999. They include Germany, France, Italy, Belgium, Luxembourg, the Netherlands, Spain, Portugal, Austria, Finland and Ireland.
The purpose of this paper is to examine the intensity of the links between the ERM currency pairs under the EMS before the Euro zone is established.

Dunis and Keller (1989) introduced the concept of zonal elasticity for measuring the intra-zonal intensity of the link between any national currency and a key currency of a given currency area. Unit zonal elasticity signifies perfect linkages between currency pairs studied within the same currency area. According to Mundell (1961), an optimal currency area implies a zonal elasticity equal or close to unity. Dunis and Keller (1989) used a single-equation, maximum likelihood approach for estimation of zonal elasticity, and traditional $t$-statistics for statistical inference. However, the inclusion of stochastic trend in time series variables would lead to spurious results (Granger and Newbold, 1974). Also, the specification of the single equation in Dunis and Keller (1989) implicitly assumed statistical exogeneity of the deutschmark. The concepts of stationarity, cointegration, weak exogeneity and error-correction mechanism, which have been very popular in applied economics in the past decade, were not adopted in their article. My paper differs in several aspects. Firstly, the focus of the analysis is spotlighted on the ERM of the EMS so that only the major ERM currencies are chosen here. Secondly, I will employ the multivariate cointegration techniques of Johansen (1991) to estimate the (long-run) cointegrating parameters. Thirdly, a vector error-correction model (VECM) is also formulated in order to specify the short-run dynamics of cointegrated variables and test for weak exogeneity in the system. By so doing, I can examine the dynamic adjustment processes between the deutschmark and other ERM currencies. Finally, intercept dummies are added in the multivariate cointegration model to allow for parity shifts over the par-value flexibility period of the EMS.

This paper is divided into six sections. Section 2 describes the model specification. Section 3 explains the econometric methods of unit root testing, multivariate cointegration and vector error-correction modeling. Section 4 shows the data source. Section 5 presents the empirical results and the final section summarizes the major findings.

2. Model specification

With the assumption of the triangular arbitrage, the regression equation for zonal elasticity is specified as follows:

$$y_t - \beta_1 - \beta_2 x_t = u_t$$

where $y_t$ is the log value of an ERM currency ($Y$) other than the deutschmark expressed vis-à-vis the US dollar, $x_t$ is the log value of the deutschmark vis-à-vis the US dollar. $\beta_1$ is the constant term, $\beta_2$ is the zonal elasticity, $u_t$ represents the sequence of disturbances.

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5 Similarly, Cheung et al. (1995) added realignment dummies in the PPP model.
6 Following Dunis and Keller (1989), the deutschmark is considered as the key currency under the EMS.
If \( y_t \) and \( x_t \) move together in the ERM in the long run, \( \beta_2 \) will approach toward the theoretical value of unity and \( \beta_1 \) will be close to the bilateral central parity rate. Temporary (short-run) deviations from the corresponding bilateral central parities, interpreted as disequilibrium errors, which are captured by \( u_t \), are non-zero. But over time, they will converge toward zero with constant variance. In other words, \( u_t \) is covariance stationary. The equation \( y_t = \beta_1 + \beta_2 x_t \) is known as the cointegrating equation or long-run equilibrium relation with the cointegrating vector \([1, -\beta_1, -\beta_2] \)^7 \( y_t \) and \( x_t \) are then said to be cointegrated. The closer \( \beta_2 \) approaches to unity, the more intense the linkage of the deutschmark and other ERM currencies within the EMS. The failure of cointegration between \( y_t \) and \( x_t \) implies the existence of persistent deviations from the central parity rate, and \( u_t \) is thus non-stationary.

Furthermore, a cointegrated relationship or long-run equilibrium implies a short-run adjustment path to reach it. If one variable in a system is not able to adjust through an (short-run) error-correcting mechanism to maintain the long-run equilibrium, this variable is said to be weakly exogenous to the long-run equilibrium (Norrbin et al., 1997). The ERM in itself does not identify the actual short-run adjustment process between deutschmark and other ERM currencies, which therefore remains an empirical issue.

3. Methodology

Prior to applying a cointegration test, it is necessary to examine the properties of the time series data. The first step is to test for unit roots in the sample data. The most popular methods for unit root testing are Augmented-Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests.

The ADF test for \( n \) unit roots is performed based on the following regression equation (Dickey and Pantula, 1987; Harris, 1995):

\[
\Delta^n S_t = \mu + \gamma t + \kappa \Delta^{n-1} S_{t-1} + \sum_{i=1}^{k-1} \phi_i \Delta^n S_t + \nu_t, \quad \nu_t \sim IN(0, \delta^2)
\] (2)

where \( S_t \) represents the variable under study.

Eq. (2) is estimated by OLS. The number of lag order, \( k - 1 \), is chosen in order to whiten the residuals. In case where the null hypothesis of \( n \) unit roots is rejected, it is required to test the null of \( n - 1 \) roots until the null cannot be rejected. If there is only one unit root in \( S_t \), \( S_t \) in level is known as integrated of order 1 or I(1).

MacKinnon (1991) derived a response surface equation to provide finite-sample critical values of the ADF \( t \)-statistic. Since the limiting distribution of the ADF

\(^7\) For simplicity, no parity realignments occur in Eq. (1), so \( \beta_1 \) is a single term. \( \beta_1 \) can be broken into a number of parity dummies to allow for the parity shifts.

\(^8\) Normalization of cointegrating vector can be done by using different coefficients. If normalization is done by using \( \beta_2 \), cointegrating vector becomes \([-1/\beta_2, \beta_1/\beta_2, 1]\).
$t$-statistic on $\kappa$ is independent of the number of $k - 1$ (Dickey and Fuller, 1979), Cheung and Lai (1995) extended MacKinnon’s critical values by considering the effect of $k - 1$ lag orders. Moreover, PP test statistics are used to modify the Dickey-Fuller $t$-statistics by allowing for an adjustment to account for weakly dependent and heterogeneous error process (Phillips and Perron, 1988). The PP test equation is the same as Eq. (2) except all lagged difference terms are excluded. Following Newey and West (1987), the number of truncation lags for the Newey-West correction for heteroskedasticity and serial correlation is equal to $4[T/100]^{2/9}$ where $T$ denotes the usable number of observations.

If all variables studied are I(1), cointegration test should be performed next. Johansen and Juselius (1990) and Johansen (1991) developed a multivariate maximum likelihood (ML) procedure for estimating the cointegrating vectors. The simulation results of Gonzalo (1994) suggest that compared with other methods, only Johansen’s ML estimates for cointegrating vectors are symmetrically distributed, median unbiased, and asymptotically efficient. The above properties based on asymptotic theory are still valid for finite samples. Also, his Monte Carlo study shows that Johansen’s procedure performs better than other methods even when errors are non-Gaussian, such as standardized chi-squared, Student’s $t$, and ARCH distributions. It is because Johansen’s procedure is a particular case of reduced rank simultaneous least squares (RRSLS), where no assumptions about any particular distribution of the error term are made. It can be proved that the asymptotic distribution of estimated parameters from RRSLS is equivalent to that from Johansen’s ML method. Also, Lee and Tse (1996) examined the performance of Johansen’s cointegration tests in the presence of GARCH errors and compared them with other cointegration tests. Their simulation study concludes that the bias is generally not very serious.

According to Johansen’s procedure, the $p$-dimensional unrestricted vector autoregressive (VAR) model is first specified with $k$ lags:

$$Z_t = \sum_{i=1}^{k} A_i Z_{t-i} + \Psi D_t + U_t, \quad U_t \sim IN(0, \Sigma) \quad t = 1 \ldots T$$

(3)

where $Z_t = [Z_1, \ldots, Z_p]'$ is a $p \times 1$ vector of stochastic variables. The values of $Z_0, \ldots, Z_{-(k-1)}$ are fixed, $D_t$ is a vector of dummies and $A_i$ is a $n \times n$ matrix.

Then, VAR model (3) can be reformulated in a VECM form:

$$\Delta Z_t = \sum_{i=1}^{k-1} \Phi_i \Delta Z_{t-i} + \Pi Z_{t-1} + \Psi D_t + U_t$$

(4)

The hypothesis of cointegration is formulated as a reduced rank of the $\Pi$ matrix. Under the Granger Representation Theorem (Granger, 1986; Engle and Granger, 1987), if the rank of $\Pi$ is equal to $r \leq p - 1$, such that $\Pi = \beta \beta'$ and $\Pi Z_{t-1} \sim I(0)$, then there exist $r$ cointegrating vectors in $\beta$ and the last $(p - r)$ columns of speed adjustment coefficients or loadings in $\alpha$ are zero. Thus, the matrix $\beta' Z_t$ constitutes $r$ cointegrating equations and $\beta' Z_{t-1}$ represents $r$ disequilibrium error terms.
The likelihood ratio (LR) reduced rank test for the null hypothesis of at most \( r \) cointegrating vectors is given by the Trace statistic, and for the null hypothesis of \( r \) against the alternative of \( r + 1 \) cointegrating vectors is known as the Maximal eigenvalue statistic:

\[
\lambda_{\text{trace}} = -T \sum_{i=r+1}^{p} \ln(1-\lambda_i) \quad \lambda_{\text{max}} = -T \ln(1-\lambda_{r+1})
\]

where \( \lambda_1 > \ldots > \lambda_p \) denotes \( p \) eigenvalues of their corresponding eigenvectors \( V = (v_1, \ldots, v_p) \). If the null hypothesis of \( r \) cointegrating vectors is accepted and then \( \beta = (v_1, \ldots, v_r) \) is known as the ML estimates for cointegrating parameters. Asymptotic critical values are shown in Osterwald-Lenum (1992) and can be adjusted by a scaling factor, \( T/(T-pk) \) to eliminate finite sample bias (Cheung and Lai, 1993).

However, if dummies in \( D_t \) change the asymptotic distribution of the LR test statistics, the bootstrap method which is a resampling technique can be used to simulate the bootstrap critical values for the reduced rank test statistics under the null for each sample.\(^9\) Ordinary bootstrap method, assuming the underlying disturbances in VECM (4) to be independent, is used in this paper. The bootstrap algorithm for reduced rank hypothesis is shown in van Giersbergen (1996).

If cointegrated relationship exists, restriction tests on cointegration vectors and loadings follow. Johansen’s procedures allow the LR tests for linear restrictions on \( \beta \) and \( \alpha \), which are asymptotically distributed as \( \chi^2 \) (Johansen and Juselius, 1990, 1992). The hypotheses about \( \beta \) and \( \alpha \) are expressed as:

\[
H_{\beta}: \beta = (H_1 \beta, \ldots, H_r \beta) \quad \text{and} \quad H_{\alpha}: B' \alpha = 0
\]

where \( H_i \) is \( (p \times s_i) \), \( \phi_i \) is \( (s_i \times 1) \) and \( 1 \leq s_i \leq p \), \( B \) is \( (p \times (p-m)) \), \( s_i \) denotes the number of unrestricted parameters and \( (p-m) \) represents the number of row restrictions.

Since Johansen’s reduced rank approach only determines how many unique cointegration vectors span the cointegration space, it is necessary to impose restrictions motivated by economic arguments on individual cointegration vectors in \( \beta \) lying within that space. Hence, \( H_i \) expresses the linear economic hypothesis to be tested on each of the \( r \) cointegration relations and \( \phi_i \) is a vector of parameters to be estimated in the \( i \)th cointegration relation. Moreover, the hypothesis of zero row restriction on \( \alpha \) is equivalent to the hypothesis of weak exogeneity. Let us partition \( Z \) into \( Z_1 = [Z_1, \ldots, Z_{p-1}]' \) and \( Z_2 = [Z_p]' \). In case where the null hypothesis of \( \alpha_{p,j} = 0 \), for \( j = 1, \ldots, r \), is accepted, the equation for \( \Delta Z_p \) will then contain no information about \( \beta \) in the cointegrated system and does not respond to any disequilibrium errors. \( Z_p \) is known as weakly exogenous to the system. It is valid to condition on \( Z_p \) and reformulate the so-called partial VECM (Johansen, 1992) in the following way:

\[
\Delta Z_{1t} = \Gamma_0 \Delta Z_p + \Gamma_1 \Delta Z_{1t-1} + \alpha \beta' Z_{t-1} + \Psi D_t + \epsilon_t \quad (5)
\]

\(^9\) Unless \( D_t \) represents centered seasonal dummies, asymptotic critical values in Osterwald-Lenum (1992) become invalid.
where \( x = [x_1, x_2, \ldots, x_{p-1}]' \), \( \Gamma_0 \) denotes the (short-run) impact multiplier, measuring the current changes in \( Z_1 \) in response to changes in \( Z_p \). The elements in \( Z_1 \), move to eliminate disequilibrium errors in the system. By conditioning on weakly exogenous variable, the rest of system may better behave statistically and the stochastic properties of the model will be improved.

4. Data

The data for this study are taken from the IMF’s International Financial Statistics. They include month-end spot exchange rates of seven major ERM currencies, which are French franc (FFR), Belgian franc (BFR), Dutch guilder (DFL), Danish krone (DKR), Italian lira (ITL), British pound (UK£), and the German deutschmark (DM). All the data series are expressed vis-a-vis the US dollar and in natural logarithms. The sample period covers the ERM period from March 1979 to December 1997, except that the data for the Italian lira are up to August 1992, and for the British pound start from October 1990 up to August 1992. Data for parity grid are taken from the International Currency Review.

5. Empirical results

5.1. Unit root test

The results of unit root test are reported in Table 1. The null hypothesis of two unit roots for all currencies is rejected but the null of one unit root cannot be rejected. These findings suggest that each currency contains one unit root and thus I(1).

Table 1

<table>
<thead>
<tr>
<th>Currencies</th>
<th>Null: two unit roots</th>
<th>Null: one unit root</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADF([q])</td>
<td>PP([q])</td>
</tr>
<tr>
<td>ITL</td>
<td>-12.208[0]***</td>
<td>-12.427[4]***</td>
</tr>
<tr>
<td>UK£</td>
<td>-4.585[0]***</td>
<td>-4.580[2]***</td>
</tr>
</tbody>
</table>

* ADF\([q]\) and PP\([q]\) represent ADF and PP test statistics respectively with \( q \) lag orders. Critical values are calculated based on Table 1 from Cheung and Lai, 1995.

** Statistical significance at the 5% level.

*** Statistical significance at the 1% level.
5.2. Cointegration test

The full sample periods of the ERM for cointegration tests include the par-value flexibility period from March 1979 to December 1986 and the par-value rigidity period from January 1987 to December 1997, for the FFR/DM, BFR/DM, DFL/DM and DKR/DM. For the ITL/DM, the par-value flexibility period runs from January 1979 to December 1989, and the par-value rigidity period from January 1990 to August 1992. For the UK£/DM, it includes only the par-value rigidity period from October 1990 to August 1992.

The VAR model for currency pairs here implies a bivariate system, \( p = 2 \) and \( Z_t = [y_t, x_t]' \). The cointegration tests start for the period of par-value flexibility. Table 2a shows that the LR statistics reject the hypothesis of \( r = 0 \) but they cannot reject \( r = 1 \) for all chosen ERM currency pairs. Thus, the existence of long-run linkages between the currency pairs is accepted. Active intra-marginal interventions, capital control policies and frequent parity realignments were the main factors for cointegration under the fixed-but-adjustable rate system (MacDonald and Taylor, 1991; Corden, 1994; Grauwe, 1994).

Both the LR(\( y_t \)) and LR(\( x_t \)) test statistics indicate that the DM acted as weakly exogenous to all the systems of the cointegrated currency pairs except the system of the ITL/DM. In other words, the FFR, BFR, DFL and DKR adjusted to eliminate the disequilibrium errors and the DM performed the error-correcting process for the system of the ITL/DM only. Furthermore, the LR(\( \beta \)) test statistics show that the hypothesis of unit restriction on zonal elasticities cannot be rejected for all the systems of the cointegrated currency pairs, except the system of the FFR/DM and ITL/DM. In other words, only the BFR, DFL and DKR had perfect linkages to the DM.

Table 3a reports the estimation results for the partial VECM during the par-value flexibility period. For the system of the FFR/DM, BFR/DM, DFL/DM and DKR/DM, the impact multipliers, \( \Gamma_0 \), are all above 0.94, and the loadings, \( \alpha_y \), are all negative, ranging from about \(-0.4\) to \(-0.6\). It indicates that the FFR, BFR, DFL and DKR moved from about 40 to 60% monthly to adjust previous deviations from their central parities. For the system of the ITL/DM, the positive loading, \( \alpha_x \), is equal to about 0.48. The impact multiplier is about 9\% over unity, which represents the overreacting short-run movement of the DM in response to the current changes in the ITL.

Table 2b and Table 3b show the estimation results for the par-value rigidity period. Table 2b shows that the null hypothesis of no cointegration is rejected for the systems of the FFR/DM, BFR/DM and DFL/DM during this period. Despite the lack of parity realignments, the cointegrated relationship is attributed to convergent economic policies for the participation of the EMU. It is found that the

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\[10\] Although the ERM period of the lira can be extended from November 1996 to December 1997, the sample size is too small for cointegration test and linear restriction tests.

\[11\] The Gauss program for ordinary bootstrap is provided by Noud van Giersbergen.
### Table 2
Testing for cointegration and for linear restriction on loadings and cointegrating vectors during the sample periods of par-value flexibility and par-value rigidity

#### (a) Par-value flexibility

<table>
<thead>
<tr>
<th>Currency pairs</th>
<th>$T$</th>
<th>$k$</th>
<th>$D$</th>
<th>Ho: $r$</th>
<th>$\lambda$trace</th>
<th>$\lambda$max</th>
<th>Q(90%)</th>
<th>Q(95%)</th>
<th>Q(99%)</th>
<th>LR($\alpha_y$)</th>
<th>LR($\alpha_x$)</th>
<th>LR($\beta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFR DM</td>
<td>94</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>94.64</td>
<td>20.44</td>
<td>23.72</td>
<td>31.09</td>
<td>92.45</td>
<td>17.72</td>
<td>20.69</td>
<td>26.96</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
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<td>21.73</td>
<td>2.19</td>
<td>12.47</td>
<td>15.50</td>
<td>21.73</td>
</tr>
<tr>
<td>BFR DM</td>
<td>94</td>
<td>3</td>
<td>7</td>
<td>0</td>
<td>53.91</td>
<td>20.09</td>
<td>23.18</td>
<td>28.93</td>
<td>51.87</td>
<td>17.39</td>
<td>20.10</td>
<td>25.94</td>
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<td></td>
<td></td>
<td>1</td>
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<td>12.39</td>
<td>15.11</td>
<td>21.11</td>
<td>2.05</td>
<td>12.39</td>
<td>15.11</td>
<td>21.11</td>
</tr>
<tr>
<td>DFL DM</td>
<td>94</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>29.00</td>
<td>20.91</td>
<td>23.80</td>
<td>30.51</td>
<td>28.50</td>
<td>17.13</td>
<td>19.63</td>
<td>24.38</td>
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<td></td>
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<td></td>
<td>1</td>
<td>0.50</td>
<td>9.13</td>
<td>11.10</td>
<td>15.30</td>
<td>0.50</td>
<td>9.13</td>
<td>11.10</td>
<td>15.30</td>
</tr>
<tr>
<td>DKR DM</td>
<td>94</td>
<td>4</td>
<td>8</td>
<td>0</td>
<td>40.38</td>
<td>24.41</td>
<td>28.36</td>
<td>35.78</td>
<td>36.62</td>
<td>20.70</td>
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<tr>
<td>ITL DM</td>
<td>130</td>
<td>7</td>
<td>9</td>
<td>0</td>
<td>67.60</td>
<td>17.92</td>
<td>20.87</td>
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#### (b) Par-value rigidity

<table>
<thead>
<tr>
<th>Currency pairs</th>
<th>$T$</th>
<th>$k$</th>
<th>Ho: $r$</th>
<th>$\lambda$trace</th>
<th>$\lambda$max</th>
<th>Q(90%)</th>
<th>Q(95%)</th>
<th>Q(99%)</th>
<th>LR($\alpha_y$)</th>
<th>LR($\alpha_x$)</th>
<th>LR($\beta$)</th>
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<tbody>
<tr>
<td>FFR DM</td>
<td>132</td>
<td>4</td>
<td>0</td>
<td>19.82*</td>
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<td>3.38*</td>
<td>2.05</td>
<td>4.29**</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
<td>6.29</td>
<td>6.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>BFR DM</td>
<td>132</td>
<td>4</td>
<td>0</td>
<td>29.07***</td>
<td>21.76***</td>
<td>1.56</td>
<td>2.98*</td>
<td>9.32***</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>DFL DM</td>
<td>132</td>
<td>3</td>
<td>0</td>
<td>28.58***</td>
<td>21.97***</td>
<td>1.99</td>
<td>3.18*</td>
<td>8.95***</td>
<td></td>
<td></td>
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</tr>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>DKR DM</td>
<td>132</td>
<td>4</td>
<td>0</td>
<td>18.09</td>
<td>10.49</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ITL DM</td>
<td>32</td>
<td>5</td>
<td>0</td>
<td>7.39</td>
<td>5.94</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
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<td>1</td>
<td>1.46</td>
<td>1.46</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK£ DM</td>
<td>23</td>
<td>2</td>
<td>0</td>
<td>5.55</td>
<td>3.67</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*a The number of $k$ is chosen based on AIC criteria. $D$ denotes the number of dummies. Q(.) represents the quantile of the bootstrap distribution. $\alpha_y$ and $\alpha_x$ represent loadings for $y_t$ and $x_t$, respectively. LR($\alpha_y$), LR($\alpha_x$) and LR($\beta$) represent likelihood ratio test statistics for zero row restriction on $\alpha_y$, $\alpha_x$, and unit restriction on $\beta$, respectively.

*b A constant is restricted to the cointegration space.

*a Statistical significance at the 10% level.

** Statistical significance at the 5% level.

*** Statistical significance at the 1% level.
Table 3
Partial vector error correction model during the sample periods of par-value flexibility and par-value rigidity

(a) Par-value flexibility

<table>
<thead>
<tr>
<th>Currency pairs</th>
<th>FFR DM</th>
<th>BFR DM</th>
<th>DFL DM</th>
<th>DKR DM</th>
<th>ITL DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_\phi$</td>
<td>-0.593</td>
<td>-0.416</td>
<td>-0.478</td>
<td>-0.391</td>
<td></td>
</tr>
<tr>
<td>($-12.54$)</td>
<td>($-8.250$)</td>
<td>($-5.349$)</td>
<td>($-6.549$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x_\alpha$</td>
<td>0.484</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($5.740$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>[1, -1.045]</td>
<td>[1, -1]</td>
<td>[1, -1]</td>
<td>[1, -1.088]</td>
<td></td>
</tr>
<tr>
<td>$\Gamma_0$</td>
<td>0.953</td>
<td>0.961</td>
<td>0.961</td>
<td>0.946</td>
<td>1.089</td>
</tr>
<tr>
<td>($43.29$)</td>
<td>($57.97$)</td>
<td>($64.79$)</td>
<td>($45.28$)</td>
<td>($48.92$)</td>
<td></td>
</tr>
<tr>
<td>$LM(4)$</td>
<td>0.091</td>
<td>0.176</td>
<td>1.341</td>
<td>0.152</td>
<td>0.040</td>
</tr>
<tr>
<td>$ARCH(4)$</td>
<td>10.25**</td>
<td>5.019</td>
<td>6.962</td>
<td>1.124</td>
<td>3.400</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.959</td>
<td>0.977</td>
<td>0.981</td>
<td>0.963</td>
<td>0.962</td>
</tr>
</tbody>
</table>

(b) Par-value rigidity

<table>
<thead>
<tr>
<th>Currency pairs</th>
<th>FFR DM</th>
<th>BFR DM</th>
<th>DFL DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_\phi$</td>
<td>-0.184</td>
<td></td>
<td></td>
</tr>
<tr>
<td>($-3.463$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x_\alpha$</td>
<td>0.250</td>
<td>0.494</td>
<td></td>
</tr>
<tr>
<td>($4.67$)</td>
<td>($4.645$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>[1, -1.256, -0.935]</td>
<td>[1, -2.997, -1.068]</td>
<td>[1, -0.107, -1.023]</td>
</tr>
<tr>
<td>$\Gamma_0$</td>
<td>0.950</td>
<td>0.983</td>
<td>0.997</td>
</tr>
<tr>
<td>($53.27$)</td>
<td>($87.97$)</td>
<td>($64.79$)</td>
<td></td>
</tr>
<tr>
<td>$LM(4)$</td>
<td>2.416</td>
<td>2.303</td>
<td>0.991</td>
</tr>
<tr>
<td>$ARCH(4)$</td>
<td>5.963</td>
<td>31.50***</td>
<td>0.334</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.965</td>
<td>0.985</td>
<td>0.991</td>
</tr>
</tbody>
</table>

$\beta = [1 - \beta_1, \beta_2]$. LM(4) and ARCH(4) represent Lagrangian multiplier tests for 4th order autocorrelation and ARCH respectively. All coefficients of dummies are significant at the 1% level. The figures in parentheses refer to t-statistics. ARCH is significant for the FFR/DM. However, as mentioned in Lee and Tse (1996), the bias is generally not serious.

DKR cannot maintain cointegrated relationship with the DM as a consequence of insufficient economic convergence.\(^{12}\) It supports the fact that Denmark will not join the Euro zone in 1999. Before she joins to the Euro zone, further efforts to achieve greater convergence are anticipated; otherwise, further delay to join the Euro zone and/or adjustment of central parities are needed.

\(^{12}\) For the system of the DKR/DM, LR statistics for the null of no cointegration marginally exceed the asymptotic critical values at the 10% level. Nevertheless, after finite-sample adjustment, the null cannot be rejected.
Also, unsurprisingly, the null hypothesis of no cointegration cannot be rejected for the systems of the ITL/DM and UK£/DM. In other words, the paths of the ITL and the UK£ moved in divergence away from that of the DM. As a consequence, the deviations from the central parities of the ITL and the UK£ persisted without reverting and led to the eventual exit of the lira and the pound from the ERM in 1992. The divergent paths of the ITL and UK£ during the par-value rigidity period are attributable to a number of factors. Fratianni and Artis (1996) blamed the lira’s suspension on the weak Italian fundamentals without parity realignment. Her weak fundamentals included large cumulative inflation differentials and output growth differentials between Italy and Germany. For the case of the British pound, Lau (1991) considered that the British economic conditions in 1990 were immature for the participation in the ERM. Higher inflation rate and interest rates had continuously undermined British intra-zonal competitiveness since she joined the ERM. He predicted that the British pound might need to be devaluated or exit from the ERM after the 1992 general election. Similarly, George Soros emphasized the business-cycle factors and the timing of Britain’s ERM entry as the main reasons for the pound’s exit from the ERM. He said that Britain went into the ERM in the midst of the recession while Germany was experiencing its post-unification boom, so the position became unsustainable as the British recession deepened (Fratianni and Artis, 1996). Hughes Hallett and Wren-Lewis (1997) blamed the pound’s inevitable exit on overvaluation of the parity and German unification.

Also, LR(β) test statistics show that the null hypothesis of unit restriction on zonal elasticities can be rejected for all the systems of the cointegrated currency pairs during the par-value rigidity period. It signifies the less intense linkages among the cointegrated currency pairs as a result of imperfect economic convergence of the ERM countries without parity adjustments. Potential economic inability in the Euro zone can be anticipated when no further efforts to reinforce convergence will be taken. Moreover, as indicated by the LR(β) test, the DM performed the role of error-correcting process for the systems of the BFR/DM and DFL/DM. Finally, as reported in Table 3b, the impact multipliers, $\Gamma_0$, range from 95% to over 99% with loadings varying from 18 to 50%.

6. Summary

Cointegration and partial VECM are useful tools in examining the various time-series properties of the ERM currencies. It is found that only the BFR/DM, FFR/DM and DFL/DM successfully maintain cointegrated relationship over all periods of EMS, although all chosen currency pairs pass the cointegration test over the period of par-value flexibility. The linkages of the cointegrated ERM currency pairs became less intense during the par-value rigidity period, reflecting imperfect economic convergence in the ERM countries. These countries are required to reinforce cooperation to achieve greater convergence. Otherwise, economic instability within the Euro zone will still exist. In Denmark, insufficient economic convergence leads to the (marginal) rejection of cointegration hypothesis under the
fixed-rate system. It means that further efforts to achieve convergence are needed before she can join the Euro zone in the next stage.

The failure of cointegration of the ITL/DM and UK£/DM during the par-value rigidity period implies that the paths of the ITL and UK£ diverged away from that of the DM. As a result, persistent deviations from the parities of the ITL and the UK£ led the two currencies to exit from the ERM in the 1992 currency crisis. Italy re-joined the ERM again in 1996 and further investigation of the time-series properties of the lira is needed when longer sample data is available in future. Britain has decided not to join the ERM again. Hughes Hallett and Wren-Lewis (1997) predicted that Britain has no enthusiasm to take the risks for re-joining the ERM but she will take steps to meet convergence criteria that are essential for monetary union.

Finally, the DM performed the role of error-correcting process for one out of five cases under the fixed-but-adjustable rate system, and it played the same role for two cases out of three under the fixed-rate system. Therefore, the DM should not be assumed a priori statistically exogenous under the EMS.

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References

International Monetary Fund, October, 1993. World Economic Outlook. IMF, Washington, DC.