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A Systems Approach to Modelling the EMS Exchange Rate Mechanism*

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Abstract: This paper examines the extent to which the EMS has succeeded in stablising intra-European exchange rates from external influences. It generalises earlier results by developing a systems approach to the problem which enables intra-currency volatility to be separated from the impact of external exchange rate shocks on the system as a whole. It is found that the EMS has indeed been successful in the intra-system task while the external effects on the entire system have increased.

I INTRODUCTION

The purpose of this paper is to analyse the extent to which the EMS has been successful in stabilising intra-European exchange rates while reducing the collective variability of these rates to changes in the major non-EMS currencies. Previous work in this area has been reported by Padoa-Schioppa (1984), Rogoff (1985), Giavazzi and Giovannini (1986), Ungerer *et al.* (1986), and Artis (1988). Our paper generalises these analyses by developing an appropriate systems framework which allows examination of the responsiveness of the complete set of participating members' bilateral exchange rates to variations in the strength of the Japanese and United States currencies. Using monthly data from January 1973 to June 1986, models were estimated for both pre- and post-EMS regimes. Amongst the major findings are that while

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the EMS as a whole has become increasingly susceptible to external influences, it has nevertheless succeeded in reducing the bilateral exchange rate volatility of its members' currencies.

The remainder of the paper is organised as follows. Section II introduces the modelling strategy and the essential properties of the data. Section III outlines the model and presents the empirical findings. Conclusions are drawn in the final section.

II THE EMS AND DISPERSION OF EUROPEAN EXCHANGE RATES

It is widely accepted that the EMS has achieved considerable success in reducing the dispersion of the exchange rates of its participating members' currencies. Figure 1 illustrates the extent to which this is the case.

Although there is obviously little point in testing for the existence of a change in the degree of dispersion among these exchange rates since the introduction of the EMS, there is some merit in describing its extent. In order to maintain some degree of consistency with the analysis which is presented in the next section, the dispersion analysis is conducted in terms of the logarithms of the US-dollar exchange rates of the EMS-participating countries (Belgium, Denmark, The Netherlands, France, West Germany, Ireland and Italy).

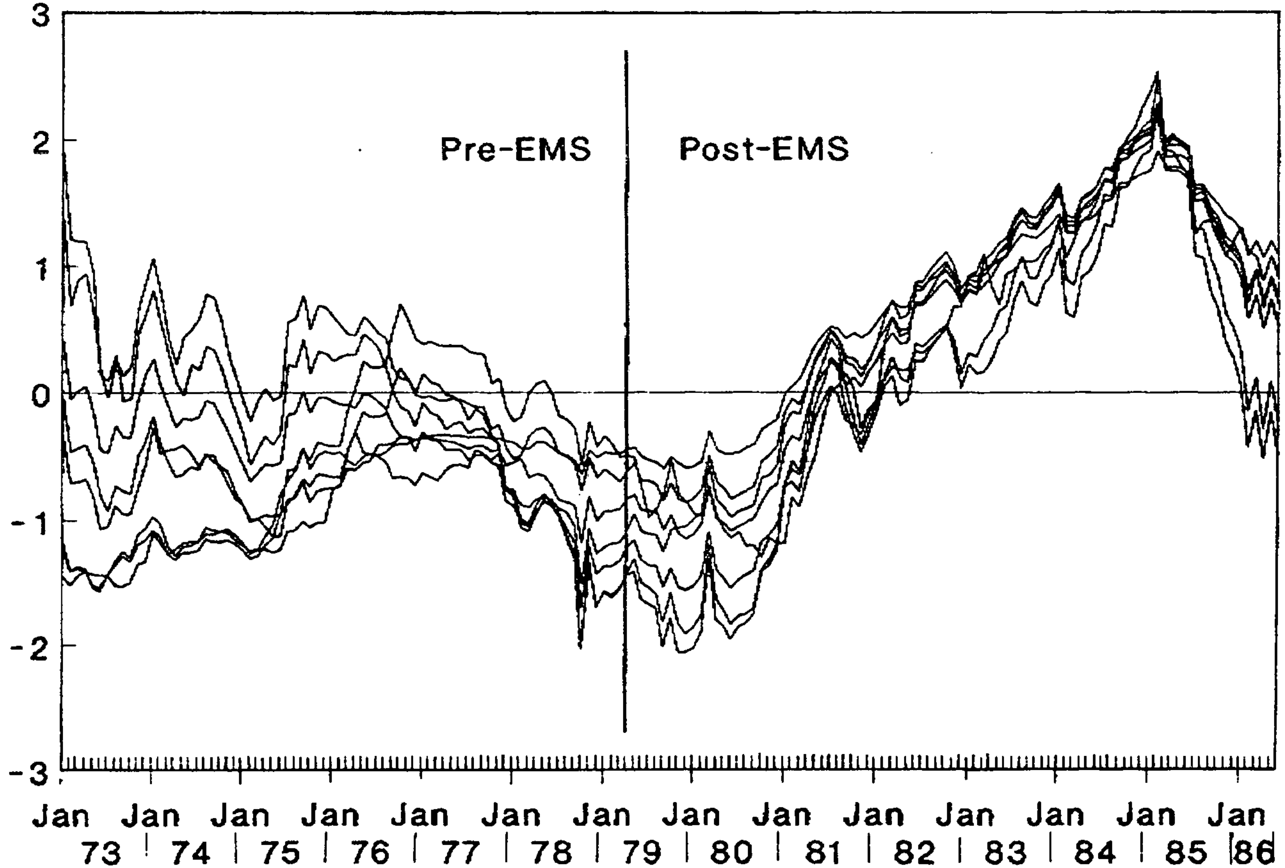
The total variation in the EMS can be described by the sum of the variances of the seven individual series expressed in logarithms. In order to gain insight into the dispersion among the currencies, various indices can be computed that attempt to account for this total variation. One simple way of effectively achieving this is to use principal component analysis. In principal component analysis, the seven exchange rates are transformed into seven uncorrelated indices with the sum of the variances of the indices being identical to that of the original total variation. The indices are constructed in order of diminishing variance so that, if all seven rates were almost perfectly correlated, the first component would account for nearly all of the total variation. As the degree of dispersion increases, more components are needed to account for total variation.

Specifically, the first component PC_1 is that index

$$PC_1 = \sum_{i=1}^{7} w_i \, ln(s_i)$$

where the s_i denote the US-denominated exchange rates of the European currencies and the fixed weights w_i ($i=1, \ldots, n$) are derived in the principal component analysis. Because PC_1 is that index with the highest variance, it tends to be heavily trending and is, therefore, a representative fixed weight index. Although all of the components are necessary to explain 100 per cent of the total variation, it is usually the case that most of the variation is accounted

Figure 1 : Normalized Exchange Rates



for with only a few components. Indeed, the number of components necessary to explain, say, 95 per cent of the total variation is an indication of how closely the series move together. Therefore, an analysis of the EMS pre-and-post its introduction should show that fewer components are necessary to provide an adequate representation of the data after its introduction if the EMS has, indeed, contained the individual rates in a tighter band. The cumulative percentage explanations of the first three components are presented in Table 1.

Table 1: *Decomposition of Total Variation by Principal Components*

Sample Period	*Cumulative Percentage Explanation by Components 1 to i*		
	1	*2*	*3*
Pre-EMS	66.48	96.65	98.63
Post-EMS	98.99	99.66	99.83

Not surprisingly, the greater pre-EMS dispersion noted in Figure 1 has led to two components being required to explain more than 95 per cent of the variation in the system whereas a greater explanation is achieved in the post-EMS period with only one component.

The principal components analysis can be extended to decompose the variation of each individual currency participating in the system. Table 2 presents these results. Interestingly, the Dutch guilder and German mark are subject to more non-trend variation than the others in the post-EMS regime. These two rates have tended to share a particularly close relationship and the greater variability in the mark reflects its role as a substitute for the major non-EMS currencies in world portfolios. During the pre-EMS period, five of the currencies exhibit similar behaviour with the first component explaining the majority of the variance and the second bringing the total up to more than 90 per cent. Two currencies, the French franc and the Danish krone, stand out as being somewhat different. The franc has almost no correspondence to trend with components 2 and 3 playing a similar role to components 1 and 2 for the other currencies.

This analysis serves as little more than a description of the data, but the same analysis on the log-changes in the rates provides an interesting insight into the volatility of the system and its component currencies.

Table 2: *Decomposition of the Variation in Each Currency*

Country	*Cumulative Percentage Explanation by Components 1 to i*		
	1	2	*3*
Pre-EMS:			
Belgium	53.63	98.71	99.00
Denmark	23.79	90.44	92.71
Netherlands	62.85	96.80	97.00
France	1.92	70.01	96.54
W. Germany	65.48	98.86	99.19
Ireland	69.03	96.81	98.99
Italy	86.97	98.84	98.99
Post-EMS:			
Belgium	99.56	99.58	99.85
Denmark	99.50	99.51	99.51
Netherlands	97.16	99.84	99.92
France	99.55	99.72	99.99
W. Germany	96.31	99.84	99.91
Ireland	99.77	99.77	99.77
Italy	98.77	99.59	99.99

III THE MODEL

The model which forms the basis of our econometric analysis expresses the log-change in each rate, $D(s_i)$ as a contemporaneous function of the log-changes of the effective US and Japanese exchange rates

$$D(s_i) = \alpha_{0i} + \alpha_{1i}D(US^e) + \alpha_{2i}D(YEN^e) + u_i \tag{1}$$

Since the seven equations in (1) have identical regressors, the complete model can be efficiently estimated by OLS and the difference between any two estimated equations is identical to a regression of the log-change of the relevant bilateral rates on the same set of regressors.

The model (1) contains a non-EMS currency, the US dollar, as the denominator in each s_i and this can be removed by following one of two approaches. By defining a base rate, say the mark, Equation (1) can be represented by an n-1 equation system of bilateral rates in the spirit of Artis (1988). There is a circularity property of the system in that any exchange rate would produce equivalent results but each would highlight different aspects. An alternative approach is to use an appropriately weighted average of all of the rates to define the numeraire.

In the previous section, the variance of the system was decomposed using principal components. If the exchange rates are nonstationary, population variances do not exist so an evolving population variance is effectively being decomposed in Section II. To the extent that exchange rate behaviour is closely approximated by a random walk, differenced data is approximated by a stationary process and, hence, decomposition of these sample variances is more appropriate. The analysis reported in Table 1 is repeated in Table 3 for the differenced data and the corresponding weights are presented in Table 4.

Table 3: *Decomposition of Total Volatility by Principal Components*

Sample Period	*Cumulative Percentage Explanation by Components 1 to i*		
	1	*2*	*3*
Pre-EMS	82.08	90.09	94.66
Post-EMS	96.12	97.44	98.17

Table 4: *Weights Defining First Component*

Country	*Pre-EMS*	*Post-EMS*
Belgium	17.13	14.90
Denmark	16.10	14.49
Netherlands	17.26	14.58
France	14.81	14.54
W. Germany	17.40	14.68
Ireland	9.01	14.10
Italy	8.28	12.71

The disparity in the explanation of the components across the two regimes has been reduced by using differenced data and this reflects the extent to which volatility within the EMS bounds has not diminished as much as the disparity in the levels. It is also interesting to note from Table 4 that the weights used to compute the first principal component are reasonably stable across the regimes with the only real difference being the increased weight for the Irish punt and the Italian lira in the post-EMS period. In both regimes all other currencies attract similar weights. The lira has been permitted a greater degree of variation under the EMS agreement and the change in the contribution of the punt is explained by its break with sterling at the time of the introduction of the EMS when the UK decided not to participate in the system.

Following Bewley (1986), the first component is subtracted from each equation in the system (1) to produce a singular, normalised equation system. Thus, any n-1 equations in that system define the entire model and can be estimated by OLS because of the common regressor property. The transformed equations can be thought of as expressing deviations from an overall fixed weight index, which we call the European Monetary Unit (EMU), as a function of external factors. There are important differences between the EMU and the ECU, which is the official "average" of the component currencies. The former is a fixed weight index for each regime but the ECU has been the subject of a number of re-alignments. While the ECU did not exist pre-EMS, the EMU can be constructed for both regimes.

The main purpose of introducing the EMU to Equation (1) is to separate the average behaviour of the EMS currencies from their dispersion about it. By so doing, we can analyse the impact of external effects on the EMS in two distinct parts; on the system as a whole via the EMU, and upon the cross-rates within the system. The final model is, therefore, a transformation of Equation (1). The seven equations in (1) have been replaced by six EMU-denominated currencies and one EMU equation.

The estimation was conducted on end-of-period monthly data over the period January 1973-March 1979 for the pre-EMS regime and April 1979-June 1986 for the post-EMS regime. The EMU equation estimates with a first-order autocorrelation correction are presented in Table 5 and the intra-system estimates are provided in Table 6.

Table 5: *The EMU Equation Estimates*

Regressor	*Pre-EMS*	*Post-EMS*
Constant	0.0009	0.0004
	(1.22)	(0.64)
$D(US^e)$	-0.4642	-0.5114
	(8.72)	(24.22)
$D(YEN^e)$	-0.1795	-0.2144
	(4.50)	(11.34)
AR(1)	0.18	0.88
	(1.40)	(4.27)
$\bar{R}^2$	0.54	0.88

Table 6: *Systems Estimates*

EMU-Denominated	*Pre-EMS*		*Post-EMS*	
Exchange Rate	D(US^e)	D(YEN^e)	D(US^e)	D(YEN^e)
Belgian franc	0.146	0.102	0.040	0.032
	(2.26)	(2.00)	(1.02)	(0.88)
Danish krone	0.145	0.092	-0.023	-0.038
	(2.04)	(1.64)	(0.72)	(1.24)
Dutch guilder	0.174	0.107	-0.027	0.007
	(2.18)	(1.70)	(1.01)	(0.28)
French franc	0.039	-0.082	0.082	-0.007
	(0.31)	(0.84)	(1.86)	(0.16)
German mark	0.135	0.052	0.012	0.048
	(1.86)	(0.90)	(0.40)	(1.78)
Irish punt	-0.610	-0.249	-0.012	0.005
	(3.61)	(1.87)	(0.40)	(0.20)
Italian lira	-0.368	-0.303	-0.082	-0.056
	(3.16)	(1.90)	(1.86)	(1.38)
Joint test	3.01	0.34	1.80	1.26

It is clear from Table 5 that while the change in the influence of the external exchange rates on the EMU is minimal across regimes, there exists a significant change in the autocorrelation structure of the residuals. It is reasonable to conjecture that the similarities in the construction of the EMU and the ECU in the post-EMS regime give rise to the same basic trends in these averages. The sharp changes due to the re-alignments of the EMS currnecies during the post-1979 era, however, cause a pattern in the residuals of the EMU equation which requires correction for the generated positive autocorrelation. The co-efficients on the external rates in the EMU equation are essentially unchanged across regimes but there is a marked increase in the significance of the effect. In both cases, the impact of the US dollar and the Yen is negative and significant so it can be claimed that the EMS has not reduced the volatility of the system as a whole which has been generated from external sources.

In order to assess the impact of external influences on the intra-system volatility, it can be noted from Table 6 that there are a number of significant coefficients in the pre-EMS regime and none in the post-EMS regime. Joint tests of significance that there is no external effect are contained in Table 6.

A 5 per cent critical value of 2.25 for this Hotelling's T^2 test confirms that only the US dollar impacts upon the system pre-EMS and neither rate does post-EMS. Since the average residual variance reduces from 34 to 7 across regimes, it can be noted that the unexplained volatility has been dramatically reduced.

IV CONCLUSIONS

This paper has been concerned with the extent to which the EMS has succeeded in stabilising intra-European bilateral exchange rates during a period of increasing external pressure. The modelling strategy is based on a complete systems approach to remove problems of defining a suitable numeraire rate and, importantly, to separate intra-system volatility from volatility of the system as a whole.

The overall conclusion that emerges from the analysis is that although the EMS has been subjected to increasing external influences during the 1980s, it has indeed been successful in insulating its participating members' bilateral exchange rates from external shocks.

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