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The Achievements of the European Monetary System*

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Abstract: This paper attempts to provide some answers to a number of related questions: Has the EMS reduced (real or nominal, bilateral or effective) exchange rate volatility? If so, has this been at the expense of increased interest rate volatility? How important have capital controls been for the operation of the EMS? Has the exchange rate mechanism reduced the volatility of *unanticipated* exchange rate changes? Has the EMS been effective in making Exchange Rate Mechanism (ERM) currencies close substitutes? What have been the implications of the EMS for the longer-run stabilisation of real exchange rates? Because of the uncertainty surrounding the statistical distributions of changes in asset prices in general and exchange rates in particular, an innovative theme of the paper is the use of non-parametric or semi-non-parametric econometric and statistical procedures wherever possible. Briefly, we conclude that the EMS has reduced the volatility of both exchange rates and interest rates; that capital controls probably have been important in its operation and that it has reduced the conditional volatility of exchange rates. We attribute many of these findings to the enhanced credibility of the exchange rate policies of ERM member countries. Some of our findings, however, namely that ERM member currencies do not appear to be perfect substitutes and that there is evidence of long-run misalignment within the EMS, do indicate that the EMS may indeed still be in its early days in terms of some of its longer-term goals.

I INTRODUCTION

This paper attempts to provide some answers to a number of related questions: Has the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) reduced (real or nominal, bilateral or effective) exchange rate volatility? If so, has this been at the expense of increased interest rate volatility? How important have capital controls been for the operation

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of the EMS? Has the EMS been effective in making member currencies close substitutes? What have been the implications of the EMS for the longer-run stabilisation of real exchange rates?

To attempt to answer these questions meaningfully, however, requires clarification of the perceived aims and objectives of the EMS. The formal objective of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) is the stabilisation, within generally narrow pre-agreed bounds, of member countries' nominal exchange rates. Since the EMS is an exchange rate mechanism of a customs union, however, it must be expected, if it is to survive in the long run, to ensure that member countries' competitiveness is protected; otherwise, the protection-reducing achievements of the customs union must be called into question as countries seek to restore their terms of trade. This is to suggest that, at the same time as the immediate and formal objective of the system is to stabilise *nominal* rates of exchange, its inner long-run rationale involves a requirement on *real* rates of exchange. This fundamental ambiguity accounts for what Goodhart (1986) has pointed out is an "unholy alliance" among those advocating British participation in the ERM, between those who seek to consolidate the counter-inflation gains of recent years and those who wish to protect the competitiveness of sterling from any repetition of the devastating over-appreciation of the 1980/1981 period. The two objectives are clearly not compatible without a convergence of inflation, at equilibrium levels of activity and external balance, between the member countries. In the period of the system's functioning so far, progress towards this objective has been provided in the historical context of the second OPEC oil shock which induced among countries generally, and members of the EMS in particular, a strong desire to reduce inflation. Given Germany's low inflation rate and (recent) historical reputation for counter-inflationary policy, this has implied to a degree convergence on the German standard.

Given the number of realignments which have taken place within the Exchange Rate Mechanism of the EMS since its inception in 1979 and the fact that variations are permitted within the parity grid margins, it remains in principle questionable whether the provisions of the system have actually induced a greater degree of stability in either the real or the nominal exchange rate. Thus, one aim of this paper is to present the results of a number of statistically rigorous tests for shifts in volatility and predictability of participating countries' exchange rates since March 1979, using data on a wide range of real and nominal, bilateral and effective exchange rates.

In the second place, however, we also examine the question of whether any reductions in exchange rate volatility that may have occurred as a result of the operation of the ERM have been bought at the expense of increased interest rate volatility. Moreover, we also examine the issue concerning the importance of capital controls in maintaining the ERM. This is clearly an important issue, given the prospect of liberalisation of capital controls in France and Italy and the possibility of full participation in the ERM by the UK, with its liberal payments regime.

Finally, we turn to two issues relevant to the longer-run credibility of the system. First, to what extent has the ERM increased the substitutability of member currencies? If the permanence of the exchange rate union is credible, one member currency should be as good as another's so that capital flight into, say, the mark, should not create undue pressure on the cross rates. Secondly, to what extent has the EMS tended to reduce the extent to which real exchange rates between members become misaligned?

Starting from a position of high and divergent rates of inflation, the survival of the EMS to date has required that full advantage be made of the provision for flexibility contained in the system (see, e.g., Taylor and Artis, 1988, for a discussion of the provisions of the EMS). It is important to note, however, that the introduction of the system did not require the abolition of exchange controls; and the use or otherwise of such controls to foster stability in the system is an issue we address below.

II EXCHANGE RATE VOLATILITY AND THE EMS

In this section, we present some new evidence on the effect of the ERM on exchange rate volatility by an examination of a number of nominal and real, bilateral and effective exchange rate changes.

2.1 *Previous Volatility Studies*

There have been 11 realignments of the currencies participating in the EMS (see Table 1); this, together with the fact that quite wide variations are allowed by the parity grid margins, leaves it an open question in principle whether the provisions of the System actually do induce a greater degree of stability in either the nominal or the real exchange rate.

Table 1: *Changes in EMS Central Rates*

	Dates of Realignments										
	24/9 1979	*30/11 1979*	*22/3 1981*	*5/10 1981*	*22/2 1982*	*14/6 1982*	*21/3 1983*	*21/7 1985*	*7/4 1986*	*4/8 1986*	*12/1 1987*
Belgian franc	0.0	0.0	0.0	0.0	-8.5	0.0	+1.5	+2.0	+1.0	0.0	+2.0
Danish kroner	-2.9	-4.8	0.0	0.0	-3.0	0.0	+2.5	+2.0	+1.0	0.0	0.0
German mark	+2.0	0.0	0.0	+5.5	0.0	+4.25	+5.5	+2.0	+3.0	0.0	+3.0
French franc	0.0	0.0	0.0	-3.0	0.0	-5.75	-2.5	+2.0	-3.0	0.0	0.0
Irish punt	0.0	0.0	0.0	0.0	0.0	0.0	-3.5	+2.0	0.0	-8.0	0.0
Italian lira	0.0	0.0	-6.0	-3.0	0.0	-2.75	-2.5	-6.0	0.0	0.0	0.0
Dutch guilder	0.0	0.0	0.0	+5.5	0.0	+4.25	+3.5	+2.0	+3.0	0.0	+3.0

The difference, stressed by John Williamson (1985), between the concepts of exchange rate *volatility* and *misalignment*, is important here. Volatility is a "high frequency" concept referring to movements in the exchange rate over comparatively short periods of time. Misalignment, on the other hand, refers to the capacity for an exchange rate to depart from its fundamental equilibrium value over a protracted period of time. For the reasons given by Williamson it seems fair to argue that the greater welfare significance attaches to the diminution of misalignment than to the reduction of volatility where there is (perhaps surprisingly) little evidence to support the view that volatility is welfare-reducing. To be more precise, what has been tested is whether exchange rate volatility appears to be trade-reducing. While a study by Akhtar and Hilton (1984) found that it was so for US-German trade, comparable studies by the Bank of England (1984) and the International Monetary Fund (1983) failed to confirm this finding for alternative trade flows, time period and volatility measures. Recent work by Cushman (1986) has, however, discovered evidence of volatility effects on trade when "third country" effects are controlled for (e.g., dollar-mark volatility may affect US-UK trade).

Nevertheless, a number of studies have concentrated on the evidence that the EMS has reduced exchange rate volatility, most notably those by Ungerer *et al.* (1983), the European Commission (1982), Padoa-Schioppa (1983), Rogoff (1985) and, most recently, Ungerer *et al.* (1987). Without exception the EMS in these studies has been judged as having contributed to improving the stability of intra-EMS bilateral exchange rates; the improvement is less marked for effective rates, and it has been argued in qualification that, with the lengthier data period over which it is now possible to run these tests, it is possible to show, in certain cases, that the earlier claims to stability of the EMS have weakened with the passage of time (c.f., House of Commons Select Committee, 1985, p. xiii).

2.2 *Some New Exchange Rate Volatility Tests*

All of the studies cited above, which have tested for a downward shift in exchange rate volatility for members of the EMS post-March 1979, have generally relied on purely descriptive statistics. As such, they can be at most suggestive, and it is perhaps difficult to assess scientifically the performance of the EMS in this respect in the light of this evidence. The most straightforward approach to the problem, namely estimating a specific parameterisation of the volatility and testing for a structural shift after March 1979, is fraught with pitfalls. This is because economists are far from certain concerning the correct statistical distribution of exchange rate changes. It is by now a stylised fact that percentage exchange rate changes tend to follow leptokurtic (fat tailed, highly peaked) distributions. Westerfield (1977), for example, finds that the stable paretian distribution with characteristic exponent less than two provides a superior fit to the change in the logarithm of spot exchange rates than the normal distribution. In a similar vein, Rogalski and Vinso (1978) suggest Student's t-distribution as a good approximation.

We wish to stress the importance of attempting to capture the correct distributional properties of exchange rate changes in any volatility study. By relying on simple variance measures, the studies cited above are implicitly invoking a normality assumption, the legitimacy of which a growing number of studies are, at the very least, bringing into question (see Boothe and Glassman, 1987, for additional references). For example, it might conceivably be the case that exchange rate changes at a certain frequency have a Cauchy distribution, for which no finite moments of any order exist.

In order to try and circumvent some of these problems, we decided to apply non-parametric tests for volatility shifts which do not require actual estimation of the distributional parameters. Instead, exchange rate changes are ranked in order of size and inferences are drawn with respect to the shape of the ranking. Intuitively, if a significant number of lower-ranked percentage changes were recorded in the latter half of the sample, a reduction in volatility would be indicated.

Let Δe_t be the change in the (logarithm of the) exchange rate at time t, then the maintained hypothesis is:

$$\Delta e_t = \mu + \sigma_t \epsilon_t \qquad (1)$$
$$\sigma_t = \exp(\alpha + \beta z_t)$$

where μ, α and β are unknown, constant scalars, ϵ_t is independently and identically distributed with distribution function F and density function f, and z_t is a binary variable reflecting the hypothesised change in volatility, i.e.:

$$z_t = \begin{cases} 1, & t \leqslant \text{March 1979} \\ 0, & \text{otherwise} \end{cases}$$

Given (1), the null hypothesis of no shift in volatility is then:

$$H_o : \beta = 0 \qquad (2)$$

Hajek and Sidak (1967) (HS) develop a non-parametric rank test for dealing with problems involving this kind of framework, which, under appropriate regularity conditions, is locally most powerful (HS, pp. 70-71).

Note, however, that although the test procedure is non-parametric in the sense that no volatility measures are actually estimated, in implementing the procedure we cannot avoid choosing an appropriate distribution for changes in the exchange rate. In order to try and minimise the damage due to choosing an inappropriate distribution we selected four well-known ones – hopefully, the true distribution of exchange rate changes is close to one of them. The densities used correspond to the normal, logistic, double exponential and Cauchy distributions. All of the chosen distributions are symmetric and both the double exponential and Cauchy distributions have fat tails.

2.3 *Exchange Rate Volatility Tests: Empirical Results*

Monthly (end month) data on bilateral US dollar exchange rates were taken from the IFS data tape for the period January 1973 to December 1986. Bilateral rates against the German mark and UK sterling were also constructed by assuming a triangular arbitrage condition. Real exchange rates were constructed by deflating by the wholesale price index (also from the IFS tape). The currencies used included 7 ERM members – German mark, Danish kroner, Belgian franc, French franc, Italian lira, Irish punt and Dutch guilder – and 4 non-ERM members – US dollar, UK sterling, Japanese yen and Canadian dollar. All results reported are for shifts in the volatility of monthly exchange rate changes. In each case, the test statistics were converted to standard normal variates under the null hypothesis by dividing through by the standard deviation. Significantly positive statistics indicate a reduction in volatility post-EMS, significantly negative statistics an increase (see Taylor and Artis, 1988, for further details).

As would be expected, the results of applying these tests to nominal bilateral rates (not reported) indicated a significant reduction in volatility for ERM currencies against the mark, whilst dollar rates generally showed a significant *rise* in volatility post-1979. Perhaps a little more interesting is that these results are largely echoed by those in Table 2a, which gives results of the tests applied to *real* mark bilateral exchange rates. There is strong evidence of a significant reduction in volatility in the real mark exchange rate against most of the ERM currencies, which is in marked contrast for all the real mark exchange rates against the non-ERM currencies. With the exception of the dollar-lira real rate, there are no significant shifts in volatility recorded for either the dollar or the sterling real rates (not reported).

Table 2b reports results of the tests applied to nominal effective rates, using the standard IMF (multilateral exchange rate model or MERM) effective indices. This appears to weaken the volatility reduction effect for the EMS currencies – only the Italian lira and, to a lesser extent, the German mark, show a significant post-March 1979 volatility reduction. For the non-ERM currencies, both the US dollar and UK sterling effective indices show a significant post-ERM *rise* in volatility, while the Canadian dollar shows a significant *reduction* in volatility. The results reported in Table 2c for the real effective MERM rates (deflated by a basket of wholesale price indices, using the standardised

MERM weights for the top 10 currencies) are much more clear cut. These show a fairly marked reduction in real exchange rate volatility for *all* the EMS countries, a slightly less marked increase in volatility of the real US dollar rate, with no significant shift for the other currencies.

Table 2: *Test Statistics for a Shift in Exchange Rate Volatility After March 1979*[a]

Table 2a: *German Mark Real Rates*

Exchange Rate	*Normal*	*Logistic*	*Double Exponential*	*Cauchy*
DMK-DKR	3.21 (0.65 E-3)	2.72 (0.32 E-2)	2.71 (0.34 E-2)	2.88 (0.20 E-2)
DMK-BFR	1.39 (0.08)	1.14 (0.12)	1.17 (0.12)	1.08 (0.14)
DMK-FFR	4.53 (0.30 E-5)	3.75 (0.90 E-4)	3.68 (0.12 E-3)	3.67 (0.12 E-3)
DMK-ITL	6.03 (0.80 E-9)	5.08 (0.18 E-6)	5.04 (0.24 E-6)	5.52 (0.17 E-7)
DMK-NGL	3.45 (0.23 E-3–	2.86 (0.20 E-2)	2.98 (0.14 E-2)	3.28 (0.50 E-3)
DMK-IRP	6.37 (0.19 E-9)	5.34 (0.93 E-7)	5.24 (0.16 E-6)	5.39 (0.70 E-7)
DMK-US$	0.17 (0.43)	-0.05 (0.48)	-0.10 (0.46)	-0.88 (0.19)
DMK-CN$	1.01 (0.15)	0.55 (0.29)	0.58 (0.28)	-0.50 (0.31)
DMK-JPY	0.96 (0.17)	0.55 (0.29)	0.47 (0.32)	-0.63 (0.26)
DMK-UK£	-0.16 (0.43)	-0.33 (0.37)	-0.25 (0.40)	-1.00 (0.16)

Notes: [a]All statistics are standard normal variates under the null hypothesis of no shift in volatility.

Figures in parentheses are marginal (two-sided) significance levels.

Significantly positive statistics indicate a reduction in volatility post-March 1979; significantly negative statistics indicate an increase in volatility.

Table 2b: *Nominal Effective Rates*

Currency	*Normal*	*Logistic*	*Double Exponential*	*Cauchy*
Danish kroner	-0.59 (0.28)	-0.48 (0.31)	-0.60 (0.27)	-0.95 (0.17)
Belgian franc	1.59 (0.06)	1.28 (0.10)	1.26 (0.10)	1.01 (0.16)
French franc	1.33 (0.09)	0.99 (0.16)	0.88 (0.19)	0.23 (0.41)
Italian lira	3.35 (0.4 E-3)	2.51 (0.60 E-2)	2.45 (0.71 E-2)	1.32 (0.09)
Dutch guilder	0.66 (0.25)	0.39 (0.34)	0.33 (0.37)	-0.40 (0.34)
Irish punt	0.82 (0.41)	0.54 (0.54)	0.48 (0.63)	-0.30 (0.77)
German mark	2.09 (0.02)	1.55 (0.06)	1.46 (0.07)	0.57 (0.28)
US dollar	-2.62 (0.43 E-2)	-2.25 (0.01	-2.31 (0.01)	-2.92 (0.17 E-2)
Canadian dollar	2.03 (0.02)	1.74 (0.04)	1.76 (0.04	2.05 (0.02)
Japanese yen	-0.94 (0.17)	-0.62 (0.27)	-0.66 (0.25)	-0.12 (0.49)
UK sterling	-1.84 (0.03)	-1.62 (0.05)	-1.66 (0.05)	-2.06 (0.02)

Let us summarise the results so far. There is strong evidence of reduced intra-ERM exchange rate volatility post-March 1979, and signs of increased volatility in dollar and (to a slightly lesser extent) sterling rates. These results hold, moreover, for both real and nominal exchange rates.[1]

1. In Taylor and Artis (1988), we report tests for shifts in the *conditional* volatility of exchange rates (i.e., a shift in predictability). These results are qualitatively identical to the results reported above for a shift in the unconditional volatility.

Table 2c: *Real Effective Rates*

Currency	*Normal*	*Logistic*	*Double Exponential*	*Cauchy*
Danish kroner	4.36 (0.65 E-5)	3.61 (0.15 E-3)	3.57 (0.18 E-3)	3.45 (0.27 E-3)
Belgian franc	1.92 (0.03)	1.61 (0.05)	1.62 (0.05)	1.95 (0.03)
French franc	2.17 (0.01)	1.78 (0.03)	1.81 (0.03)	1.72 (0.04)
Italian lira	3.14 (0.85 E-3)	2.45 (0.71 E-2)	2.49 (0.63 E-2)	2.09 (0.02)
Dutch guilder	1.78 (0.03)	1.45 (0.07)	1.41 (0.08)	1.81 (0.12)
Irish punt	5.24 (0.16 E-6)	4.41 (0.10 E-4)	4.38 (0.12 E-4)	4.72 (0.24 E-5)
German mark	3.35 (0.41 E-3)	2.54 (0.50 E-2)	2.49 (0.63 E-2)	1.32 (0.09)
US dollar	-1.3 (0.09)	-0.32 (0.09)	-1.36 (0.08)	-2.48 (0.65 E-2)
Canadian dollar	1.39 (0.08)	1.17 (0.12)	1.11 (0.13)	1.11 (0.13)
Japanese yen	0.10 (0.46)	0.11 (0.45)	0.11 (0.45)	0.22 (0.41)
UK Sterling	-1.44 (0.07)	-1.12 (0.13)	-1.10 (0.13)	-0.91 (0.18)

III INTEREST RATE VOLATILITY AND THE EMS

3.1 *Volatility Transfer*

One anti-ERM argument which is sometimes advanced rests on the notion that advanced macroeconomic systems naturally generate a "lump of uncertainty" which can be pushed from one point in the economy but which will inevitably reappear elsewhere (see e.g., Batchelor, 1983; 1985). For example, it might be argued that removing or reducing exchange rate volatility will inevitably induce a rise in interest rate volatility. Such a conclusion might follow from inverting a standard exchange rate equation and noting that the interest rate is the only other major "jump variable" in the system. Such a phenomenon might be termed "volatility transfer". In so far as the burden of increased interest rate volatility falls more widely on the general public than that of exchange rate volaility (which presumably falls mainly on the company or more particularly the tradable goods sector), then the welfare argument must hinge on which sector would find it easier to hedge the induced risk. Given that there already exist well-developed forward foreign exchange markets, it is probable that such an argument would come down against membership of the ERM.

However, it is not at all clear that ERM membership is in fact equivalent to "inverting the exchange rate equation". In so far as membership enhances the credibility of policy, there may be a significant reduction in speculative attacks on the exchange rate and hence a *reduction* in the volatility of short-term interest rates (if the authorities use interest rates as at least a short-term measure for "leaning into the wind"). Alternatively viewed, there may be a shift in the economic structure according to the Lucas (1976) critique.

In an attempt to shed some light on these arguments we carried out the non-parametric volatility shift tests outlined above, for monthly changes in onshore short-term interest rates; the results are reported in Table 3. From our discussion in the previous sub-section, the effective operation of French and Italian exchange controls for much of the post-ERM period would be expected to achieve a reduction in onshore interest rate volatility and this is borne out, at least for the Italian case. There is also, however, strong evidence of a reduction in Dutch onshore interest rate volatility whilst the converse is true for US and Canadian onshore rates. Interestingly, there is also evidence of a reduction in the volatility in UK onshore interest rates.

3.2 *Capital Controls and the EMS*

It has been argued that exchange controls over capital flows have been a particularly important feature of the functioning of the EMS. The two major member countries outside Germany – France and Italy – have deployed substantial measures of capital control. Belgium, with its two-tier market arrangements, has discriminated between commercial, or current account, and capital transactions.

The significance of these controls was first effectively highlighted by Rogoff (1985), who noted the substantial violations of (covered) interest parity exhibited by France and Italy. Subsequently, Giavazzi and Giovannini (1986) and Giavazzi and Pagano (1985) have analysed and documented further the impact of these controls. Despite anecdotal suggestions that the measures have been ineffective, a contrary impression of effectiveness is indicated by the wedge between "off-shore" (Euro) interest rates and "on-shore" (domestic) interest rates for the countries concerned. Accordingly, we employed the non-parametric tests outlined above to test for a shift in the volatility of the offshore-onshore (short term) interest differential post-March 1979, for most of the countries considered above. The results are reported in Table 4; they do indeed indicate a sharp rise in the offshore-onshore interest differential for the franc and lira, while there is some evidence of a reduction in volatility of the differential for the mark, guilder and punt. Given that the relaxation of UK and Japanese exchange control was almost contemporaneous with the formation of the EMS, it is hardly surprising that Table 4 reveals strong evidence of a reduction in the UK and Japanese offshore-onshore differentials.

Table 3: *Test Statistics for a Shift in Interest Rate Volatility After March 1979: Onshore-Offshore Differential*[a]

Rates	*Normal*	*Logistic*	*Double Exponential*	*Cauchy*
French franc	-2.70 (0.49)	-2.71 (0.47)	-1.98 (0.54)	-2.01 (0.36)
Italian lira	-2.55 (0.12)	-2.46 (0.14)	-2.43 (0.14)	-2.20 (0.03)
Dutch guilder	2.73 (0.64×10^{-2})	2.26 (0.02)	2.15 (0.03)	1.86 (0.06)
German mark	2.41 (0.02)	1.89 (0.06)	1.84 (0.06)	1.30 (0.19)
Irish punt	2.18 (0.03)	1.98 (0.05)	1.93 (0.05)	1.21 (0.23)
US dollar	-1.56 (0.12)	-1.18 (0.24)	-1.13 (0.26)	-0.79 (0.43)
Canadian dollar	-1.43 (0.15)	-1.10 (0.27)	-1.07 (0.29)	-0.59 (0.56)
Japanese yen	3.67 (0.24 E-3)	3.27 (0.10 E-2)	3.38 (0.72 E-3)	4.71 (0.25 E-5)
UK sterling	5.71 (0.11 E-7)	4.74 (0.22 E-5)	4.75 (0.20 E-5)	4.93 (0.84 E-6)

[a]See note to Table 2.

Table 4: *Test Statistics for a Shift in Interest Rate Volatility After March 1979: Onshore Short Rates*[a]

Rates	*Normal*	*Logistic*	*Double Exponential*	*Cauchy*
French franc	1.05 (0.29)	0.81 (0.42)	0.75 (0.46)	0.51 (0.61
Italian lira	4.56 (0.51 E-5)	3.69 (0.22 E-3)	3.51 (0.45 E-3)	2.87 (0.41 E-2)
Dutch guilder	2.91 (0.36 +-2)	2.37 (0.02)	2.25 (0.02)	1.85 (0.06)
German mark	0.81 (0.42)	0.41 (0.68)	0.38 (0.71)	-0.84 (0.40)
Irish punt	0.93 (0.35)	1.04 (0.30)	0.81 (0.42)	1.31 (0.19)
US dollar	-3.29 (0.10 E-2)	-2.60 (0.92 E-2)	-2.53 (0.01)	-2.01 (0.04)
Canadian dollar	-2.77 (0.56 E-2)	-2.17 (0.03)	-2.11 (0.03)	-1.42 (0.15)
Japanese yen	1.15 (0.25)	0.92 (0.36)	0.96 (0.34)	0.88 (0.38)
UK sterling	6.10 (0.11 E-8)	5.10 (0.34 E-6)	5.10 (0.35 E-6)	5.49 (0.41 E-7)

[a]See note to Table 2.

IV CURRENCY SUBSTITUTABILITY AND RISK PREMIA

Following Canzoneri (1982), we can say that the creation of an exchange rate union converts external shocks affecting member countries asymmetrically into symmetric ones; if the permanence of the union is credible, one member currency is as good as another's and an external shock inducing a flight of capital into, say, the mark, should affect the franc and lira in the same way, relieving pressure on the cross rates. Indeed, a dimunition of the exposure of German competitiveness to sentiment against the dollar was apparently a major motivation of German interest in the founding of the EMS (Ludlow, 1982). It therefore seemed of some interest to examine for the substitutability of EMS currencies during the period of operation of the EMS.

4.1 *Testing for Risk Premia in the EMS*

A number of authors have examined the issue of foreign exchange risk premia – see for example Domowitz and Hakkio (1985) and Taylor (1988). Testing for non-zero risk premia between currencies is an indirect and imperfect way of testing for perfect substitutability. The configuration of asset demand and supply may be such that the risk premium may be contingently zero between currencies whose assets are less than perfect substitutes in agents' portfolios. A non-zero risk premium is a necessary but not a sufficient condition for assets denominated in those currencies to perfect substitutes.

A non-zero risk premium should be detected as deviations from the non-risk adjusted uncovered interest parity (UIP) condition. The UIP theorem states that the interest differential between two financial assets, identical in every relevant respect except currency of denomination, should be exactly offset by the expected rate of change of the exchange rate between the relevant currencies over the period to maturity. Under the maintained hypothesis of rational expectations, the risk-adjusted UIP condition may be written:

$$\rho_t + E(e_{t+n} \mid I_t) - e_t = i_t - i_t^* \qquad (3)$$

where e_t is the (logarithm of the) domestic price of foreign currency, i_t is the exchange rate on the domestic security with n periods to maturity, an asterisk denotes a foreign variable and ρ_t denotes the (possibly time-varying) risk premium. If, for example, ρ_t is positive, agents require a premium for holding the domestic security over and above the expected depreciation adjusted interest differential.

Because of the difficulty in obtaining observed expectations of the future spot rate, empirical tests of UIP (i.e. that (3) holds with ρ_t identically zero) have generally relied on indirect evidence by assuming covered interest parity (the forward exchange premium is equal to the interest differential – see Taylor 1987a) which together with UIP and rational expectations then implies the optimality of the forward rate as a spot rate predictor. In contrast to early work by Frenkel (1981), a number of studies have rejected the simple UIP condition using this indirect method (Hansen and Hodrick, 1980; Hakkio, 1981, amongst others). We propose, however, to test currency substitutability directly by inferring the optimal conditional forecast of the future spot rate from the time series properties of the data, using a method originally developed by Sargent (1979) to test the rational expectations model of the term structure of interest rates. Since this methodology is by now well known, we shall give only a brief discussion. For further details see Taylor (1987b).

Setting the risk premium in (3) identically equal to zero the UIP condition becomes:

$$E(e_{t+n} \mid I_t) - e_t = i_t - i_t^* \tag{4}$$

If the one-period rate of depreciation, Δe_t, and the interest differential together form a linearly indeterministic, jointly covariance stationary process, then the multivariate form of a statistical theorem, known as Wold's decomposition (Hannan, 1980) implies that the process has a unique, infinite-order moving average representation. For a suitably chosen value of n, this can be approximated in finite samples by an n-th order bivariate vector autoregression. This can be written:[2,3]

$$\begin{pmatrix} \Delta e_t \\ i_t - i_t^* \end{pmatrix} = \sum_{i=1}^{n} \begin{pmatrix} \alpha_i \\ \gamma_i \end{pmatrix} \Delta e_{t-i} + \sum_{i=1}^{n} \begin{pmatrix} \beta_i \\ \delta_i \end{pmatrix} (i - i^*)_{t-i} + \begin{pmatrix} \epsilon_t \\ \eta_t \end{pmatrix} \tag{5}$$

where the innovations process $w_t = (\epsilon_t \eta_t)'$ is vector white noise:

$$E(w_t w'_{t-i}) = \begin{cases} \Theta, & i = 0 \\ o, & i \neq 0 \end{cases}$$

In companion form the model is:

$$Z_t = \Phi Z_{t-1} + \nu_t. \tag{6}$$

where

$$\Phi = \left[\begin{array}{cccc|c|cccc|c} \alpha_1 & \alpha_2 & \cdots\cdots & \alpha_{n-1} & \alpha_n & \beta_1 & \beta_2 & \cdots\cdots & \beta_{n-1} & \beta_n \\ \hline & I_{n-1} & & & 0 & & 0 & & & 0 \\ \hline \gamma_1 & \gamma_2 & \cdots\cdots & \gamma_{n-1} & \gamma_n & \delta_1 & \delta_2 & \cdots\cdots & \delta_{n-1} & \delta_n \\ \hline & 0 & & & 0 & & I_{n-1} & & & 0 \end{array}\right]$$

2. Note that the vector autoregressive representation (10) implicitly assumes that the moving average representation has zero deterministic part. In all the empirical work, the data were transformed to mean deviation form, which is equivalent to including constants in the vector autoregressions.

3. Note that this formulation does not directly contradict our earlier reasoning that the exchange rate approximates a random walk – the coefficient matrix may be sparse. Also, although we do not allow for heteroscedastic disturbances in this section, results obtained using the heteroscedastic-robust vector autoregressive tests developed in Taylor 1987c yielded qualitatively identical results to those reported below.

$$Z_t = (\Delta e_t, \ldots \Delta e_{t-n+1}, (i - i^*)_t, \ldots, (i - i^*)_{t-n+1})'$$
$$\nu_t = (\epsilon_t 0 \ldots 0\, \eta_t 0 \ldots 0)'$$

Using the first-order formulation, (6), it is then easily shown that:

$$E(e_{t+n}\ e_t \mid \Lambda_{t-1}) - E(i_t - i_t^* \mid \Lambda_{t-1})$$
$$= (h' \sum_{k=1}^{n} \Phi^{k+1} - g'\Phi)Z_{t-1} \tag{7}$$

where Λ_{t-1} is an information set consisting of only lagged values of the rate of depreciation and the interest differential and h and g are 2n-dimensional selection vectors with unity in the first and (n+1)th element respectively, and zeros elsewhere. However, taking expectations of the uncovered interest parity condition under perfect substitutability, (3), with respect to Λ_{t-1} implies that (7) should be identically equal to zero. Hence, the zero risk premium restrictions are:

$$h' \sum_{k=1}^{n} \Phi^{k+1} - g' \Phi = 0 \tag{8}$$

One way of testing these restrictions is to estimate the unrestricted system by ordinary least squares and construct a Wald test statistic. Since this is an asymptotic test, however, we also computed likelihood ratio and lagrange multiplier statistics for the restrictions as a cross-check (see Taylor, 1987b, for details on the construction of these statistics).

4.2 *Empirical Results*

Monthly (end-month) data on six-month Eurodeposit interest rates were taken from the *Financial Times*. In order to ensure compatability, the exchange rate data used in this section were also taken from this source. The ERM currencies considered were the German mark, French franc, Italian lira, Dutch guilder and Irish punt; the non-ERM currencies were the US dollar, UK sterling and Japanese yen.

The order of the vector autoregressions was chosen using the method outlined in Taylor (1987b). Basically, this involves balancing criteria such as whiteness of residuals, likelihood ratio tests on lag restrictions and minimisation of the Akaike Information Criterion (Akaika, 1973).

Table 5 gives the results of testing for zero risk premia between the mark and the other currencies examined during the period of operation of the EMS. Whatever test statistic is used, the results are qualitatively identical. As one might have expected, the simple UIP condition (zero risk premium) cannot be rejected for dollar-mark. On the other hand, there are massive rejections of simple UIP between the mark and both the yen and sterling. Perhaps the most striking finding, however, is the strong evidence of non-zero risk premia between the mark and the other ERM currencies. In particular, the simple UIP condition is rejected for the Dutch guilder-mark exchange rate, which is perhaps slightly surprising since the dollar-mark and the dollar-guilder exchange rates are often seen as moving in tandem.

Given that the assumption of rational expectations formed part of the maintained hypothesis in the tests outlined and applied above, one possible interpretation of these findings is that market participants do not in fact efficiently process and act upon all available information. However, since typical participants in foreign exchange and asset markets are highly motivated professionals with access to potentially vast information sets literally at the touch of a button, this might appear a rather unattractive option. Indeed, many economists who would demur at the rational expectations hypothesis in general would accept it as a useful working hypothesis when applied to foreign exchange or asset markets – such a view forms the basis, for example, of the "partly rational" models of Dornbusch (1976) or Blanchard (1981).

Given that a non-zero risk premium is a necessary but not a sufficient condition for the assets of two currencies to be perfect substitutes, our findings can at most be taken as circumstantial evidence of perfect substitutability between the mark and the US dollar. By denying this necessary condition for all other currencies against the mark, our results do, however, imply that the EMS has not been successful in rendering all member currencies perfect substitutes. Thus, the results of this section suggest that the EMS has *not* been successful in eliminating the vulnerability of the cross rates of its members *vis-à-vis* the mark to swings in sentiment against the dollar.[4]

V REAL EXCHANGE RATES AND THE EMS: RANDOM WALK OR DRAGGING ANCHOR?

As we noted in the introductory section, arguments for joining the ERM may hinge on the targeting of either the real or the nominal exchange rate. Although EMS realignments have probably made less than full adjustment for price level differences, one would expect the longer-run consequences of ERM

4. Radaelli (1987) provides corroborating evidence of a non-zero risk premium between the franc and the mark over this period by estimating a particular parameterisation of the risk premium suggested by Frankel (1982). From an examination of movements in the onshore-offshore differential, Radaelli also suggests that market participants may have been reasonably accurate in forecasting the timing of realignments. This is quite important in the present context since otherwise our results may suffer from the "peso problem" (Krasker, 1980). In order to be absolutely sure that our results are not dominated on the peso problem, we are currently engaged in research which separates the data into "turbulent" and "non-turbulent" periods.

Table 5: *Wald, Likelihood Ratio and Lagrange Multiplier Tests for the Zero Risk Premium Restrictions: Six Months Maturity*[a]

Exchange Rate	*Chosen of n*	R_1	R_2	Q_1	Q_2	*L(n−1)*	*L(n+1)*	*Wald Statistic*	*Likelihood Ratio Statistic*	*Lagrange Multiplier Statistic*
Franc-Mark	1	0.10	0.71	26.16	22.77	–	5.48	13.96	12.94	11.03
				(0.45)	(0.65)		(0.24)	(0.001)	(0.0015)	(0.004)
Lire-Mark	1	0.01	0.66	34.87	28.65	–	6.91	88.15	60.13	52.31
				(0.11)	(0.33)		(0.14)	(0.00)	(0.00)	(0.00)
Guilder-Mark	3	0.36	0.64	5.25	30.47	8.49	6.97	268.70	135.83	116.68
				(0.99)	(0.17)	(0.07)	(0.14)	(0.00)	(0.00)	(0.00)
Dollar-Mark	2	0.09	0.66	19.21	26.10	18.26	3.55	5.99	5.84	5.64
				(0.79)	(0.40)	(0.001)	(0.47)	(0.20)	(0.21)	(0.23)
Sterling-Mark	1	0.16	0.80	20.79	19.43	–	1.61	595.85	249.85	138.71
				(0.75)	(0.82)		(0.00)	(0.00)	(0.00)	(0.00)
Yen-Mark	2	0.08	0.87	12.53	33.63	14.51	5.67	506.54	427.03	310.16
				(0.98)	(0.12)	(0.006)	(0.22)	(0.00)	(0.00)	(0.00)
Punt-Mark	2	0.09	0.83	11.55	18.64	12.22	4.71	388.21	306.95	281.22
				(0.99)	(0.81)	(0.01)	(0.32)	(0.00)	(0.00)	(0.00)

[a]Period of estimation is July 1979 to December 1986, truncated as necessary because of lags. R_1 and R_2 denote the coefficients of determination for the rate of depreciation and interest differential regressions respectively, Q_1 and Q_2 are the corresponding Ljung-Box statistics, evaluated at 27 autocorrelations and are asymptotically central chi-square variates under the null of white noise residuals, with (27-n) degrees of freedom; L(n−1) in a likelihood ratio statistic for a vector autoregression of order (n−1) (VAR(n−)) against the alternative VAR(n), whilst L(n+1) tests VAR(n) against VAR(n+1): each is asymptotically central chi-square variate with four degrees of freedom, and was constructed with a finite sample correction for degrees of freedom as suggested in Sims, 1980; the Wald, likelihood ratio and Lagrange multiplier statistics for the zero risk premium restrictions are each asymptotically central chi-square under the null with 2n degrees of freedom; figures in parentheses denote marginal significance levels in all cases.

membership to entail convergence on some form of purchasing power parity (PPP), at least against other ERM currencies; indeed this can be viewed as a measure of policy convergence. As we noted in our introductory section, the long-run survival of the system would seem to depend upon long-run preservation of competitiveness, so that member countries are not continually tempted to try and restore their terms of trade.

In fact, however, there exists a whole literature which suggests that deviations from PPP, as measured by the real exchange rate, can generally be characterised as martingale or, more particularly, random walk behaviour. Seminal papers in this context are those of Roll (1979), who proposed a martingale PPP hypothesis based on efficient international goods arbitrage, and Adler and Lehmann (1983), who derive similar conclusions based on considerations of efficient cross-border bond arbitrage. Indeed, if the expected exchange rate depreciation over a given period is just equal to the expected inflation differential, the real exchange rate must follow a random walk.

This returns us to the distinction we made earlier (and which has been stressed by Williamson (1985) between *volatility* and *misalignment*. We believe that the results reported above constitute quite unequivocal evidence that the ERM has reduced exchange rate volatility, both real and nominal. In this section we want to investigate whether this volatility reduction has been coincident with a reduction in longer-term misalignment.

We propose to examine the long-run implications of the EMS by testing for unit roots in real exchange rates. Since the real exchange rate can be viewed as a deviation from PPP, if some form of (relative or absolute) PPP is to hold in the long run, the real exchange rate must be characterised by a stationary process. If the real exchange rate is non-stationary, there is no tendency for it to settle down at any particular level, even in the long run. Thus, PPP deviations – the degree of misalignment – will tend to get larger and larger over time.

5.1 *Testing for Unit Roots in Real Exchange Rates*

The specific hypothesis under examination is that the real exchange rate is characterised by a stochastic process with a unit root. Denote the real exchange rate c, and suppose it is generated in discrete time according to:

$$c_t = c_{t-1} + u_t \tag{9}$$

where the error sequence (u_t) may be weakly dependent and heterogeneously distributed but satisfies certain weak regularity conditions (see Phillips, 1987, or Taylor, 1987d). This assumption concerning the error process is quite important for two reasons. Much previous empirical work on this topic may be confounded because of implicit assumptions made concerning the error process in the random walk specification – i.e., that it is independently and identically distributed (iid). As noted above, a number of authors, particularly Cumby and Obstfeld (1984), and Domowitz and Hakkio (1985), have observed the presence of conditional heteroscedasticity (more particularly autoregressive conditional heteroscedasticity) in exchange rate innovations. In addition, the "peso problem" (Krasker, 1980), suggests that a perceived small probability of a large, discrete change in the exchange rate (such as an expected realignment), which does not materialise in-sample, will induce serial dependence into the forecast errors. In the present paper we therefore apply unit root tests which are non-parametric with respect to nuisance parameters and which therefore allow for weakly dependent and heterogeneously distributed forecast errors. Secondly, it may well be that the real exchange rate follows some general ARMA process with a unit root, rather than a pure random walk:

$$(1 - L)\, A(L)\, c_t = B(L) v_t$$

(where A(.) and B(.) are scalar polynomials in the lag operator, L) which can be written in the form (9) with

$$u_t = A^{-1}\, (L)\, B(L)\, v_t.$$

Thus, although we apparently test for a pure random walk, the results may in fact detect non-stationarity in higher-order processes.

In order to test the unit root hypothesis with independent and identically distributed (iid) errors, Dickey and Fuller (1981) and Fuller (1976) propose tests based on the ordinary least squares (OLS) regression:

$$c_t = \mu + \beta(t - T/2) + \alpha c_{t-1} + u_t \tag{10}$$

where T is the sample size and the null hypothesis is

$$\text{Ho: } (\mu, \beta, \alpha) = (0, 0, 1). \tag{11}$$

Under the maintained hypothesis that the error sequence is iid, Fuller (1976) and Dickey and Fuller (1981) derive the limiting distributions of the standard "t-statistics" for the individual null hypotheses $\alpha = 1$, $\mu = 0$, $\beta = 0$ (these statistics will not be distributed as t under the null because of the presence of a unit root) and use Monte Carlo methods to construct estimates of their finite sample empirical distributions. We denote these Dickey-Fuller statistics as t_α, t_μ and t_β respectively. Phillips and Perron (1986) propose amending these statistics to allow for weakly dependent and heterogeneously distributed errors (see Phillips and Perron, 1986 or Taylor, 1987d, for details). We denote these amended statistics t^*_α, t^*_μ and t^*_β respectively.

5.2 *Empirical Results*

Using the same exchange rate and price series data as in our volatility tests, we tested for unit roots in real exchange rates against the mark, pre- and post-EMS.[5] The results are given in Table 6. Interestingly, in no case, either pre- or post-EMS, can the null hypothesis of a pure random walk with zero drift be rejected as standard levels of significance.

Table 6: *Testing for Unit Root in Real Exchange Rates*[a]

$$c_t = \mu + \beta\,(t-T/2) + \alpha\, c_{t-1} + u_t$$

Exchange Rate	*Period*	*t*μ*	*t*α*	*t*β*
DMK-DKR	Pre-EMS	2.55	-0.81	-2.70
	Post-EMS	1.01	-0.23	-0.26
DMK-BFR	Pre-EMS	2.64	-0.78	-2.72
	Post-EMS	0.98	-0.24	-0.30
DMK-FFR	Pre-EMS	2.75	-0.86	-2.68
	Post-EMS	0.97	-0.21	-0.25
DMK-ITL	Pre-EMS	2.66	-0.84	-2.69
	Post-EMS	0.98	-0.25	-0.26
DMK-NGL	Pre-EMS	2.61	-0.83	-2.71
	Post-EMS	0.98	-0.22	-0.26
DMK-IRP	Pre-EMS	2.42	-0.88	-2.44
	Post-EMS	1.08	-0.26	-0.31
DMK-US$	Pre-EMS	2.81	-0.77	-2.11
	Post-EMS	1.04	-0.27	-0.31
DMK-CN$	Pre-EMS	2.59	-0.84	-2.65
	Post-EMS	0.97	-0.26	-0.25
DMK-JPY	Pre-EMS	2.63	-0.83	-2.70
	Post-EMS	0.99	-0.24	-0.26
DMK-UK£	Pre-EMS	2.65	-0.82	-2.72
	Post-EMS	1.08	-0.29	-0.30

a t*, t*, t* are the Phillips-Perron test statistics for the null hypothesis Ha: $\alpha = 1$, Hb: $\mu = 0$, Hc: $\beta = 0$.

Approximate rejection regions at the 5% level are $(t^*_\alpha \mid t^*_\alpha < -3.45)$, $(t^*_\mu \mid |t^*_\mu| < 3.42)$ and $(t^*_\beta \mid |t^*_\beta| < 3.14)$ respectively.

5. In each case, the logarithms of the real rate was normalised to zero at the beginning of each test period.

Recall, however, that the results reported in Section II show a very definite reduction in intra-ERM exchange rate volatility post-March 1979. In terms of the present section, this can be interpreted as a reduction in the (average) variance of the disturbance term, u_t, in (9). Thus, one interpretation of the present results is that although the ERM has not been able to put a halt to the tendency for exchange rates to become misaligned, it has been successful in reducing the rate at which the degree of misalignment grows. Put another way, the ERM appears to have increased exchange rate predictability.

VI CONCLUSIONS

6.1 *The Case of Ireland*

The case of Ireland is a special one in that it involves a country leaving a monetary union with sterling for an EMS which does not – in its principal respect – include sterling. Since sterling remains an important currency for Ireland (along with the dollar), it is by no means a foregone conclusion that this choice will have produced a stabilising effect on Ireland's exchanges.

Our results for the Irish punt have been included in the tables reported above. As must be expected, of course, volatility against sterling has increased over the period of operation of the EMS; our results show that it has also increased against the dollar in the same period, but has fallen significantly against the mark. As a result, the volatility of the nominal effective Irish exchange rate has shown no significant change, whilst volatility in the real effective rate has in fact undergone a significant decline.

The results for Ireland in respect of the volatility of interest rates do not show any significant change for either offshore or onshore rates, although the volatility of the differential does appear to have fallen somewhat. As with other ERM currencies, we cannot reject for the real Irish exchange rate against the DM a unit root hypothesis; nor can the punt be regarded as a perfect substitute for DM.

The overall impression is that the regime change implied in breaking with monetary union with the UK has been by no means bad for the *stability* of the Irish currency, or for the volatility of Ireland's real rate of exchange. The record in these respects would no doubt have been improved by a successful adherence on the part of the UK to the ERM and not only Ireland might have benefited from this. However, this is another story.

6.2 *General Conclusion*

The EMS has defied predictions of its imminent demise and thereby built up a stock of credibility with the market – as also with governments. Thus, we found unequivocal evidence that the ERM has brought about a reduction in both the conditional and unconditional variance of exchange rate changes and, far from having purchased this reduction at the cost of increased rate volatility, there is also some evidence of a reduction in the volatility of interest rates for ERM members. We attribute this to be enhanced credibility of the exchange rate policies of these countries.

In detail, however, the operation of the EMS has clearly owed something, at times, to the controls over capital flows by France and Italy. The present phase of liberalisation in these countries has highlighted the need for changes. Indeed, it is now recognised by ERM member countries that there is a need for constant monitoring of the system and changes in its mode of operation from time to time. In addition, it has also become more accepted that more explicit co-ordination of monetary, particularly interest rate, policy may be necessary.

Two other findings are of interest. The ERM has not, apparently, been successful in rendering member countries' currencies perfect substitutes or in establishing long-run convergence on some form of purchasing power parity. These findings are probably as much indicative of the system's comparative infancy as of any intrinsic weakness, but they do suggest that the longer-term properties of the system might reward further research.

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