Exchange Rate Behavior under the EMS

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1. Introduction

The main purpose of this study is to investigate whether the European Monetary System (EMS) has had any influence in the long run behavior of the exchange rates of member countries. More specifically, it will try to empirically determine whether membership in the System has resulted in exchange rates that fluctuate more closely together against third countries' currencies. Another purpose is to empirically investigate which countries have achieved a close enough long-run relationship between their exchange rates so as to judge them as belonging to the same currency area.

An optimum currency area is the best combination of regions (as a practical matter, of countries) within which the general means of payments is either a single common currency or several currencies whose exchange values are fixed to one another and fluctuate in unison against other countries' currencies (Mundel, 1961, McKinnon, 1963). There is no doubt that the European Union (EU) or even only the countries that will participate in the European Monetary Union (EMU), decided to start in the beginning of 1999, do not make an optimum currency area. Although there is a high level of interregional trade inside Europe, the other conditions necessary for a group of regions to be considered an optimum currency area are lacking: high labor mobility and low incidence of region-specific demand and supply shocks. But then, probably the United States are not

an optimal currency area either, as it suffers also from region-specific shocks (remember, for example, the Texas'oil boom in the early 1980s, the New England's property collapse in the late 1980s, and the southern California defense bust of the 1990s; also, see Bayoumi and Eichengreen, 1992, and Bean, 1993). But what is not doubted is that the existence of only one currency in the United States has moved it closer to becoming one (Wyplosz, 1997).

In what follows we investigate whether exchange rates of EMS member countries started to move more closely together against the US dollar after the introduction of the system, that is, whether the EMS induced the currencies of member countries to respond in the same fashion and to the same degree to the several shocks to which they are subject. We will see that with some exceptions, after the introduction of the EMS in 1979, European currencies belonging to the system started to move much more closely together against the US dollar. We will also see that, for the period that started in 1993 and ended in mid-1998, there is a group of European currencies that exhibited long-run stable bilateral relationships, showing that they satisfied the criterion of historically stable exchange rates, deemed necessary to participate in the EMU. But we will see that, for several other currencies that also will participate in the EMU from its start, stable bilateral long-run relationships with other EMU currencies were not found. However, in a multilateral setting, the exchange rates of the eleven EMU founding countries seem to present stable long-run relationships. We will also notice that, in the world at large, stable long-run bilateral relationships between currencies are more the exception than the rule, and that when they exist they are more likely to be found inside Europe than outside it.

This work is organized as follows. In the next two sections we will justify the relevance of empirical work on the behavior of exchange rates

to the study of the effects of the EMS. In Section 2 we will argue that the principal motive that lead to the creation of the EMS was aversion to exchange rate volatility. In Section 3 we will present the argument that although a country could expect to derive several desirable economic effects other than exchange rate stability from its joining the EMS, those other desirable effects, such as reduction in inflation and interest rates, could only be achieved if there was in the first place an effective change in behavior in its exchange rates. In Section 4 we will present evidence that for most of those countries that belonged to the ERM of the EMS from its start there was a significant change of behavior of their exchange rates in the desired direction of intra-European exchange rates stability. In Section 5 we will present results indicating that only a few currencies in the world exhibited bilateral stable long-run relationships, and that most of these were to be found in Europe. We summarize the findings in Section 6.

2. The origins of the European Monetary System: aversion to exchange rate volatility

With the decided move to Monetary Union by eleven countries in Europe by January 1, 1999, an appraisal of the performance of the EMS and its Exchange Rate Mechanism (ERM) has become an important empirical issue with policy implications. In evaluating the EMS it should be remembered that it was created with two main motivations.

One reason, more political in nature, and thus of no direct concern here, will be mentioned just briefly: the EMS was created as one step in the fulfillment of the desire for tighter political cohesion inside Europe (Dornbusch, 1996, Feldstein, 1997). In Europe, political integration was always preceded by increased economic integration (Giovannini, 1990). Another facet of this political motivation, already semi-economical in nature, was the desire to have a monetary policy that would be more

independent of the one conducted in Washington (Giovannini, 1992). Besides these aspects, the prospect that monetary independence would free Europe from the seigniorage that the United States had the power to levy unilaterally under the Bretton Woods system exerted enormous influence in certain European political circles during the 1960s and early 1970s (Rueff, 1967, Estaing, 1969).

The other motivation was the perception that for the European Community to prosper exchange rate stability was a necessary condition (Padoa-Schioppa, 1992). This was coupled with the historic aversion of European countries to exchange rate volatility (Giovannini, 1992). This distaste sprang from several factors. One was the recollection of the process of progressive erection of trade barriers that lead to the destruction of the liberal multilateral trading system that existed before the War of 1914-18 and was due, or at least was contemporaneous, to the competitive exchange rate depreciations that followed the collapse of the gold standard exchange system during the 1920s and 1930s (Levy, 1983).

It was also due to the concern that large and frequent unilateral exchange rate realignments would strain the European customs union and undermine the Common Agricultural Policy. Although Europe as a region is not more open than large countries such as the United States, Japan or Brazil, individual countries in Europe are in relation to other European countries very open (Giovazzi and Giovannini, 1990). The argument of Eichengreen (1993) that adjustable intra-EU[1] exchange rates would weaken the single market as changes in relative competitiveness would lead to attempts of protection has been in the minds of the European leaders for a long time. Concerns about the danger that unilateral

1) Although not strictly correct, EU will be used sometimes to indicate both the European Economic Community and the European Union, specially when referring to matters or periods that involved both the Community and the Union.

exchange values changes posed to the construction of an ever tighter economic unity were expressed as early as in the Treaty of Rome of 1957. The Treaty advocated that the liberalization of goods markets be accompanied by the removal of exchange controls, and recommended that exchange rate changes by member countries be considered of *"matters of common interest"* where unilateral decisions were to be avoided. In a first step in the effort to lock more tightly their exchange rates, the European Monetary Agreement was established in 1960 between the then six European Economic Community (EEC) countries. By this Agreement, member countries agreed to limit mutual exchange rate movements to 1.5 percent bands, much narrower than the 4 percent bands allowed for non-dollar exchange rates under the Bretton Woods rules (Obstfeld, 1997). Openness of the economy, it should be noticed, is an intra-European phenomena. Thus, it is volatility of intra-European exchange rates, more than fluctuations of European currencies against non-European currencies, that are viewed by Europeans as posing problems to the European economies.

Another long-term objective of EEC countries was also greater capital market integration. If to achieve the paramount objective of greater exchange rate stability member countries had to maintain, or worse, had to tighten the exchange controls that were in place to repel future currency speculation, greater capital market integration would be at risk. To work towards the duple objective of increased exchange rate stability within Europe and enhanced European capital market integration the EEC Central Bank Governor's Committee was created in 1964.

The aversion to exchange rate volatility became more and more visible as the parity realignments became larger and more frequent during the last years of the Bretton Woods agreement. The concern that volatility in exchange values would undermine the attainment of the goal of greater

economic union in Europe led to the Barre Report of 1969 and the Werner Report of 1971, that proposed the permanent fixing of European exchange rates by 1980 and lead to creation of the Snake as a step towards that objective. This plan, devised just before the economic turbulence of the early 1970s, soon became impracticable (Giovannini, 1990). However, the Snake, a network of mutually pegged exchange rates, continued to work until it was replaced by the EMS on March 13, 1979. It achieved only a limited success in promoting the goal of exchange rate stability in Europe, because France and Italy failed in their attempts to join in, the only consistent members being Germany and the Benelux Countries.

The central feature of the EMS is the ERM, that was intended to reduce exchange rate volatility and thus to establish a *"zone of monetary stability"* in Europe through a mutual system of *"fixed but adjustable exchange rates"* (Collins, 1992). In the ERM, exchange rates are fixed in the sense that central banks undertake the necessary actions to maintain bilateral rates within narrow bands. Exchange rates are flexible in the sense that fluctuations inside the agreed bands are determined mainly through market forces. More detailed descriptions of the EMS can be found in Ungerer, Evans, Mayer and Young (1986), Giovazzi and Giovannini (1989) or Loureiro (1996) but the three basic features of the System should be mentioned here.

The first is the existence of a grid of bilateral bands that is established jointly by member governments[2]. Exchange rates are allowed to fluctuate within these narrow bands or margins to reflect market forces. The central rates of the bands are fixed but in case of necessity can be adjusted trough

2) When the EMS was being set up in 1978 it was proposed that central rates should be defined with reference to the European Currency Unit and market rates pegged exclusively against it. Because of several technical and political problems this solution was abandoned in favor of a grid of bilateral bands (Padoa-Schioppa, 1992).

realignments that, as described below, cannot be decided unilaterally.

The second feature is the introduction of a set of rules to regulate and facilitate intervention by central banks in case a bilateral exchange rate begins to deviate from its central rate. These include "divergence indicators" that measure the distance between each currency and its European Currency Unit (ECU) central parity, and financing facilities that are extended to the central banks that need to intervene in the market to keep their currencies inside the established bands.

The third feature of the system is that realignments of parities are not unilateral but have to be decided unanimously by all member countries. This made reality the goal expressed in the Treaty of Rome that exchange rates be made matters of common interest where unilateral decisions were to be avoided, and has thus all but eliminated the risk of competitive devaluations inside the System[3]. When an adjustment in the central rates becomes necessary, the magnitude of the devaluation never has been enough to restore the competitiveness of countries with higher inflation. But this feature, by making realignments relatively easy, made possible, with the exception of the crisis of 1992, the avoidance of large misalignments of real exchange rates and the concomitant balance of payments crises and speculative attacks on weak currencies[4].

3) The Bretton Woods system also tried to discourage unilateral competitive devaluations. When joining the system every member country had to peg its currency to the US dollar and the IMF had to approve the initial exhange rate and every change thereafter. However, when countries decided to change their exchange rates they did not allow the IMF to exercise effective supervision. The Fund was informed at the last moment, to late to offer advice or to make any objection (Kennen, 1986).

4) The crisis of 1992 was probably due more to a *self-fulfilling* speculative attack, made possible by the intra-EU lift of capital controls some time before, than by any sizable misalignment of exchange rates due to different trends in monetary growth in member countries. In this setting, the occurrence of a self-fulfilling attack, might be caused by the very possibility of parity realignments that the existence of different currencies makes possible, and only a single currency might avoid (see Obstfeld, 1988, Cecco and Giovannini, 1989, Masera, 1989, for before the event previsions of the consequences of the lifting of capital controls

Very similar in its proposals to the Barre and Werner reports is the Delors Report of 1989 that lead to the Maastricht Treaty and planed Monetary Union in 1999. The details of the political vicissitudes of the process towards monetary union need not concern us here[5]. It will suffice our purpose to point that of the five convergence criteria for admission to the single currency that were consecrated into European law by the Maastricht treaty, namely price stability (consumer price inflation rate not to exceed 1.5 percent the average of the three EU members with lowest inflation rates), exchange rates stability (to have fluctuated inside the normal margins of the ERM for at least two years, without any devaluations on its own initiative against the currency of another member state), long term nominal interest rates (no more than 2 percent above the average of those of the three EU members with the lowest inflation rates) and government deficits and debt (general government deficits should not exceed 3 percent of GDP and government debt should not exceed 60 percent of GDP), only the one that concerns the stability of exchange rates was not subject to fudging with creative accounting procedures or with creative legal reinterpretations[6].

3. Economic impact of European Monetary System: the discipline and credibility effects

As a plot of ERM countries' inflation rates or interest rates would show

5) For descriptions of political developments from economists' perspectives see Giavazzi and Giovannini (1989), Eichengreen, Frieden and Hagen (1995), and Obstfeld (1997).

6) Not long after the Maastricht Treaty was signed it became evident that the criteria that was of overriding importance was exchange rate stability. As early as 1993 Thygesen (1993, p. 17) could write: "Budgetary criteria...are unlikely to be applied mechanically to bar countries which have long observed the rigid discipline of the normal margins in the EMS, from entry into the final stage". See also Obstfeld's (1997) discussion on the same subject.

(for example, see those in Loureiro, 1996, or Obstfeld, 1997), there has been a notable convergence in these economic indicators during the last 20 years. Countries that suffered from high inflation during the 1970s as Italy, France and Denmark gradually reduced their inflation rates to the levels of traditionally low inflation countries like Germany and the Netherlands, or in some cases, to even lower levels. Although after the second oil crisis in 1979 there was an increase in inflation rates in all ERM countries, that peaked between mid-1980 and mid-1982, it was followed by a generalized disinflationary trend until 1986-1987 and stable and low consumer prices increases (below 5 percent) thereafter. Similarly, long-term interest rates have fallen and converged across EMS countries.

Inflation reduction and convergence led to the formulation of two inter-related hypothesis that attributed these achievements to the operation of the system: the discipline hypothesis and the credibility hypothesis. The first states that limitations on exchange rate fluctuations against currencies of countries that are as inflation averse as Germany or the Netherlands automatically subject countries that are traditionally inflation prone, like France and Italy, to monetary discipline. The second hypothesis states that the commitment to a "fixed" exchange rate with an inflation-averse country gives monetary authorities of inflation prone countries credibility to proceed with disinflationary policies at lower output costs compared with those that would have to be incurred if similar policies had been undertaken without the announced peg. Arguments based on these hypothesis have been used by EMS supporters against France, Italy and the United Kingdom leaving the system in 1992, and for Greece, Portugal and Spain joining it (Papademos, 1990, Torres, 1990, Vinals, 1990).

Theoretical models based on the problem of time-consistent policies discussed by Kydland and Prescott (1977), Calvo (1978) and Barro and Gordon (1983), such as that of Giavazzi and Pagano (1988), show that

inflation prone countries would gain by fixing their exchange rate against the currency of an inflation-averse country, but with the implication that the low-inflation country will suffer a corresponding rise in inflationary pressures. Empirical evidence seems to support this result. While there is evidence that the EMS was instrumental in bringing down inflation in some member countries (Artis and Nachane, 1990, Kremers, 1990), there are also results that show that inflation-prone countries have benefited from lower inflation while inflation-averse countries have suffered from higher inflation, there being convergence but not lower inflation for all countries (Robertson and Symons, 1990, Blackburn, Mondiardino, and Sola, 1992).

The validity of the discipline-credibility hypothesis has been questioned with two arguments. First, the disinflationary experience of the 1980s and 1990s was not distinct from coincident developments outside the system (Giavazzi and Giovannini, 1988, Colins, 1988, Cohen and Wyploz, 1989). Second, the real activity costs from disinflationary policies were not lower in EMS member countries than in other industrialized countries (Loureiro, 1996) and the unemployment costs were higher (Grauwe, 1990).

Since no performance improvements would appear if the behavior of exchange rates did not change within the EMS, it seems that a first and essential step in the evaluation of the economic impact of the system is to examine whether that behavior changed or not for the currencies belonging to the system. Here also evidence is mixed. Some studies seem to indicate that generally, but not for all countries, membership of the EMS has brought larger falls in intra-system exchange rate volatility than for non-member countries (Fratianni and Von Hagen, 1990). Others suggest that membership in the EMS brought decreased volatility of exchange rates against the German mark at the cost of increased vulnerability to shocks due to greater kurtosis in the distribution of the bilateral exchange rates (Hallett and Anthony (1997)). Similar interpretation can be made of the

results presented by DosSantos (1997) that shows that where exists an explicit or implicit arrangement to peg one currency to another, the distribution of daily returns of that exchange rate seems to be stable Paretian, while no such arrangement does not exist, the distribution seems to be a mixture of distributions with finite variance.

4. Exchange rate behavior of ERM founding member' countries

In this section we will see that there was a significant change in the behavior of the exchange rates against the US dollar of the countries that started with the EMS in 1979. These countries were Belgium, Denmark, France, Germany, Ireland, Luxembourg and the Netherlands, that committed themselves to keep their exchange rates against each of the other participating currencies within the margin of ± 2.25 percent of the respective central rates, and Italy that had a fluctuation margin of ± 6 percent.

After describing the data used, we present first some descriptive statistics showing that ERM currencies increased the degree of their co-movements against the US dollar after 1980, and that this increased degree of co-movements was specific to the system, currencies not belonging to it not showing any significant change between before and after 1980. Then, using cointegration analysis, we confirm the increased degree of co-movements between the currencies of ERM founding members' countries.

The choice of the US dollar as the base currency against whom the value of all other currencies are measured was due to several reasons. The most important is that we did not want to use one of the EMS currencies, namely the German mark, as we would lose the possibility of analyzing its behavior. Thus the choice of the dollar, as the most important currency

outside Europe imposed itself. Another reason is that the longest time-series of exchange rates available are those against the dollar.

The emphasis on bilateral relationships among exchange rates should also have a word of justification. The main reason is that the ERM was constructed based on bilateral relationships between currencies, not with reference to a multilateral relationship with a single base currency. Thus, with the exception of the results presented in Section 5.4, the cointegration tests performed have the objective of testing if bilateral relationships existed or not. But in the context of the testing methodology used (that of Johansen, 1991, 1995) to determine whether a bilateral stable linear relationship existed it is necessary to perform the cointegration tests with only those two variabeles. This is due to the fact that in tests performed with more than two variables it is not possible to distinguish between two variable relationships and n-variables relationship (for $n \geq 3$)

4.1 Data description

The data used in this section is constituted by the daily dollar exchange rates for the currencies of the following seven EMS founding countries: Belgium, Denmark, France, Germany, Ireland, Italy and Netherlands. Luxembourg was not included because it has formed a currency union with Belgium since the 1920s. In Section 5, similar data for countries that will belong to the European monetary union (Austria, Finland, Portugal and Spain), for EU countries that will not participate in the European Monetary Union, (Greece, Sweden and the United Kingdom), and for other non European Union countries (Australia, Canada, Hong Kong, Japan, South Korea, Switzerland and Thailand) will also be utilized. The data was supplied by the Federal Reserve Bank of New York and consists of the noon buying rates in New York for cable transfers payable in foreign currencies, collected from a sample of market participants, which are

certified by the Federal Reserve Bank of New York for several legal purposes. The sample data covers the period from January 2, 1973 to June 12, 1998, with a total of 6386 observations.

For the tests performed in this section, the sample was partitioned into two periods: the first period, lasting until December 31, 1979 with a total of 1752 observations, and the second period, starting in January 2, 1980 with 4634 observations. In Section 5 we analyze in more detail the shorter sample period that starts in January 4, 1993 and ends in June 12, 1998, with a total of 1370 observations. It has been pointed that 1983 might be a more appropriate break as the system seems to have settled down around this time (Hallett and Anthony, 1997) and the number of realignments fell after 1983. Nevertheless we preferred the end of 1979 as breaking point and thus do not try to explain away the turbulence in exchange rates that existed during the first years of functioning of the system. Although that turbulence might in fact have been caused by the oil crisis of 1979-1981, the world recession of 1980-1982, and the divergent macroeconomic policies pursued by European countries during the first years of the system, it was felt that by choosing the end of 1979 as a dividing point we could better isolate the effects of the system on the behavior of exchange rates.

Throughout we will use y_t to designate the logarithm of the nominal exchange rate of the currency under consideration. In all cases the nominal exchange rate is expressed as the number of units of that currency per US dollar.

4.2 Preliminary evidence

How effective was the ERM in making the member currencies moving more closely together? Did the margins of fluctuation on bilateral exchange rates make any difference at all taking in consideration the frequent realignments of parities and the turbulence of 1992 that affected

Table I - Correlation coefficients for ERM currencies' exchange rates against the US dollar (1973-1979 and 1980-1998)

	Belgium					
Denmark	0.9144					
	0.9975	Denmark				
France	0.5333	0.7136				
	0.9716	0.9635	France			
Germany	0.9873	0.8854	0.4731			
	0.9367	0.9495	0.8352	Germany		
Ireland	−0.2090	−0.0116	0.4509	−0.2931		
	0.9181	0.9128	0.9697	0.7620	Ireland	
Italy	−0.5036	−0.2720	0.2814	−0.5787	0.9136	
	0.5153	0.5030	0.6491	0.2855	0.7776	Italy
Netherlands	0.9887	0.8987	0.4843	0.9922	−0.2881	0.5670
	0.9487	0.9601	0.8554	0.9990	0.7837	0.3105

Ireland and Italy and that of 1993 that affected Belgium, France and Denmark?

A simple way to measure the degree to which two currencies move together against a third one is to see the correlation coefficients of their exchange rates against the currency of the third country. The correlation matrix of ERM currencies' exchange rates against the US dollar is presented in Table I. Two values are reported: the first refers to the 1973-1979 period, the second to the 1980-1998 period.

As can be noticed, for almost all pairs of currencies there was an increase in the correlation coefficient after 1980, quite spectacular in some cases, such as those involving Ireland and Italy[7]. Only for three pairs there was a small decrease of the coefficient: for Belgium and the Netherlands,

7) As Italy left the Mechanism in September 17, 1992, the values of the correlation coefficient for the second period presented in Table I underestimate the effect that the ERM had on the lira. The correlation coefficients for the period from January 2, 1980 to September 16, 1992 for Italy are: 0.9268 with Belgium, 0.9120 with Denmark, 0.9831 with France, 0.7217 with Germany, 0.9787 with Ireland and 0.7534 with the Netherlands.

Belgium and Germany and Ireland and Italy, what for the case of Belgium might indicate that the Snake was marginally a more effective arrangement to stabilize its franc against the German mark and the Dutch guilder than the ERM is.

It is also interesting to observe graphically the behavior through time of the correlation coefficient of several currencies'exchange rates with the German Mark exchange rate. Figure 1 presents for each month the correlation coefficient of the daily rate of return of each country exchange rate against the US dollar with the daily rate of return of the mark exchange rate against the dollar. The nearer the correlation coefficient is to its upper limit of one, the closer two currencies move together against the US dollar. We can observe several patterns. On one extreme there are the countries that belonged to the ERM from its inception and never left it, such as Belgium, France and the Netherlands. After 1980 there is a considerable increase of the correlation coefficient that becomes even higher, and much more stable, after 1984. The only significant decrease of the correlation coefficient for these countries occurs in 1993.

On the other extreme there are countries such Canada and Japan, whose correlation coefficient meanders for most of the time around zero, never approaching the upper limit of one for significant amounts of time.

In between these two extremes we have the countries that belonged to the ERM for only part of the time. One is Italy, whose correlation coefficient reflects very well the history of its exchange rate. Before joining the system, the lira did not move much in step with the mark: its correlation coefficient was between zero and +0.6 for most of the time during this period. This situation changed gradually after the start of the EMS and especially between 1982 and 1992 the correlation coefficient stays very close to one. During 1992-1996, when the lira was out of the ERM, the correlation coefficient shows a behavior very similar to that of the 1973-

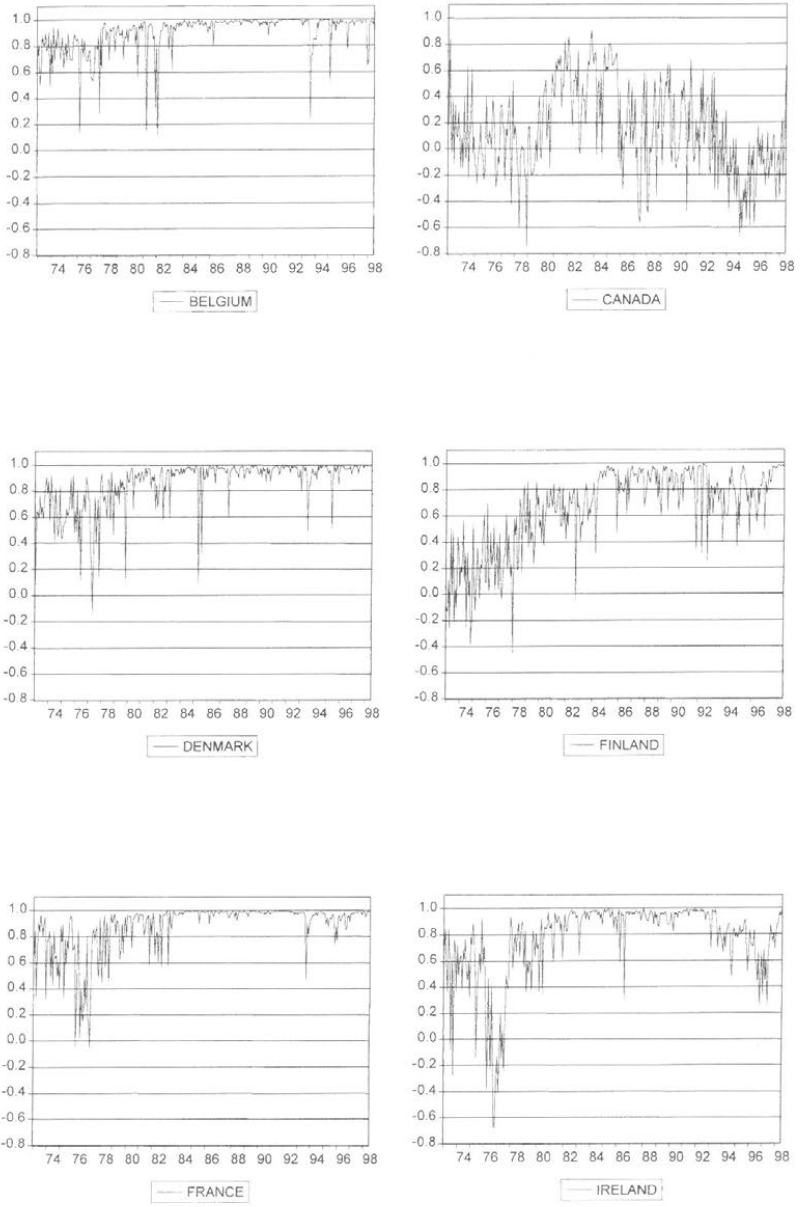
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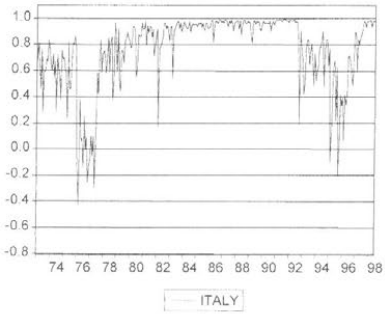
Figure 1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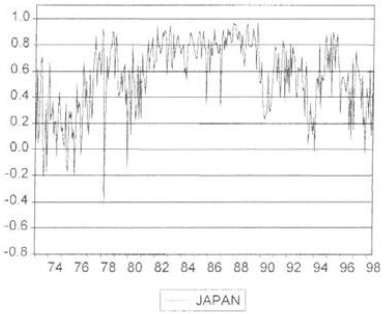
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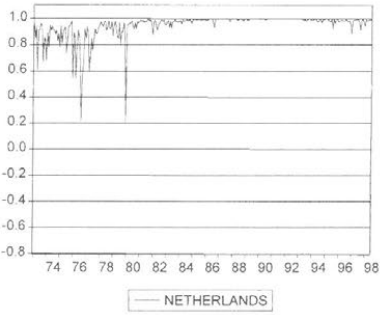
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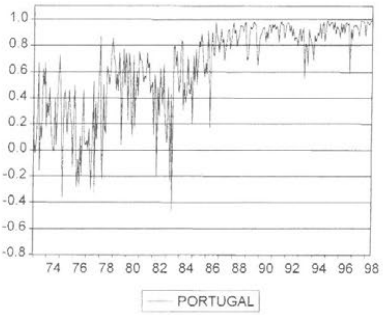
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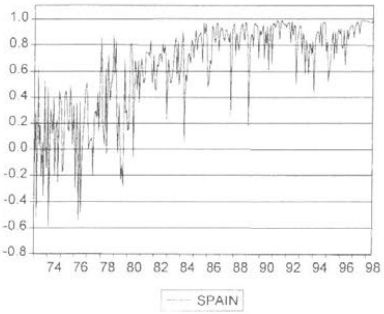
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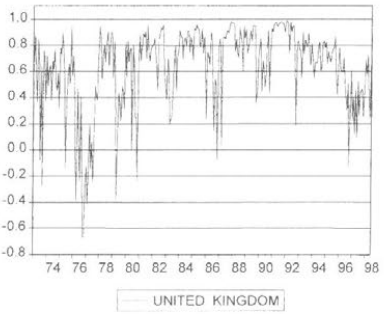
SPAIN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UNITED KINGDOM

Figure 1-2

1979 period. It returns to the vicinity of one after its re-entering the mechanism. Portugal and Spain are also interesting examples. Before joining the ERM in 1992 and 1989 respectively, the values of their correlation coefficients do not differ much from those of countries like Canada or Japan, except perhaps in that as the moment of their adhesion to the mechanism draws near there is a gradual increase of the coefficient. After their adhesion their correlation coefficients remain near one, more so for Portugal than for Spain.

From these and from the cases of the other countries presented Figure 1 it is apparent that belonging or not to the ERM made a substantial difference in what concerns the correlation between the rates of change of each currency exchange rate and the mark exchange rate.

4.3 Unit root tests

Although correlation coefficients present some evidence that the EMS succeeded in making member currencies move more closely together it can only give a rough idea of the short-run relationship between two currencies. To get an idea of the long-run relationship between two or more currencies we have to use the framework of cointegration tests and Error Correction Models.

Before applying these tests and models, the first step is to test for the presence of unit roots in each exchange rate. When testing for unit roots, one danger that should be avoided is to misspecify the deterministic part of the regression equation. As Campbell and Perron (1991) demonstrate, if the estimated regression model includes deterministic variables that are not in the actual data-generating process, the power of the unit root test decreases in proportion to the number of additional deterministic regressors added. To avoid this problem, we used the Augmented Dickey-Fuller test (Dickey and Fuller, 1979), but followed the testing procedure

proposed by Doldado, Jenkinson and Sosvila-Rivero (1990) as modified by Enders (1995).

We start by the least restrictive of the possible models, regressing the first differences of each variable on a constant, a time trend, the lagged value of the variable and several lagged values of the first difference:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=2}^{p} \phi_i \Delta y_{t-i+1} + \varepsilon_t \qquad (1)$$

where y_t is the log of each exchange rate to be tested, t is a time trend, ε_t is an error term and α, β, γ and ϕ_i are parameters to be estimated[8]. The results for each of the seven countries and for the two periods under consideration are presented in Table II.

For each currency the first line shows the t-statistics of the estimated coefficients for the constant, trend and lagged value of the variable (respectively α, β and γ). To save space, the results for the lagged values of the first difference of the variable are omitted, but the number of such lags included in the regression is shown. For each exchange rate and period the most appropriate number of lags p was determined as follows: equation 1 was regressed first using the lag length of p=40. Lags for which the usual t-test were not significant at the 5% level were deleted and equation 1 was estimated again. Remaining lags were then deleted one by one, starting with the longest one, and each time equation 1 was re-estimated. The best lag length was then determined using the information criterion proposed by Schwarz (1978).

The null hypothesis that a unit root is present in the sample series (H_0: $\gamma = 0$) is then tested in the model with the best lag length. Throughout we

8) It can be noticed that equation (1), when applied to the logarithms of nominal exchange rates, can be interpreted in terms of the Purchasing Power Parity (PPP) hypothesis, the right hand side of the equation measuring the difference of inflation rates between the country under consideration and the US.

Table II - Unit root tests for EMS founding countries (1973-1979 and 1980-1998)

	1973 - 1979				1980 - 1998			
	Number of lags	*t*-statistics of coefficients			Number of lags	*t*-statistics of coefficients		
		α	β	γ		α	β	γ
Belgium franc	0	1.7767	−1.5827	−1.8058	0	2.5894	−2.2357	−2.4734
	0	0.8802		0.8191	0	1.6183		−1.5866
	0			−1.9597*	0			0.4992
Denmark kroner	0	2.7238	−1.2911	−2.7845	0	2.7039	−2.2194	−2.5497
	0	2.5008		−2.5398	0	1.6967		−1.6536
	0			−1.1020	0			0.3545
France franc	0	1.7037	−0.3526	−1.7464	0	2.9812	−2.2245	−2.7022
	0	1.6675		−1.7133	0	2.2195		−2.1376
	0			−1.0962	0			0.6574
Germany mark	0	1.8934	−1.7429	−2.0798	0	2.1902	−1.8996	−2.1313
	0	0.7394		−1.1475	0	1.0900		−1.1182
	0			−2.5763**	0			−0.2670
Ireland pound	0	0.2443	−1.0742	−0.0933	1	−1.0025	−1.5270	−2.6318
	0	−0.9727		−1.0716	1	−1.9114		−2.4215
	0			−0.6493	1			−1.7262
Italy lira	1	0.8055	0.0223	−0.7615	0	2.6571	0.0131	−2.5683
	1	1.4938		−1.4618	0	2.8833*		−2.8401
	1			1.3294				
Netherland guilder	0	2.0624	−1.8567	−2.2075	0	2.2043	−1.8948	−2.1217
	0	−1.2038		0.9005	0	1.1287		−1.1321
	0			−2.3563*	0			−0.1703

* denotes significance at 5%

** denotes significance at 1%

use the 5% critical value of the relevant statistic as the cut off level for the rejection of the null hypothesis. In this case, we do not employ the usual values tabulated in Fuller (1976), but use instead those proposed by MacKinnon (1991), that are respectively -3.4149 and -3.4135 for samples of the size of the first and second periods under consideration. As can be noticed, the null hypothesis cannot be rejected for none of the exchange rates, neither for the first or the second period.

As the null hypothesis is not rejected, the next step is to determine whether the trend term should be deleted from the model or not. We test for the significance of the trend term under the null of a unit root (H_0: $\beta = 0$ given that $\gamma = 0$) by using Dickey and Fuller's (1979, p.1062, Table III) $\tau_{\beta\gamma}$ statistic. For very large samples, at the 5% significance level, the value of this statistic is 2.78. As can be observed, in no case can we reject the null, so we conclude that the trend term should be deleted.

The following step is to estimate the above equation without the trend term:

$$\Delta y_t = \alpha + \gamma y_{t-1} + \sum_{i=2}^{\mu} \phi_i \Delta y_{t-i+1} + \varepsilon_t \qquad (2)$$

The estimated results for each currency and period are also presented in Table II (in the second line for each currency). Again we test for the presence of a unit root (H_0: $\gamma = 0$), using the critical values suggested by MacKinnon (1991) that, for the model represented by equation 2, are respectively -2.8637 and -2.8627 for the first and second sample periods. Again, for no country and for none of the sample periods can we reject the null that the data generating process has a stochastic trend. The significance of the drift term can then be evaluated, i.e., we can test the null hypothesis H_0: $\alpha = 0$. To do this we compare the *t*-value obtained for the constant with Dickey and Fuller's (1979, p.1062, Table II) $\tau_{\alpha\gamma}$ statistic, which for a 95% confidence interval for samples of this size is 2.52. With

one exception, none of the values is significant at the 5% level so the null hypothesis that there is no deterministic drift cannot be rejected. The exception is Italy for the period after 1980. At this stage we can conclude that, for the period from 1980 to 1998, the lira/US dollar exchange rate generating process includes a unit root and a deterministic drift term[9]. For the remaining exchange rates the following equation is estimated:

$$\Delta y_t = \gamma\, y_{t-1} + \sum_{i=2}^{n} \phi_i\, \Delta y_{t-i+1} + \varepsilon_t \qquad (3)$$

The results obtained are presented in the third line of the corresponding currency's results in Table II. The MacKinnon (1991) 5% critical values for the null H_0: $\gamma = 0$ are respectively -1.9395 and -1.9394 for samples of the size of the first and second periods. It can be noticed that the null hypothesis can be rejected for the currencies of the following three countries for the 1973-1979 period: Belgium, Germany and Netherlands. For the 1980-1998 period the null hypothesis cannot be rejected for any currency.

Thus we have that for the first period only the exchange rates of the Danish kroner, French franc, Irish pound and Italian lira have unit roots. The currencies of the remaining countries, Belgium, Germany and the Netherlands, all belonging to the Snake, do seem to be stationary and, as seen above, seem to have moved very closely against the US dollar (the correlation coefficients between them during this period are all around 0.99). For the second period, the exchange rates of all currencies have unit root, but Italy's lira has also a deterministic drift in its data generating process.

9) Similar results are obtained for Italy when the sample period is from January 2, 1980 to September 16, 1992.

4.4 Cointegration tests

Given that four exchange rates in the first period, and seven in the second are non-stationary series, we are interested in determining whether there is a long-run stable relationship between them, i.e., whether they are cointegrated, and if they are, in identifying the long-run equilibrium cointegrating relationships that might be present. We test first the bilateral cointegrating relationships using Vector Autoregression (VAR) based cointegration tests using the methodology developed by Johansen (1991, 1995).

For each pair of exchange rates we estimate the following VAR model of order p:

$$y_t = A_0 + A_1 y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t \qquad (4)$$

where y_t is a (nx1) vector of I(1) exchange rates, A_0 is a (nx1) vector of intercept terms, A_i (i=1,...., p) are (nxn) matrices of coefficients and ε_t is a (nx1) vector of error terms, with n=2. We can rewrite the above equation as:

$$\Delta y_t = A_0 + \Sigma \pi_i \Delta y_{t-1} + \pi y_{t-p} + \varepsilon_t \qquad (5)$$

where

$$\pi_i = -(I - \Sigma A_j)$$

and

$$\pi = -(I - \Sigma A_i).$$

Granger's representation theorem asserts that if the coefficient matrix π has reduced rank $r < n$, then there exist (nxr) matrices such that $\pi = \alpha \beta'$

and $\beta' y_t$ is stationary. r is equal to the number of independent cointegrating vectors and each column of β is the cointegrating vector[10].

To determine the rank of π, we test the number of eigenvalues (characteristic roots) that are insignificantly different from one using the likelihood ratio test statistic:

$$\lambda_{trace}(r) = -T \sum_{i=r+1} \log(1-\hat{\lambda}_i)$$

for $r = 0, 1, ..., k-1$, where $\hat{\lambda}_i$ is the i-th largest estimated eigenvalue from π, and T is the number of usable observations. $\lambda_{trace}(r)$ tests the null hypothesis that the number of different cointegrating vectors is less than or equal to r. The further the estimated eigenvalues are from zero, the larger will be the $\lambda_{trace}(r)$ statistic.

As the unit root tests presented in the previous section did not show the presence of deterministic trends in the data generating process of most exchange rates, we will only consider the following two of the five possibilities admitted by Johansen (1995, pp.80-84):

1) that the series have no deterministic trends and the cointegrating equations do not have intercepts;

2) that the series have no deterministic trends and the cointegrating equations have intercepts.

Because the results of the test can be sensitive to the lag length, for each pair of I(1) exchange rate series we estimate equation (5), with and without intercepts, for lag lengths from p=1 to p=10, evaluating the best fit with a multivariate generalization of the Schwarz criterion. Table III summarizes the results obtained for the first period: ○ represents pairs of exchange rates for which it was found a cointegrating relationship at the 5% significance level; × represents those pairs for which no cointegrating

10) It can be noticed that equation (5) can also be interpreted in terms of the PPP hypothesis.

Table III - Bilateral cointegrating relationships during 1973-1979

	Denmark	France	Ireland
France	×		
Ireland	×	×	
Italy	○	○	×

relationship was found. Table A-III in the Appendix shows the results of $\lambda_{trace}(r)$ statistics from which Table III was drawn: for each pair of countries the upper figure corresponds to the null hypothesis H_0: $r \leq 0$ (i.e., there are no cointegrating relationships) and the lower figure corresponds to the null hypothesis H_0: $r \leq 1$ (i.e., there is at most one cointegrating relationship). The critical values used are those of Osterwald-Lenum (1992), not those tabulated in Johansen and Juselius (1990).

As the data generating processes of the exchange rates against the US dollar of the currencies of Belgium, Germany and the Netherlands were not I(1) no cointegration tests were performed that involved the exchange rates of these currencies. As can be noticed only two bilateral cointegration relations were found: between the Danish krona and the Italian lira and between the French franc and the Italian lira. All other bilateral relationships were found to be non-stable.

Table IV summarizes the results for the period staring in 1980. As for

Table IV - Bilateral cointegration relationships during 1980-1998

	Belgium	Denmark	France	Germany	Ireland	Italy
Denmark	○					
France	×	○				
Germany	○	○	○			
Ireland	×	×	×	×		
Italy	×	×	×	×	×	
Netherlands	○	○	○	○	×	×

Table III, ○ represents pairs of rates for which it was found a cointegrating relationship; × represents those pairs for which no cointegrating relationship was found at the 5% significance level. Table A-IV in the Appendix shows the results of $\lambda_{trace}(r)$ statistics from which Table IV was drawn.

As for all exchange rates the null that the data generating process included a unit root could not be rejected, the relationship between all the seven countries is shown. However, no cointegration tests were performed for pairs of exchange rates that included the Italian lira, because it was found that besides a unit root the data included a deterministic linear time trend, so there can be no cointegration between the exchange rate of this currency and those that have no deterministic linear time trend in their data generating processes. It can be noticed that with the exception of pairs involving the currencies of Ireland and Italy (and the odd Belgium-France pair), all other pairs of exchange rates seem to be cointegrated[11].

These results show that, with the exception of Ireland and Italy, there was a clear change in the behavior of exchange rates of ERM member countries before and after the start of the Mechanism. While before the Mechanism came into existence there only two bilateral cointegrating relationships existed, after its start the number of bilateral cointegrating relationships increased to nine (eleven, if we exclude the period after September, 1992). This indicates that the ERM was successful in linking

11) Performing the same tests for the period from January 2, 1980 to September 16, 1992 it was found also that there was no cointegration relatinship for the Belgium-France pair; neither there was cointegrating relationships for the Belgium-Ireland, Denmark-Ireland and Ireland-Netherlands pairs, but for France-Ireland and the Germany-Ireland pairs it was found one cointegration relationship. The same tests were also performed for the pairs involving Ireland for the period from January 2, 1980 to January 29, 1993, (thus excluding the ten percent devaluation of January 30, 1993) with the same results.

the movements of the exchange rates of Belgium, Denmark, France, Germany and the Netherlands. It shows also that it failed in linking the exchange rates of Ireland and Italy to those of the other members'.

Why it failed in the case of Ireland and Italy is worth further research as these countries present quite dissimilar cases. While Irish pound came to be considered one of the strong currencies of the System, the lira was always one of the weakest. For example, in the period from the beginning of 1980 to September 1992, when the lira not able to resist market pressures was suspended, Italy had to realign downwards its parity seven times, more than any other country. During the same period, Ireland had to make only four realignments, less than any other country, and only two of these were devaluations. The bands to which these currencies were subject were also very different: while in the case of Ireland they allowed maximum bilateral movements of 4.5 percent, in the case of Italy the maximum allowable was 12 percent (although it did not made full use of this wide fluctuation band for most of the time). The monetary policies of the two countries also offer a striking contrast. Since its entry to the EMS, the Irish central bank does not try to control domestic money supply nor interest rates, being its prime function to maintain stability with EMS and to smooth out any short-term imbalances that might appear on the interbank market (Leddin and O'Leary, 1991, McAleese and O'Reardon, 1992). In Italy, the central bank and the Treasury jointly managed the large and growing public debt until the mid-1980s, and continued to monetize part of it during the ensuing decade (Ciocca, 1992). So, while the conclusion that Italy had no bilateral cointegration relationships with the other currencies of the System might be accepted as natural, the same does not applies to Ireland.

5. Long-run stable relationships during the 1993-1998 period

In this section we will examine, for the 1993-1998 period, the relationships between exchange rates of twenty one countries: the ten countries that will belong to the EMU from its start in 1999 (as before, we do not include Luxembourg in the analysis because it forms already a monetary union with Belgium); the four EU countries that will not participate in the EMU; and seven other countries from various regions in the world. The purpose of these tests is to determine if during this period there were stable relationships between the exchange rates of EMU currencies and if stable relationships could be found only inside the EMU area or were also present in other regions of the world. We will see that, with few exceptions, there are bilateral long-term stable relationships for only a sub-group of the ten countries that will belong to the EMU.

5.1 Unit root tests

Using the same testing procedures as in Section 4.3, unit root tests on the exchange rates of the currencies of twenty one countries against the US dollar were performed for the period starting in January 4, 1993 to June 12, 1998, with a total of 1370 observations. The results are reported in Table V.

As can be noticed, only for the United Kingdom and Hong Kong the null hypothesis of no unit root can be rejected at the usual 5% significance level. For Japan, although the null of no unit root cannot be rejected, the null of no deterministic quadratic time trend can be rejected. Thus the data generating process of the yen/US dollar exchange rate differs from those of the majority of exchange rates examined because besides a unit root it also includes a deterministic trend.

Table V - Unit root tests (1993-1998)

	Number of lags	1993-1998 *t*-statistics of coefficients		
		α	β	γ
Austria	0	1.2538	1.2333	−1.295
	0	1.0475		−1.0316
	0			0.4549
Belgium	0	1.1918	1.1369	−1.2194
	0	1.0277		−1.0162
	0			0.4643
Finland	0	0.773	0.6428	−0.8613
	0	1.0784		−1.0687
	0			0.1172
France	0	1.2214	1.1297	−1.2763
	0	1.1211		−1.1035
	0			0.3615
Germany	0	0.9693	1.2774	−1.2593
	0	1.0524		−0.9843
	0			0.3087
Ireland	0	−1.781	0.0814	−1.8913
	0	−1.7947		−1.8982
	0			−0.9153
Italy	0	2.3977	1.2044	−2.3921
	0	2.073		−2.0669
	0			0.8762
Netherlands	0	0.9957	1.3082	−1.2288
	0	1.0007		−0.9396
	0			0.3634
Portugal	0	1.5099	0.8022	−1.5013
	0	1.3004		−1.2852
	0			0.991
Spain	0	1.6819	0.9309	−1.6629
	0	1.4011		−1.3791
	0			1.2923

Table V (continuation)

	Number of lags	1993-1998 *t*-statistics of coefficients		
		α	β	γ
Denmark	0	1.1596	1.0245	−1.2121
	0	1.1218		−1.1049
	0			0.3725
Greece	0	1.7037	1.7531	−1.7009
	0	0.5591		−0.5351
	0			1.4723
Sweden	0	1.5901	−0.0913	−1.5875
	0	1.6153		−1.5983
	0			0.4785
United Kingdom	0	−4.1107	−3.2777**	−4.1216**
Australia	0	−1.0468	2.3741	0.5256
	0	0.0942		0.058
	0			0.7731
Canada	0	2.3262	1.7755	−2.2603
	0	1.5463		−1.4057
	0			1.2399
Hong Kong	1	5.4511	2.9426*	−5.4515**
Japan	0	1.5759	3.3361**	−1.6702
South Korea	2	0.2664	1.3655	−0.2973
	2	−0.6365		0.6705
	2			1.2509
Switzerland	0	0.4551	1.2217	−1.2021
	0	1.2207		−1.2558
	0			−0.3059
Thailand	4	0.6202	1.9407	−0.7092
	4	−0.5895		0.673
	4			1.5447

* denotes significance at 5%

** denotes significance at 1%

5.2 Bilateral cointegration tests

Following the procedures described in Section 4.4, bilateral cointegration tests were performed for each pair of the twenty one currencies' exchange rates. Table VI summarizes the results obtained and Table A-VI in the Appendix gives the results of $\lambda_{trace}(r)$ statistics for each case. As before, ○ represents pairs of rates for which it was found a cointegrating relationship; × represents those pairs for which no cointegrating relationship was found at the 5% significance level.

The EU countries that will participate in the EMU are shown on the top of the table, followed by the EU countries that will not participate in the EMU and then by several other countries. As can be noticed, of the seventeen bilateral cointegrating relationships found, ten are between EMU countries, two are between EMU countries and one EU country (Denmark) that will not participate in the EMU (but has belonged to the ERM of the EMS), two are between EMU countries and non-European countries (those between Ireland and Australia and between Spain and Canada), another two are between non-EMU EU countries with non-EU countries (those between Sweden and Switzerland and Greece and Canada) and the remaining one is between two non-EU countries (that between South Korea and Thailand).

Another interesting pattern can be observed more easily if the portion of Table VI containing EMU countries is rearranged as we have done in Table VII.

Table VII makes clear that of those countries that will participate in the EMU from its beginning, there are three sub-groups of countries that presented bilateral cointegration relationships between them: one, made up by Austria, Germany, Netherlands and Portugal; another constituted by Portugal, France and Belgium; and a third one that includes only the Belgium-Spain pair. Finland, Ireland and Italy did not present any bilateral

Table VI - Pairwise cointegration relationships during 1993-1998

	Austria	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Portugal	Spain	Denmark	Greece	Sweden	United K.	Australia	Canada	Hong Kong	Japan	South Korea	Switzerland
Belgium	×																			
Finland	×	×																		
France	×	○	×																	
Germany	○	×	×	×																
Ireland	×	×	×	×	×															
Italy	×	×	×	×	×	×														
Netherlands	○	×	×	×	○	×	×													
Portugal	○	○	×	○	○	×	×	○												
Spain	×	○	×	×	×	×	×	×	×											
Denmark	×	○	×	○	×	×	×	×	×	×										
Greece	×	×	×	×	×	×	×	×	×	×	×									
Sweden	×	×	×	×	×	×	×	×	×	×	×	×								
United K.	×	×	×	×	×	×	×	×	×	×	×	×	×							
Australia	×	×	×	×	×	○	×	×	×	×	×	×	×	×						
Canada	×	×	×	×	×	×	×	×	×	○	×	○	×	×	×					
Hong Kong	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×				
Japan	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
South Korea	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		
Switzerland	×	×	×	×	×	×	×	×	×	×	×	×	○	×	×	×	×	×	×	
Thailand	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	○	×

Table VII - Bilateral cointegration relationships between EMU countries (1993-1998)

	Austria	Germany	Netherlands	Portugal	France	Belgium	Spain	Finland	Ireland
Germany	○								
Netherlands	○	○							
Portugal	○	○	○						
France	×	×	×	○					
Belgium	×	×	×	○	○				
Spain	×	×	×	×	×	○			
Finland	×	×	×	×	×	×	×		
Ireland	×	×	×	×	×	×	×	×	
Italy	×	×	×	×	×	×	×	×	×

cointegration relationship either between them or with other EMU countries.

It is also interesting to find that for this smaller sample period the results differ from those obtained for a larger sample reported in Section 4.4, Table IV. While for the larger period the exchange rates of both Belgium and France were cointegrated with the exchange rates of Germany and the Netherlands, for the period from 1993 to 1998 they were not. This may reflect the larger weight that the volatile year of 1993 had on the smaller than on the larger sample. Also, while for the larger sample the exchange rates of the Belgium and French francs were not cointegrated, for the smaller they were. This may be due to synchronous movements of the French and Belgium francs during 1993 having greater weight in the smaller sample than in the larger.

From these results it seems safe to conclude that the exchange rates of neither Finland, or Ireland, or Italy presented stable bilateral relationships with the other currencies of the Mechanism. If the criterion of stable bilateral exchange rates with the other currencies of the mechanism were

to be interpreted as requiring bilateral cointegration of their exchange rates against a non-ERM currency, these three countries would not be part of the EMU.

5.3 Vector Error Correction estimations

If two variables are cointegrated then their time series behavior are influenced by the extent of any deviation from the long-run equilibrium that exists between them. If the movements of at least one of the variables does not respond to some disequilibrium that might appear, then the variables do not move together, i.e., they are not cointegrated. If we know that two exchange rates are I(1) we can assume that the following simple Error Correction Mechanism (ECM) can describe their joint behavior:

$$\begin{aligned} \Delta y_{ut} &= \alpha_u (y_{vt-1} - {}_1\beta\, y_{ut-1} + {}_1\rho) + \sum_{i=1}^{n} a_{11,i}\ \Delta y_{ut-i} + \sum_{i=1}^{n} a_{12,i}\ \Delta y_{vt-i} + \varepsilon_{ut} \\ \Delta y_{vt} &= \alpha_v (y_{ut-1} - {}_1\beta\, y_{vt-1} + {}_1\rho) + \sum_{i=1}^{n} a_{21,i}\ \Delta y_{ut-i} + \sum_{i=1}^{n} a_{12,i}\ \Delta y_{vt-i} + \varepsilon_{vt} \end{aligned} \qquad (6)$$

where y_u and y_v represent the exchange rates of countries u and v against a third country currency, and ε_{ut}, ε_{vt}, and all terms involving Δy_{ut-i} and Δy_{vt-i} are stationary. α_u and α_v are the parameters representing the speed of adjustment, the larger their estimated values the greater the response of a variable to the previous period's deviation from long-run equilibrium.

Table VIII presents the estimated results of the ECM of equation (6) for ERM member countries, for the period from 1993 to 1998. For every pair of countries u and v we present the optimal number of lags, the estimated normalized values of ${}_1\beta$ and ${}_1\rho$ of the cointegrating equation, and the speeds of adjustment α_v and α_u. The cointegration equation is normalized by making the estimated coefficient for the first country in each pair equal to one. The number in parenthesis under the estimated coefficients are the corresponding t-values. To save space the estimated values of the lagged parameters are not presented. The optimal number of lags was

chosen by a procedure similar to the described above, using a multivariate generalization of the Schwarz criterion. The decision to include or not the constant term in the cointegrating equation was based on the results obtained for the cointegration tests reported in Section 5.2 above: if no cointegration relationship was found using a constant but there was a

Table VIII - Bilateral VER estimations (1993-1998)

	Number of lags	Normalized Cointegrating Equation		Error Correction	
		β	ρ	α_r	α_u
Austria					
Germany	1	−0.9984	−1.9517	−1.1024	−0.1479
		(−1891.46)	(−7732.01)	(−7.5705)	(−1.01)
Netherlands	4	−0.9756	−1.8496	−0.3285	−0.0846
		(−441.62)	(−1412.78)	(−2.89)	(−0.74)
Portugal	4	−0.9751	2.5576	0.0017	0.0117
		(−9.08)	(4.68)	(0.37)	(2.54)
Belgium					
France	3	−1.1717	−1.4990	0.0597	0.0675
		(−39.01)	(−29.20)	(3.50)	(4.34)
Portugal	2	−0.6830		−0.0010	0.0051
		(−233.78)		(−0.29)	(1.47)
Spain	1	−0.7101		−0.0007	0.0054
		(−193.72)		(−0.22)	(1.91)
Denmark	3	−1.1077	−1.1476	0.0493	0.0562
		(−30.14)	(−21.95)	(3.57)	(4.27)
France					
Portugal	1	−0.9226	3.0110	0.0002	0.0107
		(−9.78)	(6.26)	(0.03)	(2.01)
Denmark	3	−0.9301		0.0068	0.0305
		(−682.29)		(0.37)	(1.59)
Germany					
Netherlands	5	−0.9746	0.1008	−0.1893	−0.1190
		(−250.83)	(−43.84)	(−1.65)	(−1.04)
Portugal	1	−0.9937	4.6020	0.0043	0.0126
		(−9.13)	(8.30)	(0.94)	(2.74)

cointegration relationship when the constant was omitted, no constant was used when estimating the ECM.

As can be noticed from Table VIII, the estimated values of β are very close to minus one in all cases, as was to be expected. However, the sign of the estimated values of α_r and α_u are not always respectively negative and positive as was to be expected. When the estimated coefficient has not the expected sign we can notice that its estimated value is near zero and the t-statistic is, with few exceptions, below one in absolute value indicating that the estimated value is not statistically significant from zero at the usual levels. When the estimated coefficient has the expected sign the t-statistic is almost always statistically significant. As for all cases one of the estimated coefficients (α_r or α_u) has the expected sign, this indicates that the ECM is working as expected.

5.4 Multivariate Cointegration and ECM between EMU countries

Although only a sub-group of those countries that will participate in the EMU from its start seemed to exhibit bilateral stable long term relationships between their exchange rates against the US dollar, the question arises whether the ten countries' exchange rates taken together exhibited a stable long-term relationship or not, i.e., whether they were cointegrated or not in the period from 1993 to 1998.

To test whether the ten exchange rates' time series were cointegrated we can use the Johansen testing procedure presented in Section 4.4. The only difference is that now the dimension of vectors and matrices is different, namely n=10. Table IX presents the results obtained.

The null hypotheses that for the 1993-1998 period there were less than zero, one or two cointegrating relationships between the exchange rates of the ten countries that will participate in EMU from its start can be rejected

Table IX - Cointegration test between the exchange rates of EMU countries

Null Hypothesis	λ_{trace} (r)
r≦0	474.117**
r≦1	247.867**
r≦2	174.796*
r≦3	125.31
r≦4	79.16
r≦5	58.56
r≦6	38.32
r≦7	22.58
r≦8	7.80
r≦9	1.96

* denotes significance at 5%

** denotes significance at 1%

at the 5% significance level. As the hypotheses that there were three or less cointegrating relationships between the ten variables cannot be rejected, we can conclude that there existed three cointegrating relationships.

The results of the estimation of the ECM are presented in Table X. The three cointegrating equations and the ten equations of the ECM were estimated simultaneously assuming the existence of an intercept, but not of a trend, in the cointegrating equations and using four lagged first differences of each variable. The three lines on the top of the table present the estimated normalized values of the three cointegrating equations that were found to exist. The three lines on the bottom present the speeds of adjustment (α_1, α_2, and α_3) of each country exchange rate to deviations from the equilibrium represented by the respective cointegrating equation. In parenthesis are the *t*-values.

Table X - Multilateral ECM estimation (1993-1998)

	Austria	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Portugal	Spain	ρ
Equation 1	1.0000	0.0000	0.0000	−0.0006	−0.9750	0.0043	0.0011	−0.0284	0.0071	−0.0033	−1.9712
				(−0.0886)	(−13.5289)	(1.7444)	(0.4996)	(−0.4227)	(1.3456)	(−0.8595)	(−124.4340)
Equation 2	0.0000	1.0000	0.0000	−1.2893	8.8707	−0.1074	0.2744	−8.6076	0.1256	−0.1541	−2.3976
				(−4.0809)	−(2.7939)	(−0.9928)	(2.8711)	(−2.9112)	(0.5396)	(−0.9056)	(−3.4354)
Equation 3	0.0000	0.0000	1.0000	−1.9670	−5.8469	−0.4858	0.2276	5.6110	0.4655	0.6036	−6.0231
				(−4.9464)	−(1.4632)	−(3.5677)	(1.8916)	(1.5078)	(1.5883)	(2.8185)	(−6.8568)
α_1	−0.9752	−0.2816	−0.1259	−0.0808	−0.0497	−0.0453	−0.1560	−0.0813	−0.2190	−0.1426	
	(−4.0681)	(−1.1438)	(−0.4769)	(−0.3554)	(−0.2052)	(−0.1879)	(−0.6923)	(−0.3361)	(−0.9057)	(−0.6039)	
α_2	0.0043	0.0004	−0.0167	0.0096	0.0069	−0.0094	−0.0189	0.0138	−0.0072	0.0003	
	(0.3725)	(0.0333)	(−1.3005)	(0.8686)	(0.5831)	(−0.8058)	(−1.7254)	(1.1733)	(−0.6109)	(0.0239)	
α_3	0.0031	0.0059	−0.0326	0.0045	0.0030	0.0032	−0.0110	−0.0001	−0.0060	−0.0144	
	(0.3997)	(0.7446)	(−3.8085)	(0.6105)	(0.3877)	(0.4093)	(−1.5059)	(−0.0132)	(−0.7709)	(−1.8864)	

It can be noticed that Germany presents the largest absolute values of the estimated coefficients of each of the cointegrating equations and among the smallest of the estimated speed of adjustment parameters. This can be interpreted as indicating the central role that the mark plays in the EMS: it has a larger weight than other currencies in determining the equilibrium of the system and adjusts more slowly than the others to any disequilibrium that appears.

6. Conclusions

The results presented above show that the ERM of the EMS induced changes in the behavior of the exchange rates of most member currencies: with the exception of two of them, these currencies started to move much more closely together, as was to be expected. The two exceptions, Ireland and Italy, present quite different cases: while Italy had for most of the time large fluctuation bands of ± 6 percent and had to realign its parity seven times between the beginning of 1980 and September 1992, when it was suspended, Ireland had narrow ± 2.25 percent bands and had only to make four realignments. Why the ERM failed in these two cases deserves further research.

They show also that only a few of the eleven countries that will participate in the EMU presented bilateral cointegration relationships between their exchanges rates against the US dollar, what indicates a failure by the majority to keep stable relationships between the exchange rates of their currencies against the US dollar.

Appendix

Table A-III - $\lambda_{trace}(r)$ statistics for the several pairs of currencies for 1973-1979

	Denmark		
France	13.39 3.11	France	
Ireland	12.48 2.12	12.08 5.04	Ireland
Italy	23.14* 2.12	12.68* 0.75	11.80 1.51

*denotes significance at 5%

Note: no constant term in the cointegrating equation for the France - Italy pair

Table A-IV - $\lambda_{trace}(r)$ statistics for several pairs of currencies for 1980-1998

	Belgium					
Denmark	20.89* 2.90	Denmark				
France	17.81 2.23	14.12* 0.50	France			
Germany	27.18** 5.60	25.68** 6.95	30.72** 7.06	Germany		
Ireland	12.85 1.23	12.46 1.64	12.46 2.78	17.60 5.94	Ireland	
Italy	× ×	× ×	× ×	× ×	× ×	Italy
Netherlands	23.49* 4.56	22.14* 5.27	27.52** 6.17	26.5** 2.78	16.50 4.89	× ×

* denotes significance at 5%

** denotes significance at 1%

Table A-VI - $\lambda_{trace}(r)$ statistics for the several countries for 1993-1998

	Austria	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Portugal	Spain	Denmark	Greece	Sweden	United Kingdom	Australia	Canada	Hong Kong	Japan	South Korea	Switzerland
Belgium	5.39 0.72																			
Finland	5.53 1.81	5.07 1.78																		
France	12.77 1.88	20.63* 1.99	5.32 1.33																	
Germany	194.51** 1.25	9.32 1.25	5.43 1.80	12.70 1.75																
Ireland	14.68 1.96	15.97 1.81	15.47 1.59	15.61 2.08	14.59 1.94															
Italy	10.59 2.41	11.23 2.78	8.29 2.83	11.40 3.08	10.51 2.36	9.49 1.38														
Netherland	61.12** 1.16	8.27 1.23	5.30 1.86	12.13 1.52	24.68** 0.98	14.64 1.82	10.53 2.24													
Portugal	20.57* 2.42	12.74* 0.23	7.61 1.44	21.50* 1.66	20.93* 1.99	9.82 2.49	9.79 2.18	20.27* 1.89												
Spain	16.14 1.50	12.82 0.28	8.22 1.39	17.30 1.56	16.59 1.47	8.87 3.61	15.27 3.58	16.27 1.37	9.08 2.55											
Denmark	12.11 2.28	21.67* 3.29	4.50 1.16	13.95 0.13	11.91 3.17	15.54 1.58	10.23 2.83	11.42 2.87	16.76 1.48	14.28 1.49										
Greece	9.33 1.16	8.60 1.14	7.08 1.10	8.88 1.47	9.19 1.78	8.01 2.68	9.13 2.09	9.04 1.13	5.97 2.46	8.87 2.66	7.93 1.48									
Sweden	10.58 2.55	11.64 2.55	11.42 2.93	12.01 2.55	10.60 2.59	12.16 2.96	9.09 3.38	10.61 2.45	6.27 2.73	5.65 2.58	11.60 2.42	5.65 2.58								
United K.	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×							
Australia	5.66 0.73	5.39 0.72	4.05 0.81	6.06 0.72	5.69 0.70	20.33* 0.96	10.30 1.47	5.12 0.68	8.22 2.13	10.78 0.77	5.61 0.69	11.89 3.24	10.78 0.77	× ×						
Canada	11.78 1.81	11.45 2.03	8.28 2.64	12.10 2.14	11.87 1.74	12.87 1.34	14.38 4.31	11.78 1.65	19.72 3.99	21.09* 4.09	11.85 2.36	20.27* 2.27	8.83 3.58	× ×	9.01 2.86					
Hong Kong	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×				
Japan	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×	× ×			
South Korea	4.83 1.07	4.39 1.09	3.47 1.11	5.07 1.12	5.00 1.08	10.17 0.91	10.19 1.26	4.98 1.11	6.14 1.68	5.55 1.00	4.60 1.10	12.54 2.34	5.55 1.00	× ×	4.47 1.72	10.81 1.81	× ×	× ×		
Switzerlan	7.38 1.32	8.42 1.27	16.40 2.71	9.22 2.79	7.08 1.35	17.92 1.41	13.15 4.95	7.17 1.26	19.63 2.36	17.07 2.02	11.59 3.19	11.66 1.10	20.15* 5.21	× ×	4.66 0.37	9.84 1.74	× ×	× ×	5.15 1.01	
Thailand	6.52 1.35	5.67 1.25	3.48 0.58	6.27 1.46	6.52 1.36	10.08 1.50	14.47 3.25	6.41 1.33	8.36 2.82	10.27 3.22	5.86 1.56	13.40 5.65	6.01 2.21	× ×	9.55 1.90	11.22 3.08	× ×	× ×	21.13* 1.12	5.31 1.39

* denotes significance at 5%

** denotes significance at 1%

Notes: With the following exceptions the tests assumed no trend in data generating process of the time series and an intercept but no trend in the cointegrating equation and four lags: Belgium – Portugal: no constant; Belgium – Spain: no constant; France – Denmark: no constant, 2 lags; Sweden – Switzerland: 1 lag; Soth Korea – Thailand: 3 lags.

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