MEAN-REVERSION VERSUS ADJUSTMENT TO PPP : THE TWO REGIMES OF EXCHANGE RATE DYNAMICS UNDER THE EMS, 1979-1998

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SUMMARY

This paper examines jointly the empirical relevance of the mean-reversion and the PPP hypotheses in the exchange rate dynamics under the EMS. Given the non stationarity and the nonlinearities characterizing foreign exchange rate dynamics, this question is studied in the framework of a MS-ECM model : it allows a discontinuous adjustment towards the cointegration relationship. We find that the European exchange rates of the ERM members display mean-reversion in the credible regime, whereas they adjust to the PPP during the volatile period. The first mechanism is due to the stabilizing effect of a credible target-zone, while the second one can be explained by the realignments made in accordance with the underlying inflation rates.

1. INTRODUCTION

The European Exchange Rate Mechanism (ERM) was founded on March 13, 1979. At the beginning, eight currencies participated in this arrangement : the Belgian Franc, the Danish Krone, the French Franc, the German Mark, the Irish Pound, the Italian Lira, the Luxemburg Franc and the Dutch Guilder. A major purpose of the EMS was to reduce real and nominal exchange rate volatility. The currencies were allowed to fluctuate within a band of ±2.25% around an official parity (except the Italian Lira which initially obtained a margin of ±6%). Nevertheless, the EMS had experienced several crises, which had led to realignments of the bilateral parities among the participants.

Both theoretical and empirical studies highlighted the peculiar dynamics of the macroeconomic variables, especially of the exchange rates under such a semi-fixed exchange rate regime. On the theoretical side, the target-zone literature

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emerged in 1991 and tried to model explicitly the exchange rate dynamics under a target-zone regime. The so-called first-generation model developped by Krugman (1991) is based on a fully credible target-zone. Nevertheless, given that the implications of this model (the U-shaped distribution of the exchange rates within the band, the negative correlation between the interest differential and the exchange rate (Svensson (1991)) are empirically rejected, Krugman's model has been extended to account for endogenous expectations of realignment (Bertola and Caballero (1992), Bertola and Svensson (1993), Tristani (1994)). This second-generation model allows for a time-varying credibility affecting significantly the exchange rate behavior. On the empirical side, by estimating Markov-Switching models, many authors point that the European exchange rate dynamics is typically characterized by periods of relative calm when the target-zone is credible, punctuated by sudden and short-lived phases of speculative attacks (Engel and Hakkio (1996), Peria (1999), Amato and Tronzano (1998) and Tronzano (1999)). Thus, both theoretical and empirical approaches stress the influence of punctual decrease of the confidence of the markets in the sustainability of the target-zone in the exchange rates dynamics.

Related to this time-varying credibility, the possibility of two anchors in the European Exchange Rate Mechanism seems relevant : on the one hand, during the credible regime, the exchange rate should fluctuate around the central parity, hence displays mean-reversion, whereas in the uncredible regime, the exchange rate departs from the central parities but is dragged back to the Purchasing Power Parity (PPP) value when realignments occur. Indeed, many authors indicate that realignments were made in accordance with the underlying inflation rates in order to maintain the Purchasing Power Parity (PPP). In other words, realignments seemed to be designed to attenuate the deviations from the PPP, i.e. to maintain competitiveness between the EMS members.

The existence of these two anchors –central parity and PPP- has already been explored in the literature but only separately. Some evidence of mean-reversion towards central parities has been provided by conducting unit root tests (see, for instance, Anthony and MacDonald (1998, 1999)) or by using diffusion processes (see, among others, Ball and Roma (1993), De Jong et al. (1996), Pentecôte and Roncalli (1996)). More conflicting evidence for the PPP hypothesis has been found. Empirical studies on PPP use cointegration analysis, because exchange rates are found to have a unit root (Meese and Singleton (1982)). In this econometric framework, these studies present no clear-cut evidence for the EMS countries. On the one hand, Artis and Nachane (1990), Edison and Fisher (1991) did not find that the European real exchange rates are cointegrated i.e. rejected the PPP hypothesis under the EMS. On the other hand, MacDonald and Taylor (1991), Fung and Lo (1992), Cheung et al. (1995) presented evidence in favour of PPP in the EMS.

However, very little attention has been paid to testing jointly the relevance of these two mechanisms. The purpose of this paper is to show empirically the existence of two alternative long-run equilibrium relationships : a relationship describing the mean-reverting behavior of the European exchange rates towards central parities and the PPP relationship. Our intuition is that the mixed results obtained in the last framework could be linked to the presence of regime shifts in the European exchange rate process, as noted previously both in the theoretical and empirical literature. In regard to these papers, the regime-switching approach seems to be the appropriate one to characterize the exchange rate dynamics under the EMS. In other words, to test the relevance of mean-reversion and the PPP in the European exchange rates dynamics under the EMS, we have to account for the nonlinearities inherent to their dynamics. We will thus consider a Markov-Switching Error Correction Model (MS-ECM) so as to show the existence of a discontinuous adjustment in time towards two long-run equilibria : the central parity during the credible periods (mean-reversion) and the PPP during the speculative periods. We will implement this approach for the European exchange rates of six countries : Belgium, Denmark, France, Ireland, Italy and the Netherlands from the inception of the European Exchange Rate Mechanism in 1979 to the establishment of the European Monetary Union on January 1999.

The rest of the paper is organised as follows. The first part reviews existing theoretical and empirical models on the exchange rate dynamics under a target-zone. Section 2 briefly describes our data sources and our sample period. The MS-ECM model underlying our empirical work is described in the third section. Section 4 comments the results. The last part concludes. A GAUSS program that implements the estimation methods of the Markov-Switching Error Correction Model is available on request from the author.

2. THEORETICAL AND EMPIRICAL BACKGROUND

This first section presents supportive evidence in favour of two alternative anchors in the European Exchange Rate Mechanism that can be found both in the previous theoretical and empirical literature. On the theoretical side, first-generation models based on a fully credible target-zone and only inframarginal interventions are rejected in favour of the second-generation models allowing for episodes of decreasing credibility. On the empirical side, the Markov-switching models introduced by Hamilton are frequently used to model the European exchange rate dynamics under the ERM and point the significant alternance of a stable regime (low mean and variance) and a more unquiet state (large mean and variance).

On the theoretical side, the target-zone literature tries to model explicitly the exchange rate dynamics under a target-zone regime.

The basic target-zone model was introduced by Krugman in 1991. His so-called first-generation model highlights the stabilizing effect of a target-zone on the exchange rate behavior, because of the market expectations of monetary interventions if the exchange rate hits the edge of the band (the so-called inframarginal interventions).
Formally, it suggests a non linear S-shaped relationship between the exchange rate and some fundamental variables (the velocity of the money and the money supply) instead of the 45° line under a free-floating regime (zero expected change in the exchange rate) : the market expectations allowing for the marginal interventions by the authorities drag down the exchange rate at the top of the band and pull up the series when it nears the lower limit.
Yet, the implications of this model, like the U-shaped distribution of the exchange rates inside the zone or the negative correlation between the interest rate differentials and the exchange rate (Svensson (1991)), are empirically rejected. An obvious shortcoming of the Krugman specification is the two assumptions it is based on : Krugman supposes a fully credible exchange rate band i.e. irrevocably fixed and he only allows for inframarginal interventions by the monetary authorities, that is when the exchange rate hits the edge of the band. However, many realignments occurred during the EMS period (from 3 for the Netherlands to 12 for Italy) and the intramarginal interventions (that is when the exchange rate lies inside the band) largely exceed the marginal ones (see among others Bini-Smaghi and Micossi (1989), Lindberg and Söderlind (1992)).

Consequently, new models often referred to the second-generation models extend the Krugman specification in two alternative directions.
On the one hand, Bertola and Caballero (1992), Bertola and Svensson (1993), Tristani (1994) integrate an endogenous realignment risk by introducing an exogenous drift in the stochastic
component of the devaluation risk (Bertola and Svensson (1993)) or a dependence of the expected rate of devaluation on the dynamics of fundamentals or closely on the position of the exchange rate within the band. It is worth noting that, in this model, a high probability of realignment can cancel out the stabilizing effect of the target-zone advocated by the proponents of target-zones.
On the other hand, Froot and Obstfeld (1991), Lindberg and Söderlind (1994) combine inframarginal interventions with interventions inside the band (intramarginal interventions) by introducing a mean-reverting mechanism in the fundamental process.
Nevertheless, it should be noted as in Tristani (1994) or in De Haan, Knot and Dijkstra (1999) that these two extensions are closely interrelated. Indeed, a large deviation of the exchange rate from the central parity may correspond to a weaker control of the monetary authorities but this devaluation may have been entailed by a continual deterioration in fundamentals.

De Haan, Knot and Dijkstra (1999) present a direct test of the first and second-generation models for the currencies of six European countries –Austria, Belgium, Denmark, France, Italy and the Netherlands- with respect to Germany over the period 1983-1993 (except for Italy for which the sample ends on September 1992, when Italy was forced out the ERM). They find that the French and Italian estimates fit better with the second-generation model, whereas the countries with a high degree of economic integration and convergence vis-à-vis Germany, namely Belgium after 1990, Austria and the Netherlands, are better described by the Krugman specification. Denmark constitutes an intermediate case, displaying features of both models. Basically, the first-generation model is more suited to countries that have pegged strongly their currency to the Deutsche Mark : the parities of the ERM are more credible there. Consequently, the endogenous devaluation risk of the second-generation model is not significant in these countries. On the contrary, parities for countries like France or Italy are less credible because of deteriorating fundamentals or less commited policies towards the European economic integration. Consequently, they are better described by the second-generation models allowing for a time-varying credibility.

On the empirical side, the regime-switching approach is largely employed to analyse the European exchange rate dynamics within the EMS. We can quote papers by Engel and Hakkio (1996), Peria (1999), Amato and Tronzano (1998) and Tronzano (1999). The first authors are interested in characterizing the exchange rate dynamics under the European target-zone, whereas the later want to identify the speculative attacks and their determinants.

Engel and Hakkio (1996) estimate a MS-autoregressive model on the French and Italian exchange rates with respect to the Deutsche Mark from 1979 to 1992 for the Lira or 1993 for the French Franc. They consider first a specification with fixed transition probabilities and then allow transition probabilities to depend on the position of the exchange rate within the band. They show among other things that the dynamics of the French and Italian exchange rates is characterized by long periods of stability interrupted by short periods of extreme volatility, that a Markov-Switching model can appropriately account for. Moreover, their estimates of the time-varying transition probabilities suggest that the probabilities of remaining in both states increase significantly when the exchange rate nears the edge of the band.

More recently, Peria (1999) applies MS-models on the exchange rates of Belgium, Denmark, France, Ireland (1979-93), Italy (1979-92), Spain (1989-93) and the United-Kingdom (1990-92) vis-à-vis Germany. Peria considers a MS specification in order to identify speculative attacks episodes captured by the unstable state and, as Engel and Hakkio (1996), allows transition probabilities to be time-varying functions of observable variables to determine what causes the shifts towards the unstable state i.e. to identify the determinants of speculative attacks. Peria estimates an univariate MS-AR model on the exchange rate and given that the speculative attacks do not always result in exchange rate devaluations but can be avoided by the governments by selling reserves or by raising interest rates, she also considers a MS-VAR of changes in exchange rates, reserves and interest rates. Her MS-VAR model enables her to identify most speculative episodes captured previously by Eichengreen, Rose and Wyplosz with their index of speculative pressure and other ones for which one can find evidence in the financial press or in IMF's reports. Moreover, she finds that both fundamentals variables (the budget deficit) and expectations (captured by the interest differentials) are significant determinants of the European currency crises.

A similar analysis has been carried out by Amato and Tronzano (1998) and Tronzano (1999) on the peculiar case of the Italian currency from 1990 to 1996. They conclude that indicators of imbalance in domestic public finance, indicators of domestic real activity (industrial production changes) and external equilibrium indicators (real exchange rate, current account balance) affect significantly the exchange rate behavior. These studies provide empirical evidence to the consensus view in the literature that speculative attacks against the Italian currency were largely driven by growing macroeconomic imbalances (see for instance Eichengreen and Wyplosz (1993)).

In conclusion, the empirical literature is generally based on the existence of two alternative phases in the dynamics of the European exchange rates supporting the second-generation models ; empirical papers highlight the existence of stable periods featured by a small mean and variance and interrupted by more unquiet episodes characterized by wider fluctuations of the European exchange rates around a larger mean. The first ones correspond to periods of strong credibility in the future of the EMS, while the second ones are periods of decrease of the confidence. Krugman's hypothesis of a fully credible target-zone seems consequently unrealistic. It seems relevant that different equilibria characterize these two alternative states. We will investigate it in the following sections.

2. AN OVERVIEW OF THE DATA

The data are extracted from the IMF's International Financial Statistics database. They consist of monthly observations on exchange rates and on consumer price index of the countries participating in the Exchange Rate Mechanism since its inception. These are Belgium, Denmark, France, Germany, Ireland, Italy, Luxemburg and the Netherlands. We excluded Luxemburg from our analysis, because Belgium and Luxemburg maintained a fixed parity. For the sake of comparison throughout this paper, we also do not consider countries that joined the ERM after 1979.

The sample period spans from March 1979 (inception of the ERM) to December 1998 (end of the ERM), which yields 238 observations. All series haved been transformed by taking their logarithm. Because the price index was not available for Ireland, we have used the normalized unit labor costs for this country. Germany is treated as the base country, because it is the traditional anchor of the European Exchange Rate Mechanism.

Table I reports the realignment dates and the central parities of the ERM.

Table I. Realignment dates and central DM parities in the ERM

Realignment Dates	NG/DM	FF/DM	BF/DM	IL/DM	DK/DM	IP/DM
79:03:13	1.08370	2.30950	15.7164	457.314	2.82237	0.263932
79:09:24	1.10537	2.35568	16.0307	466.460	2.96348	0.26921
79:11:30	…	…	…	…	3.11165	…
81:03:23	…	…	…	496.232	…	…
81:10:05	…	2.56212	16.9125	539.722	3.28279	0.284018
82:02:22	…	…	18.4837	…	3.38433	…
82:06:14	…	2.83396	19.2693	578.574	3.52817	0.296090
83:03:21	1.12673	3.06648	20.0285	626.043	3.63141	0.323703
85:07:22	…	…	…	679.325	…	…
86:04:07	…	3.25617	20.4252	699.706	3.70332	0.333416
86:08:04	…	…	…	…	…	0.362405
87:01:12	…	3.35386	20.6255	720.699	3.81443	0.373281
90:01:08	…	…	…	748.217	…	…
92:09:15	…	…	…	802.488	…	…
93:02:02	…	…	…	out	…	0.414757
93:08:02	Margins of the ERM broadened to $\pm$15% except for the Dutch Guilder					
96:11:25	…	…	…	990.004	…	…
98:03:16	…	…	…	…	…	0.402676

Figures 1 and 2 show plots of the BF/DM, DK/DM, FF/DM, IL/DM, IP/DM and NG/DM exchange rates[1] and the bands in which they are allowed to fluctuate in level (figure 1) and in first difference (figure 2). It is worth noting that,

[1] BF denotes the Belgian Franc, DM the Deutsche Mark, DK the Danish Krone, FF the French Franc, IP the Irish Pound and NG the Dutch Guilder.

following important speculative attacks, the Italian Lira withdrew from the ERM from September 1992 to November 1996.

The visual inspection of these series supports the results found in previous empirical studies using Hamilton's model : there exists an alternance of phases of high volatility and phases less turbulent in the dynamics of the European exchange rates. Such an evolution justifies the approach based on regimes of the following sections.

Figure 1. European exchange rates in level in the Exchange Rate Mechanism

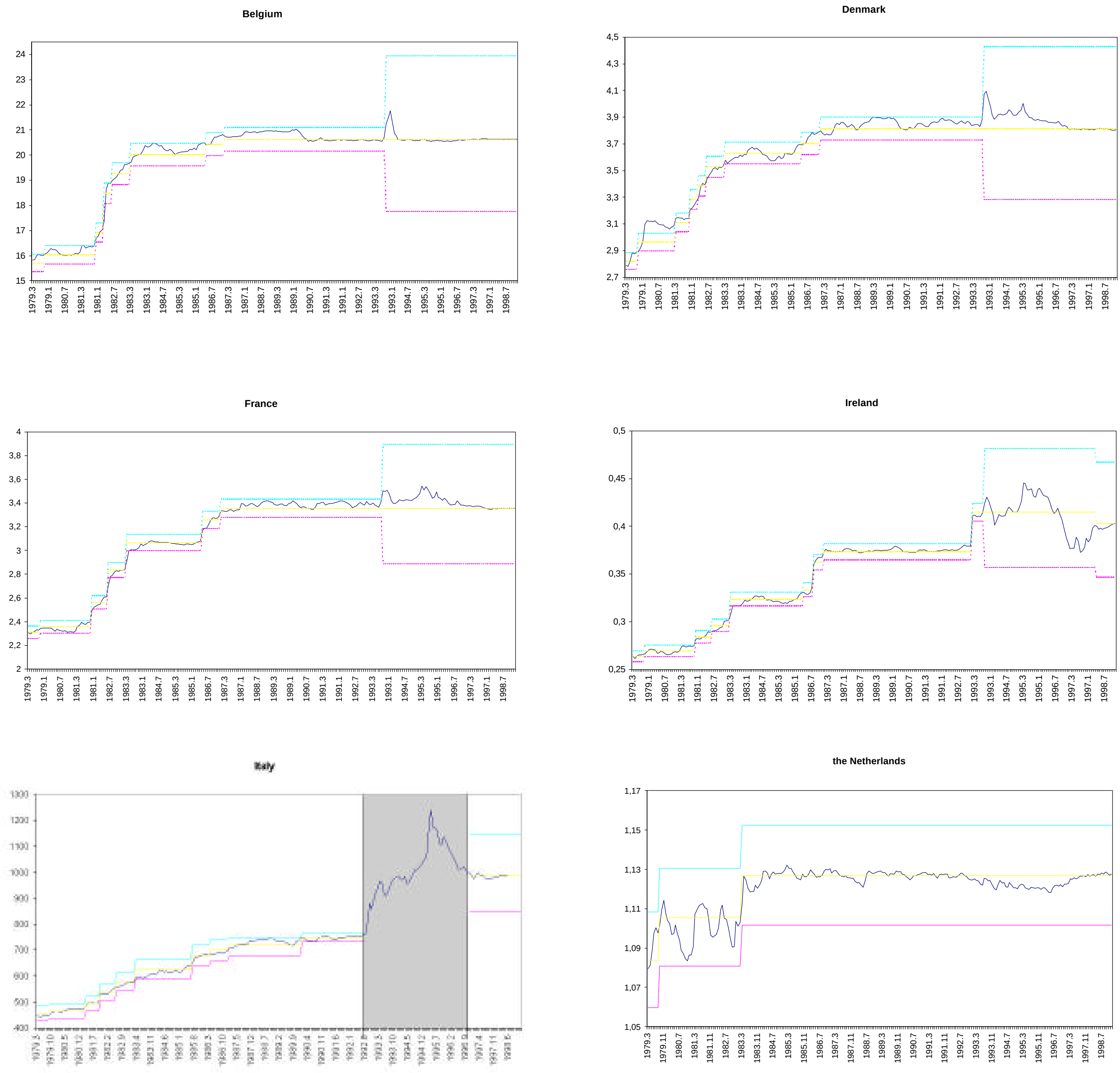
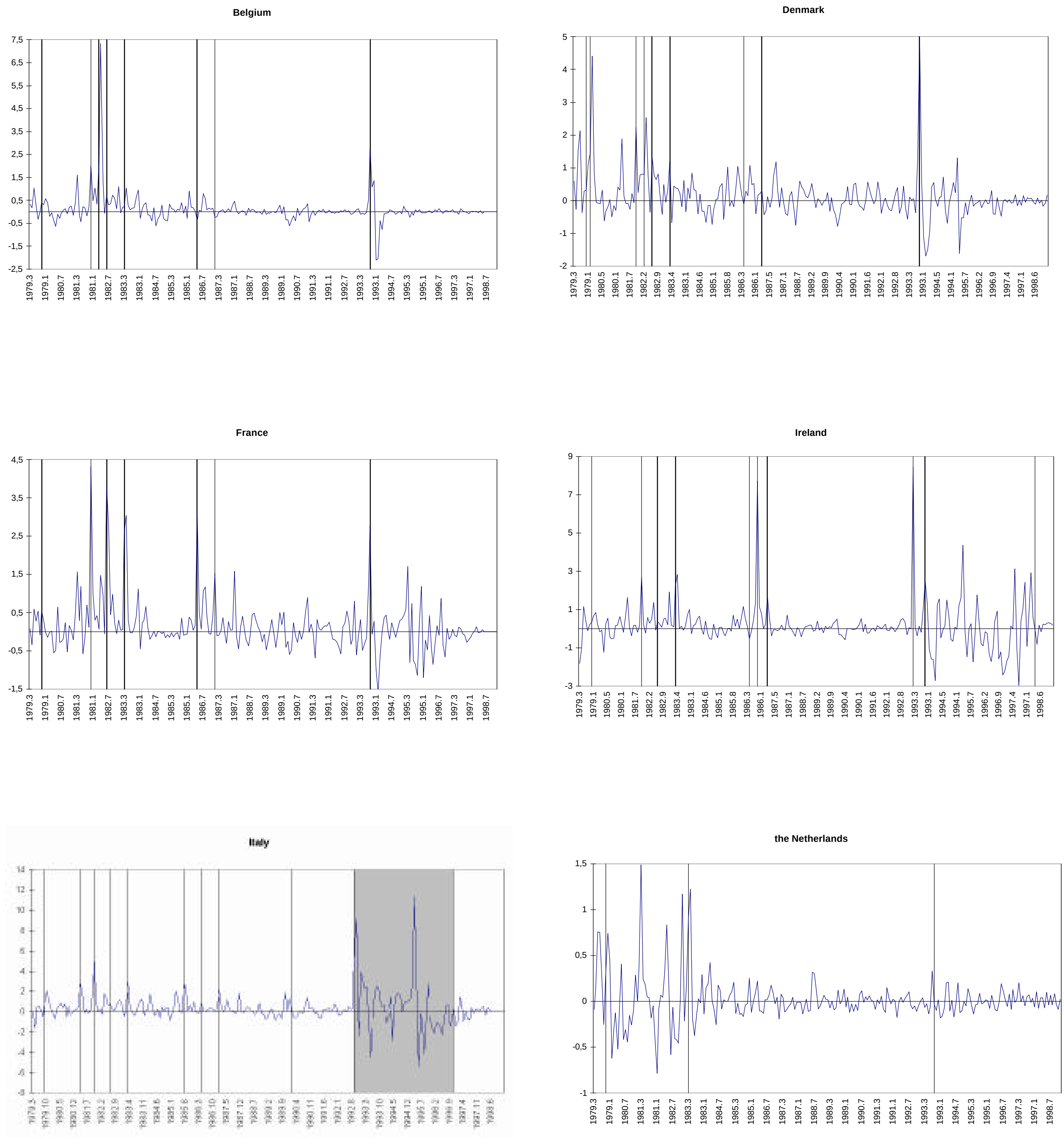


Figure 2. first difference of the logarithm of the European exchange rates and realignment dates (vertical lines)[1]



[1] In the Italian case, the dark band corresponds to the phase of withdrawal of the Italian Lira from the ERM.

3. MS-ECM MODEL

Given the apparent non-constancy of unconditional moments of first and second order (mean and variance) that we observe on the figures 1 and 2 especially on the figure 2 and that is pointed out in the previous empirical literature, we have used the dicrete regime-switching model of Goldfeld and Quandt (1973), Cosslett and Lee (1985) and Hamilton (1989) to characterize the exchange rates growth. Such a model enables the description and the forecast of recurrent stochatic changes in the behavior of economic series. To achieve this aim, the parameters of this model are allowed to switch, potentially every period, depending on which value (zero or one) an unobserved variable S_t takes on. This variable characterizes the "state" or "regime" in which the process of the exchange rates was at date t. When $S_t = 1$, the first difference of the logarithm of the exchange rates, De_t, is distributed $N(m_1, s_1^2)$ and when $S_t = 0$, De_t is distributed $N(m_0, s_0^2)$. The states are assumed to follow a first-order Markov chain ; it means that the process for S_t is supposed to depend on past realizations of e and S only through S_{t-1}.

$$P(S_t = i | S_{t-1} = j) = P(S_t = i | S_{t-1} = j, S_{t-2} = k, ..., Q_{t-1}) \quad (1)$$

Consequently, this process is completely described by the following constant transition probabilities :

$$\begin{aligned} P(S_t = 1 | S_{t-1} = 1) &= p \\ P(S_t = 0 | S_{t-1} = 1) &= 1 - p \\ P(S_t = 0 | S_{t-1} = 0) &= q \\ P(S_t = 1 | S_{t-1} = 0) &= 1 - q \end{aligned} \quad (2)$$

Contrary to what has been done previously by Engel and Hakkio (1996), Peria (1999), Amato and Tronzano (1998) or Tronzano (1999) when they study the dynamics of exchange rates under the EMS, we do not consider in this paper a MS autoregressive model but a MS Error Correction Model (MS-ECM) in order to study the adjustment towards one or several cointegration relationships. A cointegration relationship between several nonstationary variables can be interpreted in term of a long-run equilibrium relationship. ECM models describe how the variables respond to deviations from this equilibrium.

It is generally assumed in ECM representations that the adjustment towards the long-run equilibrium relationship is always present. However, the movement towards the equilibrium relationship need not occur in every time period. There exist two models in which the error correction mechanism is discontinuous in the time : the threshold cointegration model and the Markov-Switching Error Correction model. In threshold cointegration models described by Balke and Fomby (1997), there is an adjustment if the series moves too far away from the equilibrium relationship, but this correction does not take place as long as the series is relatively close to the equilibrium. In Markov-Switching Error Correction Models (MS-ECM), the presence of the adjustment depends on the dynamics of the considered variable (which determines the realized regime). Such a model was for example used by Hall, Psaradakis and Sola (1997) to detect periodically collapsing bubbles in the British house prices. They interpreted the regime without adjustment towards the cointegration relationship as a regime of bubble.
In this paper, we will use a MS-ECM representation instead of a threshold cointegration model, because we think that there is an alternance between two long-run equilibrium relationships depending on which exchange rates regime is realized. Indeed, we show here that for most countries, there is an adjustment towards the central parity (mean-reversion) in the credible regime, while there is a correction of deviations from the PPP in the unstable regime.

Formally, to test this hypothesis, we consider the following representation :

$$\begin{aligned} De_t = {} & m_{S_t} + b_{1,S_t}(e_{t-1} - C_{t-1}) + b_{2,S_t}(e_{t-1} - P_{t-1} + P^*_{t-1}) + \\ & \sum_{i=1}^{k_1} f_i De_{t-i} + \sum_{i=1}^{k_2} z_i DC_{t-i} + \sum_{i=1}^{k_3} d_i D(P_{t-i} - P^*_{t-i}) + s_{S_t} e_t \end{aligned} \qquad (3)$$

where e_t is an *i.i.d. N(0,1)* variable, e_t represents the logarithm of the nominal exchange rate, P_t the logarithm of the domestic price index, P_t^* the logarithm of the foreign price index, C_t the logarithm of the central parity and $S_t = \{0,1\}$.

This model is an ECM model with two long-run equilibria corresponding to two alternative anchors of the ERM. The first one (C_t) is the European central parity around which European exchange rates have to fluctuate. The adjustment towards this equilibrium illustrates the mean-reverting behavior of exchange rates. The second potential equilibrium ($P_t - P_t^*$) is the Purchasing Power Parity (PPP). The difference between the nominal exchange rate and the PPP is the real exchange rate which measures the competitiveness of the home country relative to the reference country (Germany).

Thus, $(e_{t-1} - C_{t-1})$ and $(e_{t-1} - P_{t-1} + P^*_{t-1})$ reflect the deviations of the exchange rate from these two anchors and the coefficients b_1 and b_2 capture the potential adjustment to departures from these anchors. If b_1 and b_2 are significantly negative, there is a tendency of the system to drift back towards the equilibrium relationship. On the contrary, if these two parameters are positive or non significant, there is no adjustment.

To test the idea of a discontinuous adjustment towards the two equilibria, we allow the error-term parameters (i.e. b_1 and b_2) to switch across the regimes. Thus, not only the intercept (m) and the variance (s^2) but also these two coefficients depend on the realized state S_t.

4. EMPIRICAL RESULTS

In a first part, we estimate an unconstrained MS-ECM model where there may be a correction to deviations from the two cointegration relationships in both regimes. Then, given the non significant error correction term towards the central parity in the unstable regime and the non significant error correction term towards the PPP in the credible regime in most countries, we estimate a constrained model with an adjustment process towards only one of the two equilibrium relationships in each regime.

4.1 Estimation of the unconstrained model

Let us consider first the following simplified specification [2]:

$$\begin{aligned} De_t = m_{S_t} + b_{1,S_t}(e_{t-1} - C_{t-1}) + b_{2,S_t}(e_{t-1} - P_{t-1} + P^*_{t-1}) + \\ f\,De_{t-1} + z\,DC_{t-1} + d\,D(P_{t-1} - P^*_{t-1}) + s_{S_t} e_t \end{aligned} \qquad (4)$$

Numerical maximization[3] of the Gaussian likelihood function of the MS-ECM model leads to the estimates reported with their t-statistics (in parentheses below parameter estimates) in table II. It should be noted that, in the Italian case, we have set to zero the first error term $(e_{t-1} - C_{t-1})$ from September 1992 to November 1996. Indeed, following important speculative attacks in the summer of 1992, the Italian Lira (and the Pound Sterling) had been driven out from the European Exchange Rate Mechanism in September 1992. On November 25, 1996,

[2] We only consider one lag for the adjustment terms because it does not change significantly the results and because it makes easier the numerical optinization.

[3] Maximization of the Likelihood function was carried out by means of the BFGS algorithm in a GAUSS program. This program is available on request.

the Italian Lira reentered the ERM. Thus, there can not be an adjustment towards the central parity from September 1992 to November 1996. Consequently, we have set to zero the deviations from the central parities during this period, to offset this potential adjustment during this phase.

The “smoothed’’ probabilities of being in the stable regime are depicted together with the exchange rate growth by figure 3. We recall here that a “ smoothed ’’ probability $P(S_t = i | I_T)$ is the probability that the exchange rate growth at time *t*, De_t, comes from the state *i* at time *t* conditional on all observations of the sample.

Now, let us describe the results obtained with our unconstrained specification. First, we can check that, as noted previously in the literature, the exchange rates switch between a tranquil and persistent state i.e. with a low variance (when the EMS is credible) and a large transition probability *p* and a more unquiet and short-lived state i.e. with a larger variance and a small transition probability *q* (when the EMS is not credible and consequently encountered severe speculative attacks). The comparison of the datation of the two states (see the smoothed probabilities) and the timing of some events occuring from 1979 to 1998 (see table V in appendix) and affecting the confidence of markets and politicians in the future of the European Monetary Union allows this interpretation of the regimes in term of credibility.

Then, we can consider the estimates of the two error-term parameters b_1 and b_2. As expected, in Denmark, France, Ireland and Italy, we find a statistically significant adjustment process towards the PPP in the unstable regime (b_{20} negative and significant) and a statistically significant adjustment process towards the central parity in the credible regime (b_{11} negative and significant). On the contrary, there is no adjustment towards the PPP in the stable regime (b_{21} non significant) and no adjustment towards the central parity in the turbulent regime (b_{10} non significant). Nevertheless, the adjustment towards the central parity is also significant in the unstable state in the case of Denmark.

However, Belgium and the Netherlands exhibit a different pattern. In the Netherlands, the numerical optimization fails and in Belgium, we obtain only mean-reversion in the unstable regime.

All these results are confirmed by the estimation of the constrained specification.

Table II. The unconstrained MS-ECM model

Country	*p*	*q*	*f*	*z*	*d*	b_{10}/ b_{11}	b_{20}/ b_{21}	s_0	s_1	m_0	m_1	*L(q)*
						-0.28	-0.01					
Belgium	0.93	0.90	0.19	0.25	0.016	(-4.94)	(-0.67)	0.69	0.08	3.62	-0.63	-2.69
	(6.86)	(5.48)	(6.01)	(11.39)	(0.76)	0.005	0.002	(13.57)	(12.09)	(0.76)	(-0.42)	
						(0.49)	(0.42)					
						-0.31	-0.32					
Denmark	0.97	0.86	0.35	-0.13	-0.07	(-5.36)	(-4.21)	0.82	0.32	45.20	0.98	-135.68
	(7.21)	(2.03)	(4.66)	(-2.50)	(-1.41)	-0.09	-0.007	(5.26)	(15.55)	(4.26)	(0.82)	
						(-3.12)	(-0.75)					
						-0.12	-0.13					
France	0.89	0.58	0.09	0.04	-0.02	(-1.34)	(-2.17)	1.02	0.27	16.0	0.13	-145.29
	(6.09)	(0.63)	(1.84)	(1.18)	(-0.28)	-0.06	-0.001	(8.56)	(13.41)	(2.28)	(0.17)	
						(-2.00)	(-0.14)					
						-0.012	-0.013					
Ireland	0.90	0.74	0.16	-0.015	-0.001	(-0.20)	(-2.39)	1.86	0.30	-1.19	-0.05	-231.51
	(7.05)	(2.66)	(2.37)	(-0.23)	(-0.08)	-0.08	-0.001	(10.18)	(13.1)	(-1.72)	(-0.36)	
						(-3.24)	(-0.73)					
						0.05	-0.09					
Italy	0.89	0.72	0.23	-0.26	-0.10	(0.16)	(-2.77)	2.30	0.43	61.0	-5.50	-306.16
	(6.41)	(2.44)	(5.26)	(-3.87)	(-1.24)	-0.04	0.008	(10.43)	(11.0)	(2.80)	(-1.67)	
						(-1.88)	(1.53)					

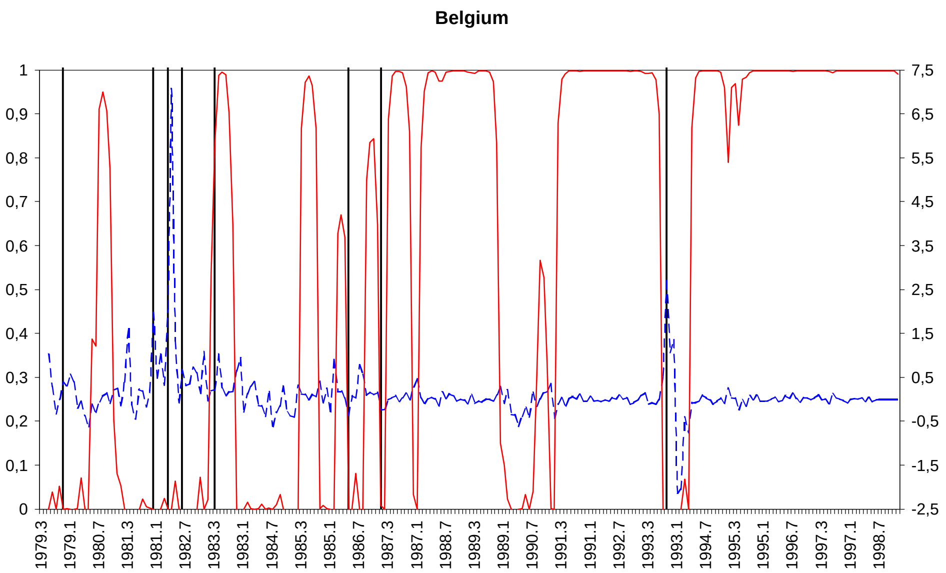
Explicative notes to table II :

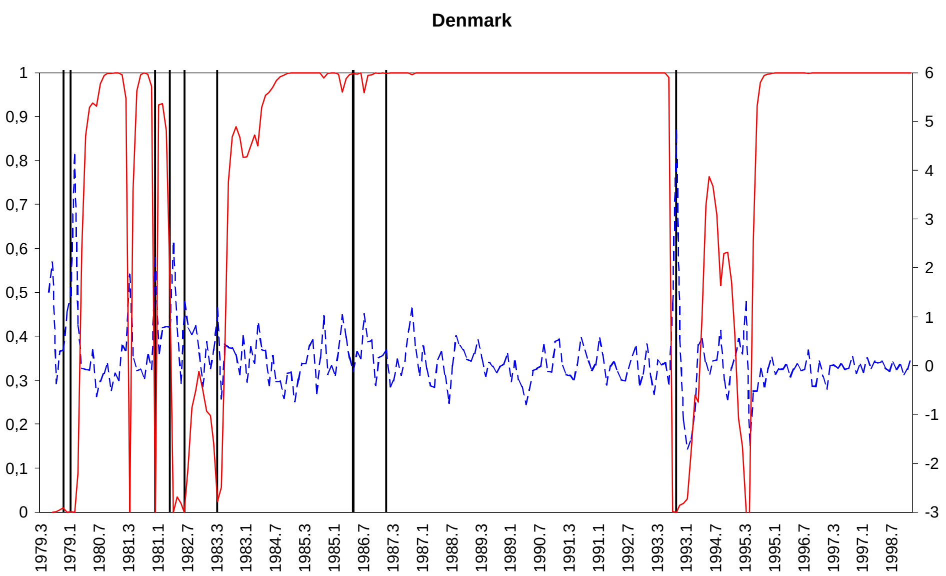
1) t-statistics are given in parentheses below parameter estimates.

2) The state zero ($S_t = 0$) refers to the unstable regime and the state one ($S_t = 1$) to the credible state.

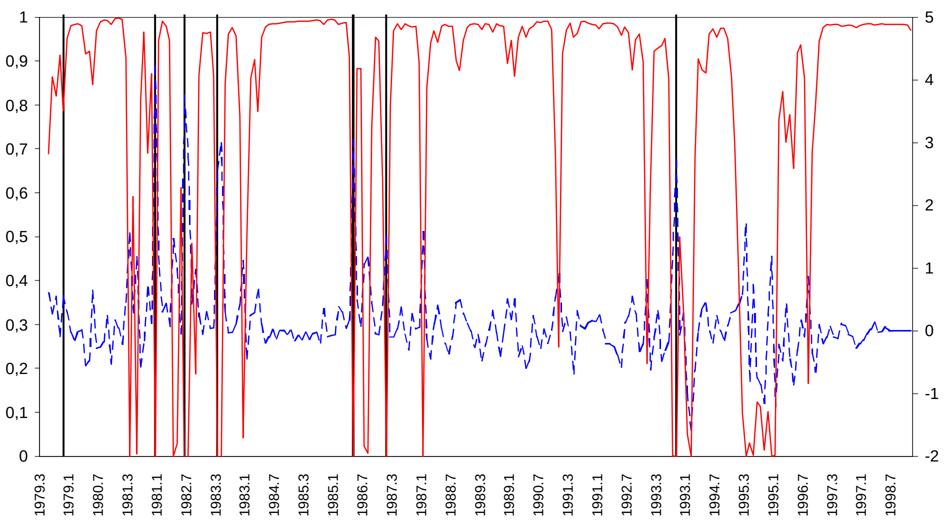
3) The different coefficients (first line of the table) are defined in the following way :
p and *q* are the constant transition probabilities of remaining, respectively, in state *1* and *0*.
f, z, d are the coefficients of the first-difference of, respectively, the exchange rate, the central parity and the Purchasing Power Parity (adjustment terms).
b_0 and b_1 are the error-correction parameters of the two regimes.
s_0 and s_1 are the innovation standard deviations, m_0 and m_1 are the intercepts.

Figure 3. smoothed probabilities of being in the stable regime (state 1) in the unconstrained MS-ECM model

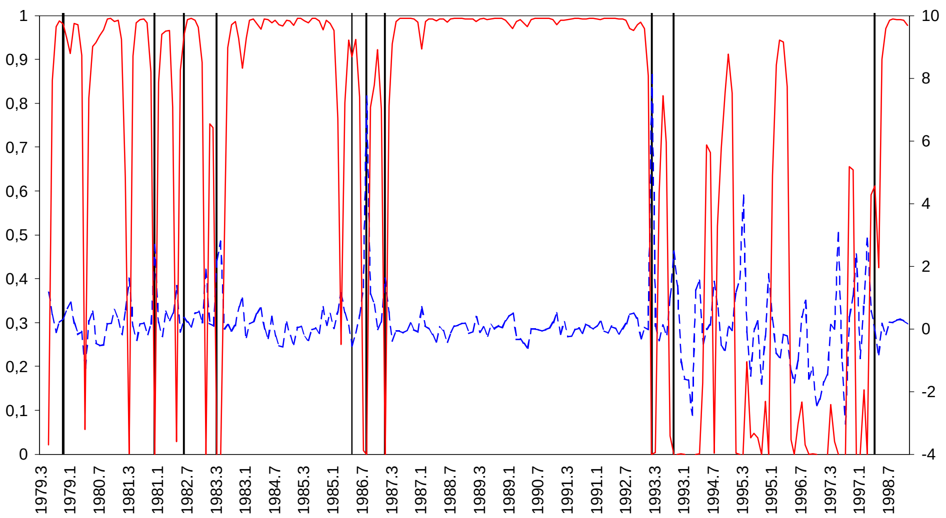




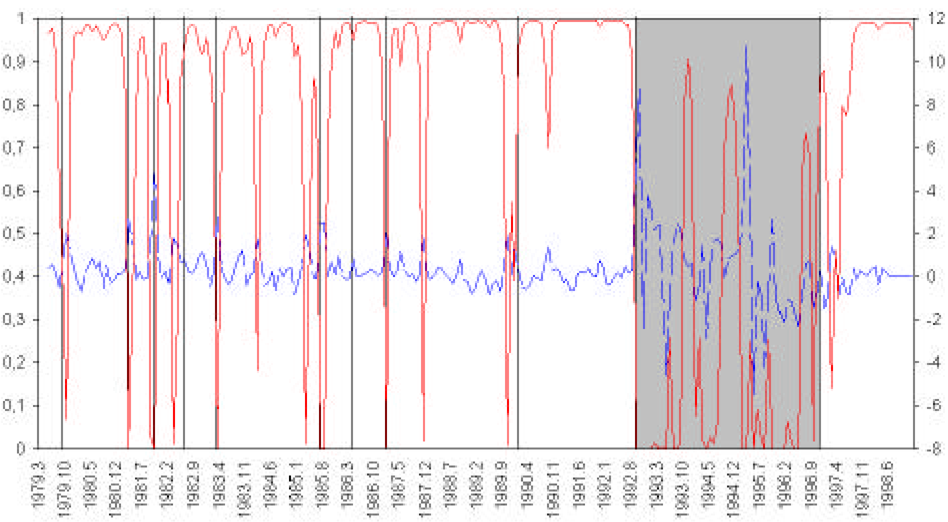
France



Ireland



Italy



4.2 Estimation of the constrained model

As the error correction parameters b_{10} and b_{21} seem to be not significant in Denmark, France, Ireland and Italy, we may consider the following parcimonious representation of our MS-ECM model in these countries :

$$De_t = \begin{cases} m_0 + b_{20}(e_{t-1} - P_{t-1} + P^*_{t-1}) \\ m_1 + b_{11}(e_{t-1} - C_{t-1}) \end{cases} + f\,De_{t-1} + z\,DC_{t-1} + d\,D(P_{t-1} - P^*_{t-1}) + s_{S_t} e_t \qquad (5)$$

Table III contains the estimates of this constrained model, table IV reports the likelihood ratio statistics of the null hypothesis $b_{10} = b_{21} = 0$ and figure 4 depicts the smoothed probabilities of being in the stable state.

All these results provide further support to those of the section 4.1. First, the two correction error parameters we keep, b_{20} and b_{11}, are still very significant (see table III). Moreover, the difference between the log-likelihood of the constrained and unconstrained models is small (see tables II and III). Consequently, the ratio likelihood test[6] reported in the table IV rejects the unconstrained model at the 5% significance level, except in Denmark, where there was also a significant adjustment towards the central parity in the unstable regime. At last, as can be seen in figure 4, the smoothed probabilities remain essentially unchanged.

Consequently, we can conclude that there exist two alternative anchors in the ERM depending on which regime we are. In the credible state, the European exchange rates fluctuate around the central parity, whereas they converge towards the Purchasing Power Parity value in the unstable regime.

Based on the interpretation of the regimes in term of credibility, we can explain the existence of these two anchors in Denmark, France, Ireland and Italy in the following way. In the stable regimes where the official parities are credible, the exchange rate fluctuate around the central parity. This mean-reversion can be related to the stabilizing impact of a credible target-zone as it is stressed by the target-zone literature. On the contrary, in the unstable regimes, some events affect the credibility of the target-zone, which encounters severe speculative attacks. Consequently, the exchange rates depart from the central parities of the less credible target-zone. Thus, the adjustments towards the first anchor disappear but realignments which mostly take place during the unstable regime drag back the exchange rates on their PPP value. This can be found by comparing the datation of regimes (smoothed probabilities) and the realignment dates (vertical lines) of the figures 3 and 4. The inspection of the smoothed probabilities shows that most transitions towards the regime where there is only an adjustment towards the PPP

[6] This test statistics may have a non-standard distribution. Nevertheless, the weak difference between the likelihood of the two specifications is a supportive evidence in favour of the constrained representation.

Table III. The constrained MS-ECM model

Country	*P*	*q*	*f*	*z*	*d*	b_{11}	b_{20}	s_0	s_1	m_0	m_1	*L(q)*
Denmark	0.96 (7.84)	0.72 (1.58)	0.29 (5.72)	-0.09 (-1.75)	-0.09 (-1.88)	-0.12 (-5.75)	-0.34 (-2.49)	1.22 (6.63)	0.34 (19.07)	48.34 (2.53)	0.10 (3.50)	-143.03
France	0.89 (6.23)	0.57 (0.58)	0.08 (1.78)	0.05 (1.45)	-0.01 (-0.19)	-0.06 (-1.99)	-0.17 (-3.78)	1.03 (8.41)	0.28 (13.90)	21.17 (3.87)	0.02 (0.75)	-146.23
Ireland	0.90 (7.0)	0.76 (2.89)	0.19 (3.12)	-0.04 (-0.74)	3.10^{-5} (0.005)	-0.09 (-4.29)	-0.01 (-2.40)	1.82 (10.9)	0.30 (14.24)	-1.16 (-1.74)	0.05 (2.05)	-231.78
Italy	0.90 (6.68)	0.78 (3.14)	0.21 (4.07)	-0.60 (-2.60)	-0.04 (-0.58)	-0.05 (-2.34)	-0.08 (-2.69)	2.18 (11.01)	0.43 (12.16)	54.91 (2.72)	0.08 (1.64)	-308.59

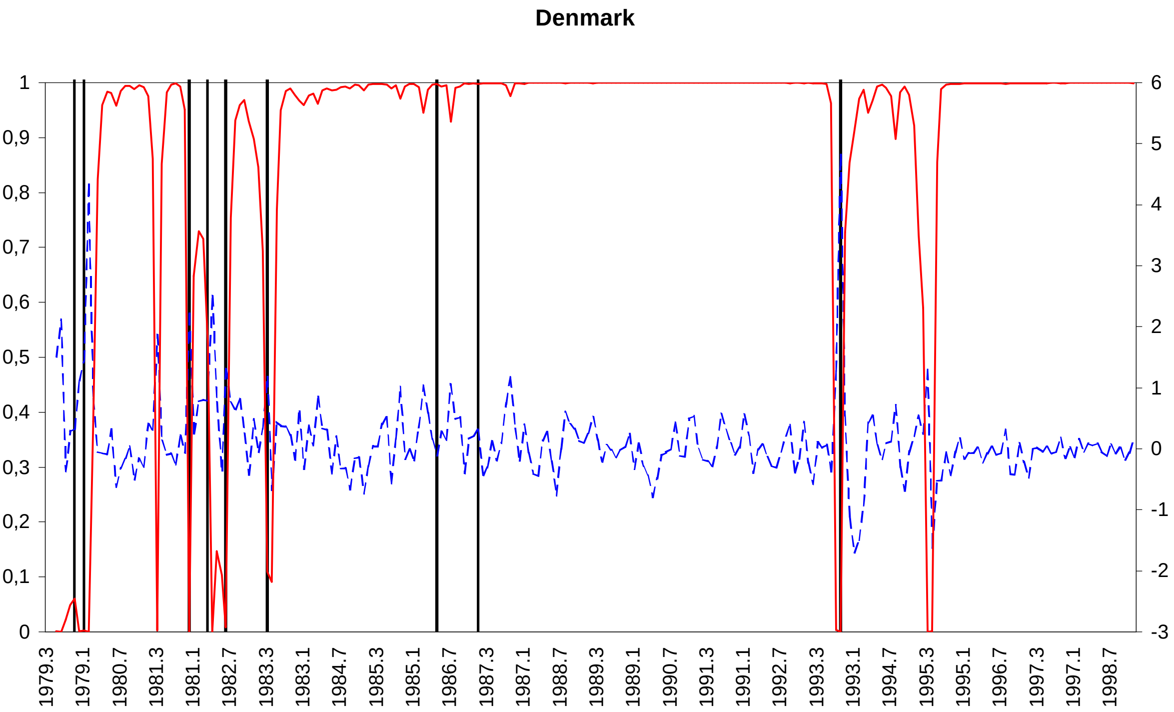
See the notes of table II

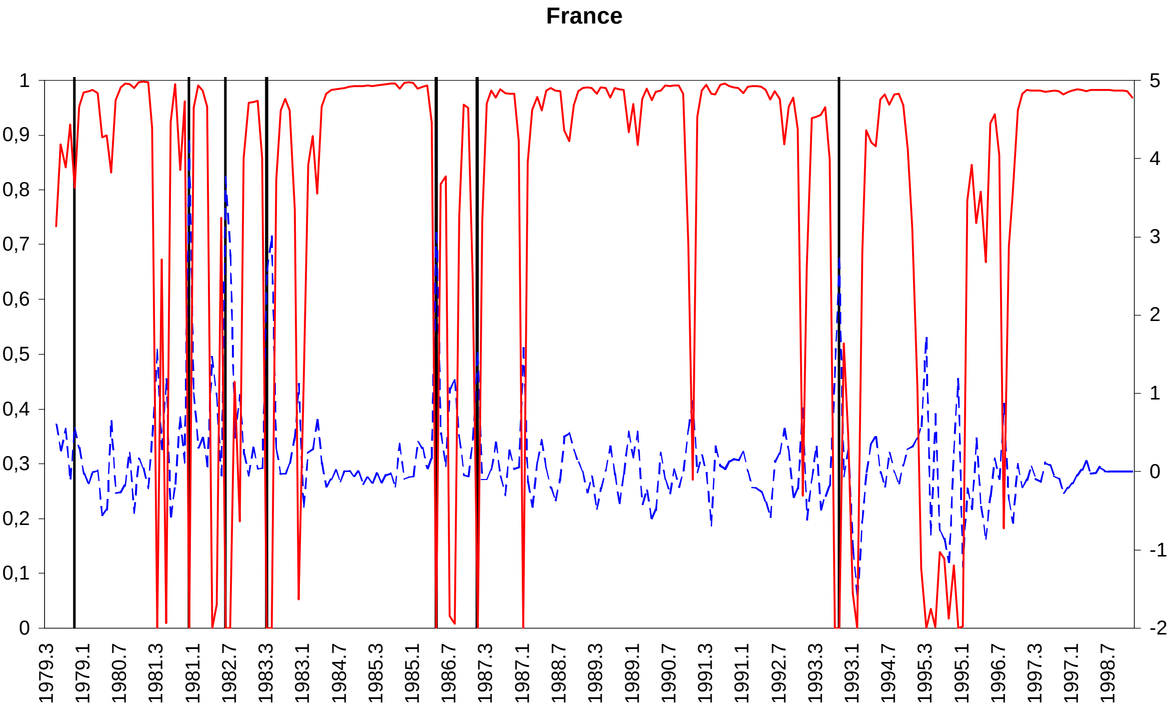
Table IV. The ratio likelihood test of the constrained versus the unconstrained model

Country	*Denmark*	*France*	*Ireland*	*Italy*
Statistics[7]	14.70	1.88	0.54	4.86

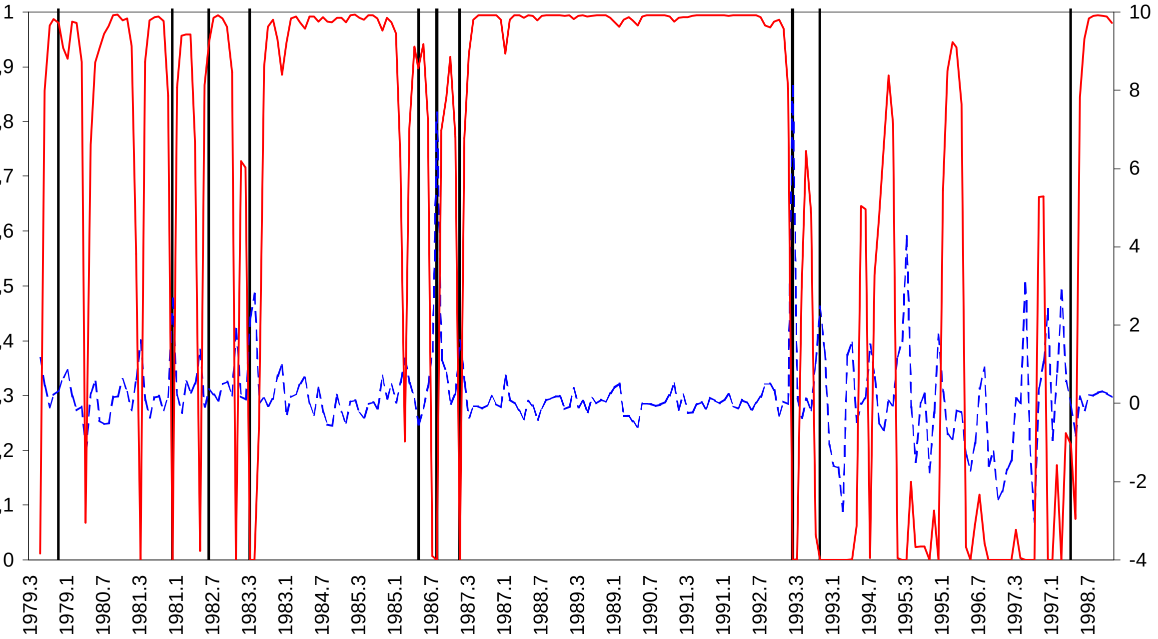
[7] Assuming a standard distribution, the test statistics have to be compared to the 5% $c(2)$ critical value equal to *5.99*.

Figure 4. Smoothed probabilities of being in the stable regime (state 1) in the constrained MS-ECM model





Ireland



Italy

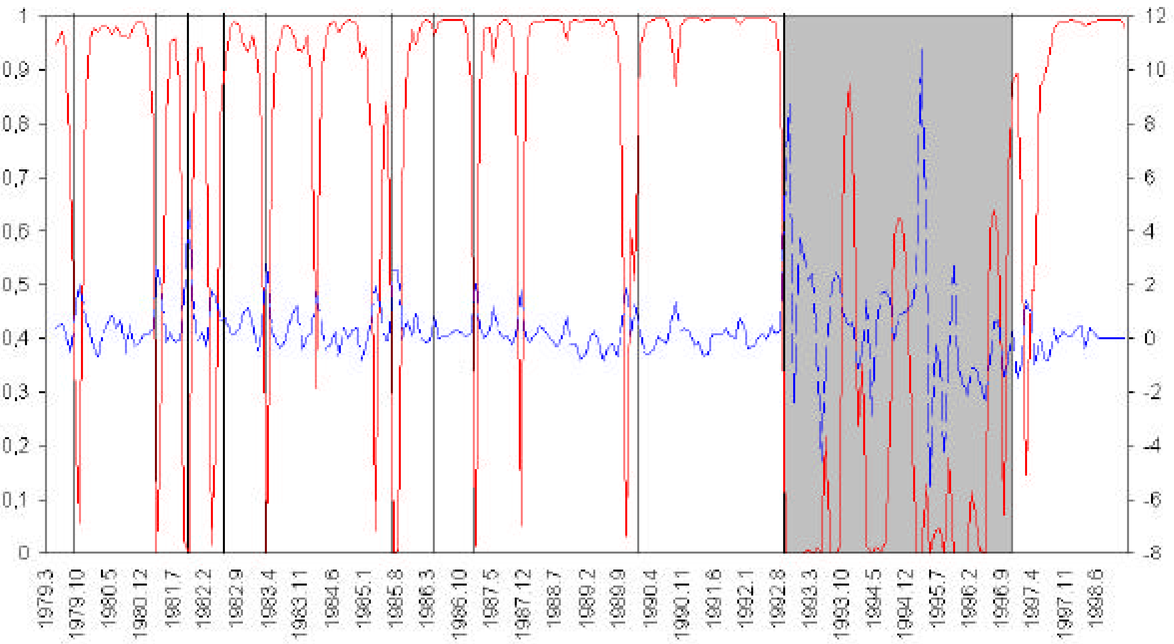
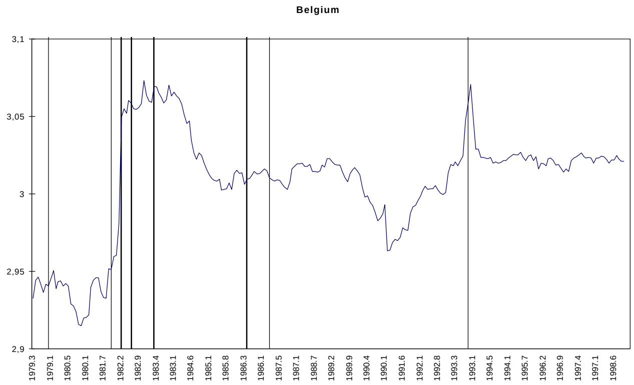
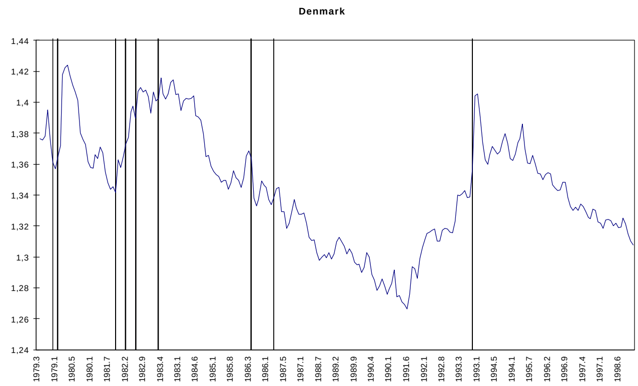
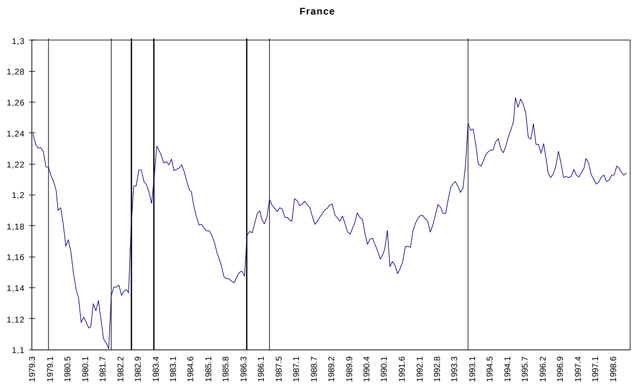
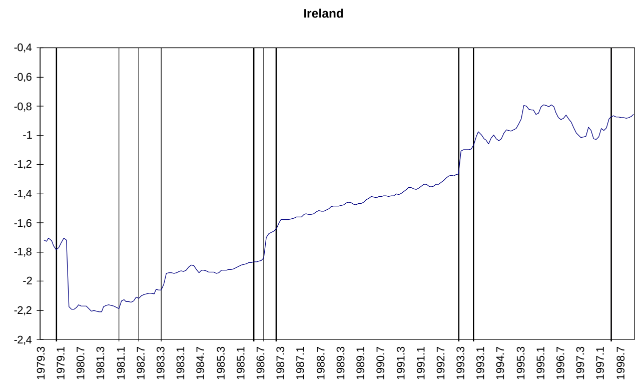


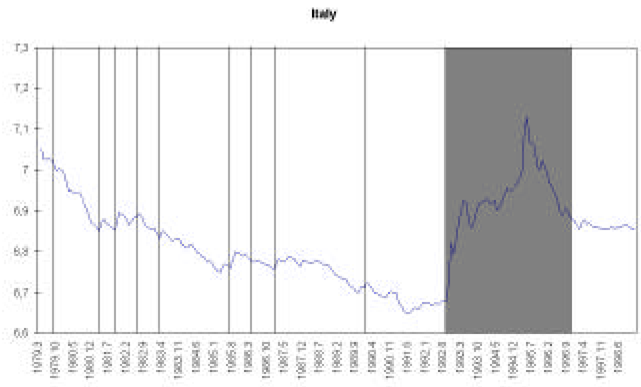
Figure 5. Plots of real exchange rates and realignement dates

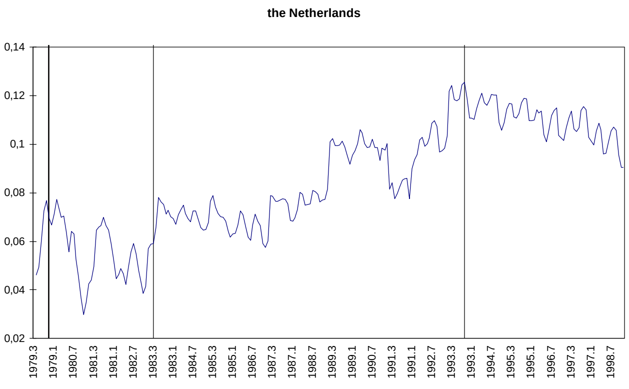












correspond to realignments of the European currencies. It corroborates the results obtained by Engel and Hakkio (1996) showing on the FF/DM and IL/DM exchange rates with MS models with fixed and time-varying transition probabilities that most realignments for these two countries occured during the volatile period. It means that the existence of this second long-run equilibrium relationship is artificially brought by the authorities' interventions designed to lower competitiveness differentials between the countries participating in the EMS ; realignments were designed to offset inflation differentials between the EMS partners. This idea is confirmed by fig. 4. It plots our second error-term : the deviation of the nominal exchange rate from the PPP (i.e. the real exchange rate). We notice on this picture that the realignment dates correspond mainly to peaks of this error term and that this series decreases afterwards. Consequently, the real exchange rate exhibits no long-run increase thanks to the realignments which broke their increase, corresponding to a loss of competitiveness of the considered country relative to the reference country ; the realignments prevent the nominal exchange rates to move too far away from the PPP.

However, the Netherlands and Belgium make exception to this analysis. The failure of our specification to model their exchange rates dynamics can be explained by their high degree of convergence with respect to Gemany. Indeed, the Dutch Guilder and the Belgian Franc have been pegged to the Deutsche Mark respectively since 1984 and 1990. This involves a strong stability of these exchange rates explaining the inadequacy of our specification for these two countries.

5. CONCLUSION

This paper has explored the possibility of two alternative anchors -the central parity and the Purchasing Power Parity value- in the European Exchange Rate Mechanism during the whole period of the EMS for six European countries. To test this hypothesis, we have used the Markov-Switching approach, as it is recommended by the empirical literature and implicitly by a part of the theoretical literature. In this framework, it turns out that the Danish, French, Irish and Italian exchange rates switch between a credible state with mean-reversion towards the official parities and an unstable regime with an adjustment to the PPP value. Yet, the Belgian Franc and the Dutch Guilder which have been pegged sooner or later to the Deutsche Mark constitute peculiar cases.

We have thus reconciled two issues rarely treated together : the mean-reversion and the PPP hypotheses in the dynamics of exchange rates within a target-zone system. Anyway, at the end of the ERM, these two questions became redundant : with the gradual convergence of the European economies and consequently the removal of the competitiveness differentials between the European members, the PPP was converging towards the central parity (see Gros and Thygesen 1998, p.78). Consequently, the adjustment towards the Purchasing Power Parity value became equivalent to a convergence of the exchange rate towards the central parity.

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This paper owes a great deal to suggestions and comments from P.Y. Hénin. I am also grateful to F. Karamé, P. N'Diaye and C. Perraudin for fruitful discussions on an earlier version of this paper. However, all remaining errors are of course mine.

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APPENDIX

Table V. Main events occuring during the EMS

Date	*Event*
79:03:13	Inception of ERM
87:09:12	Basle-Nyborg Agreement
89:06:19	Entry of Spain
90:01:08	Reduction of the Italian margin
90:06:16	The Belgian Franc is pegged to the Deutsche Mark
90:10:08	Entry of United Kingdom
91:12	Maastricht Summit
92:04:06	Entry of Portugal
92:06:02	Negative outcome of the Danish referendum on Maastricht
92:06	Irish referendum on Maastricht
92:08:25	French polling result indicating a short majority of French voters in favour of the ratification of the Maastricht treaty
92:09:14	Devaluation by 7% of the Italian Lira
92:09:17	Withdrawal of Italy and Britain from the ERM
92:09:20	Positive outcome of the French referendum on the Maastricht Treaty with a slim majority
92:11:23	Devaluation by 6% of the Spanish Peseta and the Portuguese Escudo
93:02:01	Devaluation by 10% of the Irish Pound
93:05:13	Devaluation of the Spanish Peseta and the Portuguese Escudo
93:08:02	ERM bands widening to ± 15% except for the Dutch Guilder
95:01:07	Entry of the Austrian Schilling
95	Entry of Finland
96:11:24	Reentry of Italy
98:03:16	Entry of Greece
98:05	Bruxelles Summit announcing the future bilateral parities between the European currencies