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Exchange Market Pressures and Speculative Capital Flows in Selected European Countries

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Abstract

This paper estimates a speculative attack model of currency crises in an attempt to identify the roles of macroeconomic fundamentals and speculative market pressures in the recent crisis, as well as earlier devaluations in adjustable fixed exchange rate systems in the European currency markets. For a sample of five countries, including Denmark, Ireland, Spain, Norway, and Sweden, our empirical analyses show that both economic fundamentals and speculative factors have a significant influence on the probability of devaluations. The recent experience in the European foreign exchange markets suggests that the latest realignments are mainly the result of foreign exchange market tensions amidst the growing conflict between the needs of the domestic economies and the policies needed to maintain fixed exchange rates. Our results confirm that regardless of the source of the deterioration in economic conditions, market participants perceived the existing parities of the currencies in these five countries as inconsistent with their underlying economic fundamentals, thus effectively bringing about either a realignment or a modification of the exchange arrangement.

JEL Classification Numbers
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Contents

Summary

The emergence of intense pressures within the exchange rate mechanism (ERM) of the European Monetary System (EMS) in late 1992 and 1993 led to the suspension of two currencies, devaluations of three currencies, and a substantial widening of the fluctuation bands for most of the currencies of the ERM. The underlying causes of the recent currency turmoil attracted significant attention. Some have claimed that while sound economic policies were necessary, they were not sufficient to prevent speculative runs on currencies. Others have claimed that the speculative attacks were justified by the underlying economic fundamentals.

This paper estimates an extended speculative attack model of currency crises in an attempt to identify the roles of macroeconomic fundamentals and speculative factors in the recent and earlier currency crises in the European foreign exchange markets. Three approaches were used to estimate market expectations of devaluations and to calculate the probability of a regime change--either a discrete devaluation or a switch to flexible exchange rates--in a sample of five countries: Denmark, Ireland, and Spain, which are members of the ERM, and Norway and Sweden, which pegged their currencies to currency baskets or to the European currency unit (ECU). The first approach applies the probit technique to the basic speculative attack model, which calculates the probability of a regime change as a function of economic fundamentals (level of domestic credit, real effective exchange rates, foreign interest rates and price level, real output, unemployment rate, trade balance, and foreign reserves). This approach was used to evaluate whether a regime change was justified by economic fundamentals alone. Second, a version of the Bertola and Swensson (1990) model was used to capture the existence of speculative pressures on these currencies which operate through interest rate differentials, the current position of the currency within its fluctuation band, and the level of foreign reserves. Finally, speculative proxies were combined with economic fundamentals to evaluate the combined impact of these factors on the probability of a regime change.

The empirical analysis shows that both economic fundamentals and speculative factors had a significant influence on the probability of regime changes for the sample countries. The analysis also confirms that the latest realignments in the European foreign exchange markets were mainly the result of foreign exchange market tensions amidst the growing conflict between the needs of the domestic economies and the policies needed to maintain fixed exchange rates. Market participants perceived that the existing parities of the currencies in these five countries were inconsistent with their underlying economic fundamentals, regardless of the source of their deterioration, at the time of realignment. Furthermore, defensive interest rate policies to maintain existing parities have proved ineffective, as the market perceived such policies to be inherently unsustainable.

I. Introduction

The emergence of intense pressures within the exchange rate mechanism (ERM) of the European Monetary System (EMS) in late 1992 and 1993 led to a suspension of two of the currencies from the ERM, devaluations of three of the currencies, and a substantial widening of the fluctuation bands for most of the currencies. While the intensity of the crisis has been unprecedented, the process underlying the crisis is neither new nor specific to the EMS. Speculative currency attacks and balance of payments crises have been experienced throughout the history of fixed exchange rates. It has been claimed that the recent turmoil in foreign exchange markets has shown that sound economic policies are necessary but not sufficient to prevent speculative runs on currencies. The purpose of this paper is to estimate a speculative attack model of currency crises in an attempt to identify the roles of macroeconomic fundamentals and speculative market pressures in the recent crisis, as well as earlier devaluations within target zones, in the European currency markets.

There is a large body of theoretical literature analyzing currency crises in the context of a small open economy with a fixed exchange rate regime. 1/ In its simplest form, formalized by Flood and Garber (1984), the crisis model outlines a process in which fiscal imbalances may lead to an eventual regime collapse. Such imbalances generate domestic credit expansions that initially cause a gradual erosion of the official foreign exchange reserves, since the central bank must offset the excess domestic credit to maintain the fixed exchange rate and money market equilibrium. This gradual erosion of reserves is followed by generally self-fulfilling speculative attacks on the currency, as forward-looking investors engage in one-sided bets against the currency, anticipating that the central bank would not have sufficient reserves to defend the fixed parity. Eventually, the fixed exchange rate can no longer be sustained and the prevailing regime collapses. The latter involves either a discrete devaluation or a switch to a flexible exchange rate regime, which is usually followed by a sharp depreciation of the currency.

The basic currency crisis model has been extended in various directions. Such extensions consider market imperfections, alternative post-attack exchange rate regimes other than a switch to a flexible exchange rate system, the possibility of real effects from speculation, the relaxation of the assumption of perfect foresight and perfect knowledge about the critical reserve level, and policy actions to postpone or avoid

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1/ See Krugman (1979), Flood and Garber (1984), Blanco and Garber (1986), Grilli (1986), Obstfeld (1986), Wyplosz (1986), Buiter (1987), Cumby and van Wijnbergen (1989), Penati and Pennacchi (1989), Willman (1987, 1989) and Goldberg (1988, 1991).

an attack such as external reserve borrowing and/or capital controls. Survey articles on speculative currency crises by Agénor, Bhandari, and Flood (1992) and Blackburn and Sola (1993) provide a detailed description of these extensions. 1/

Empirical tests for the basic currency crisis model has been conducted in the context of Latin American countries by Blanco and Garber (1986), van Wijnbergen (1987), Goldberg (1988), and Cumby and van Wijnbergen (1989). In the context of developed countries, Grilli (1990) applies the speculative attack model to the episode of foreign exchange market pressure on the U.S. dollar in the 1890s. Edin and Vredin (1993) formulate and estimate a model of devaluations within target zones in Nordic countries using monthly data for the period 1978:2-1989:7, by relating devaluations to economic fundamentals. These studies have found empirical support for the basic currency crisis model.

An alternative technique to model market expectations of devaluations was suggested by Bertola and Svensson (1990), and implemented by Svensson (1991, 1993), Rose and Svensson (1991) and Caramazza (1993) for some European currencies. The technique uses a target zone model to estimate market expectations of devaluations as a function of interest rate differentials and the deviation of the exchange rate from its central parity. In a contemporaneous work, Thomas (1993) addresses the question of whether the episodes of exchange market pressure are related to economic fundamentals in the case of France and Italy. By using the Bertola and Swensson (1990) approach, he estimates the expected central parity changes for the French franc and the Italian lira, using variables representing persistent deviations from internal and external balance, institutional constraints captured by foreign exchange reserves, and speculative behavior measured by the position of the currency within the fluctuation band. His main findings are that changes in fundamental variables have only a weak effect on devaluation risk in France and Italy, while the position of the currency within the band, which is the indicator of speculative pressure, has the most significant influence on the devaluation risk.

In this paper, we provide an empirical application of the currency crisis models to analyze the recent as well as previous experiences of some of the European countries which adopted pegged but adjustable exchange rate policies. We use both of the above approaches--the basic speculative attack model, and the target zone approach--to estimate market expectations of

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1/ In addition, Grilli (1986) generalizes rational expectations models of speculative attacks on fixed exchange rate systems to take into account the possibility that the central bank can be forced either to devalue or revalue depending on whether its foreign reserves are subject to buying or selling attacks. Several papers, including Obstfeld (1986), Calvo (1987), Drazen and Helpman (1987a and 1987b), van Wijnbergen (1987) and Penati and Pennacchi (1989) model the foreign exchange crisis in a dynamic optimization framework.

devaluations by calculating the probability of a regime change, which involves either a discrete devaluation or a switch to flexible exchange rates. Our sample includes Denmark, Ireland, and Spain which are participants of the ERM, and Norway and Sweden, which had pegged their currencies to currency baskets or to the European Currency Unit (ECU). Our analysis aims to identify the respective roles of macroeconomic fundamentals and speculative factors, and hence to evaluate whether the speculative pressures on these currencies were justified by economic fundamentals.

The analysis of the probability of a regime change is based on the calculation of an equilibrium exchange rate that would prevail in the absence of a change in the current exchange rate regime. This rate is called "the shadow exchange rate," which is never observed unless the central bank changes its policy. The level of this rate reflects the underlying fundamentals of the economy and the stochastic shocks that affect the model's behavioral relationships. We relate the existence of a speculative attack and the probability of a regime change to the fulfillment of the condition that the shadow exchange rate exceeds by a certain margin (i.e., is depreciated compared to) the actual (fixed) exchange rate. Since the shadow rate reflects economic fundamentals, the probability of a regime change is a function of these factors as well.

Our empirical analyses identify the conditions which raise the probability of devaluations within target zones and in the recent European currency crisis. Both economic fundamentals and speculative factors have been found to have a significant influence on the probability of devaluations for the sample countries. Among the economic fundamentals, the increase in domestic credit, unfavorable trends in output and employment, loss of foreign exchange reserves, the upward trends in the anchor country's price level, and the loss of external competitiveness have been found to increase the probability of devaluation in target zones. With respect to speculative factors, an increase in the deviation of the exchange rate from its central parity and increases in interest differentials have been found to imply an increased likelihood of a regime change.

Furthermore, our analyses confirm that the latest realignments in the European foreign exchange markets are mainly the result of foreign exchange market tensions amidst the growing conflict between the needs of the domestic economies and the policies needed to maintain fixed exchange rates. However, even with favorable internal and external balances, the currencies of some countries came under speculative pressure, in part reflecting the difficulty of the markets in assessing fundamentals and also the speculative nature of the foreign exchange markets.

The paper is organized as follows. In Section II, we provide an overview of the exchange rate developments for each country in our sample, and a brief review of the late 1992 and early 1993 currency turbulence. 1/ In Section III, the model is presented. In Section IV, the estimation procedure is described. Section V gives the empirical results. Finally, some concluding remarks are provided in Section VI. The overview of the economic performance of the sample countries, and the data sources are provided in Appendices 1 and 2, respectively.

II. Overview of Exchange Rate Developments in Selected European Countries

1. Pre-crisis developments

The countries in our sample maintained various fixed exchange rate arrangements. Denmark and Ireland have been members of the ERM since March 1979, and Spain joined in June 1989. Until August 1993, Denmark and Ireland operated within the narrow 2.25 percent fluctuation bands, while Spain operated within a wider fluctuation margin of 6 percent. 2/ Within the ERM, the Danish krone and the Irish pound were realigned downward eight times and the Spanish peseta three times, each involving a decline in their respective central rates against the deutsche mark.

Between December 1978 and October 1990, Norway maintained a fixed exchange rate arrangement using a currency basket; the Norwegian krone was allowed to fluctuate within a ±2.25 percent band around a central rate calculated as a weighted average of 14 currencies. 3/ The weights of the currencies in the basket were selected so as to stabilize the competitiveness of Norwegian exports. The krone was devalued four times under this system. 4/ In October 22, 1990, the krone was pegged to the ECU and the same fluctuation margin of 2.25 percent was maintained.

1/ A detailed and thorough analysis of the ERM crisis can be found elsewhere, including Eichengreen and Wyplosz (1993), Isard (1993), and Goldstein and Folkerts-Landau (1993).

2/ On July 31, 1993, ministers and central bank governors of the member states of the European Community decided to widen temporarily the obligatory marginal intervention thresholds of the participants in the ERM to ±15 percent around the bilateral central rates, with the exception of Germany and the Netherlands, which maintain the previous arrangement.

3/ The basket included 12 currencies until mid-1984.

4/ Two of these devaluations were "actual devaluations" involving a change in the central rate, while the other two were "effective devaluations." We use the latter term for a depreciation in the value of the currency as a result of a change in the weights associated with the currencies in the basket and of a change in the definition of the basket from an arithmetic to a geometric average.

Similarly, Sweden pegged its currency against a basket of 15 currencies between August 1977 and May 1991, where the basket weights were based on foreign trade and were adjusted every year. The Swedish krona was devalued twice under this system, in 1981 and 1982. After these devaluations, the authorities aimed at avoiding exchange rate devaluations against the background of short-lived competitiveness gains provided by such devaluations, and a pickup in domestic inflation. In June 1985, the fluctuation margin for the krona was narrowed from ±2.25 percent to ±1.5 percent around the central rate. Following Norway, Sweden linked its currency to the ECU on May 17, 1991, but kept the fluctuation margin at ±1.5 percent. That is, the Swedish krona was more restricted in its movements against the ECU than the other Nordic currencies pegged to the ECU.

2. Developments during the Fall 1992 crisis

The European foreign exchange markets experienced periods of intense pressures beginning in mid-1992. The lack of convergence in different countries' economic performances, and loss of external competitiveness due to divergent inflation rates and economic activity generated tensions in the foreign exchange markets. These tensions were intensified by wage and inflation pressures in Germany, which prompted tightening of the monetary policies in the absence of a fiscal adjustment following the German unification.

The crisis in the foreign exchange markets erupted when the "no" vote on the Maastricht Treaty by Denmark in June, and the marginal "yes" vote in the French referendum on September 20 raised serious doubts about the prospects of the European Monetary Union. Given the large, cumulative investment in high-yielding ERM currencies over the past years, these doubts had the potential to generate major speculative attacks on several currencies. Some currencies have been particularly vulnerable to such attacks because of increasing differences in the economic strength and lack of fiscal discipline in these countries, high interest rates, and weak financial systems. The central banks of the weak currency countries have lost a substantial part of their foreign currency reserves through massive interventions. Major hikes in various official interest rates have also been used to stem speculative attacks. However, such high interest rates could not be sustained during a period of economic downturn and high unemployment rates. Consequently, the Finnish markka, which was pegged to the ECU, was allowed to float freely on September 8. Furthermore, two of the ERM currencies, the Italian lira and the Spanish peseta, were devalued on September 13 and 17, respectively, and the lira and the pound sterling were suspended from the ERM on September 17.

These regime changes in September 1992 reportedly prompted further speculative attacks on some of the remaining currencies in the EMS, as the devaluations or suspensions of the above currencies from the fixed exchange rate system resulted in significant depreciations and, thus, reduced the export competitiveness of their major trade partners. In the wake of

these developments, Sweden suspended the link of the krona to the ECU on November 19, 1992, as export competitiveness declined, speculative attacks depleted foreign currency reserves, and high interest rates could not be sustained in light of a weak economy and high fiscal deficits. Similarly, Spain and Portugal devalued their currencies within the ERM by 6 percent on November 22.

Denmark, Ireland, and Norway had achieved significant progress in decreasing inflation rates, and improving the current account balances and budget deficits since 1987. 1/ Nevertheless, the regime changes experienced in the other countries increased the intensity of speculative attacks on the currencies of these three countries, leading to massive combined interventions and very high interest rates. Norway subsequently suspended her link to the ECU on December 10, 1992 as recurring speculative attacks depleted a major part of foreign reserves. After experiencing a series of speculative attacks, Ireland devalued its currency by 10 percent--the largest devaluation since the establishment of the ERM--on January 30, 1993. This devaluation was prompted by Ireland's loss of competitiveness against its major trade partner, the United Kingdom, which was made more severe by the latter country's successive interest rate cuts following sterling's suspension from the ERM, by the sharp fall in Ireland's foreign exchange reserves and sharp rises in Irish interest rates that had become too painful to maintain in the existence of high unemployment rates. 2/ Continued selling pressures on the Spanish peseta in expectation of an imminent devaluation finally forced the Spanish Government to devalue the peseta by 8 percent, in May 1993. Even though the loss of competitiveness against major trade partners following their devaluations caused occasional runs on the Danish krone, no realignment had been made for that currency since 1987. A summary of the devaluations and regime changes of the five countries are shown in Table 1 and Chart 1. Charts in Appendix 1 provide an overview of the economic developments in the five countries during the sample period.

3. Policy responses to the crisis

All five countries used interest rate hikes and foreign exchange market interventions to defend their currencies as speculative attacks mounted within the EMS. Although sharp increases in official interest rates have been effective in stemming speculative pressures, they could

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1/ In the case of Norway, the budget deficit includes oil revenues.

2/ In Ireland (and similarly in the United Kingdom and Sweden), mortgage interest payments are indexed to money market rates. Hence, higher money market rates can impose significant costs on homeowners. In fact, in addition to the adverse effects of high interest rates on unemployment, the fact that these interest rates were being passed through to mortgage rates has been claimed to be one of the major causes of the speculative pressure on the Irish pound, as high interest rates were regarded as unsustainable by speculators, given the importance of home ownership in Ireland.

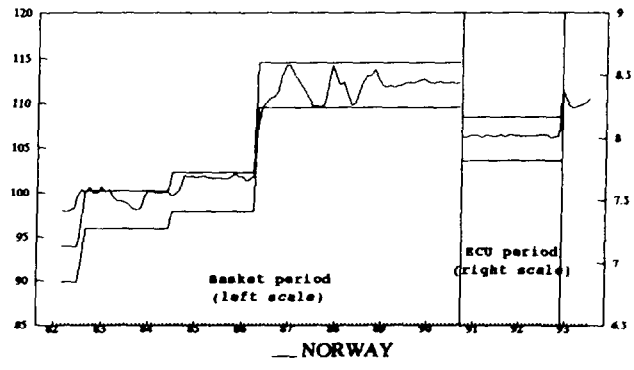
Table 1. Devaluations within the ERM and in Nordic Countries 1/

Realignment date	Ireland	Denmark	Spain	Norway	Sweden
September 1979	1.96	5.00			
November 1979		5.00			
September 1981					10.00
October 1981	5.21	5.50			
February 1982		3.09			
June 1982	4.08	4.25			
August 1982				3.50	
September 1982				3.09	
October 1982					16.00
March 1983	8.53	2.93			
July 1984				2.00	
April 1986	2.91	1.98			
May 1986				12.00	
August 1986	8.00				
January 1987	2.90	3.00			
September 1992			5.26		
November 1992			6.38		float
December 1992				float	
January 1993	10.00				
May 1993			8.70		

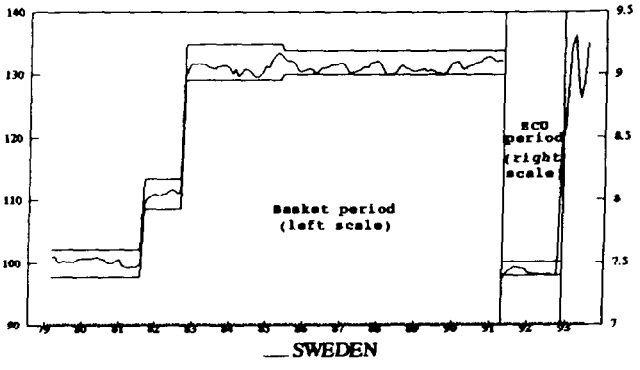
1/ Devaluations refer to a percentage change in the bilateral central rate vis-à-vis the deutsche mark for the Danish krone, the Irish pound, and the Spanish peseta, and vis-à-vis the currency baskets for the Norwegian krone and the Swedish krona. They include those devaluations which result from general realignments within the ERM or from a change in the definition of the basket to which the currency is pegged, which we refer to as "effective" devaluations.

Chart 1. Devaluations within the Target Zones*

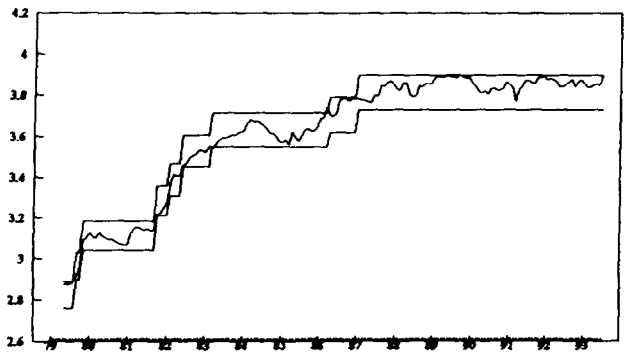
(In percent)



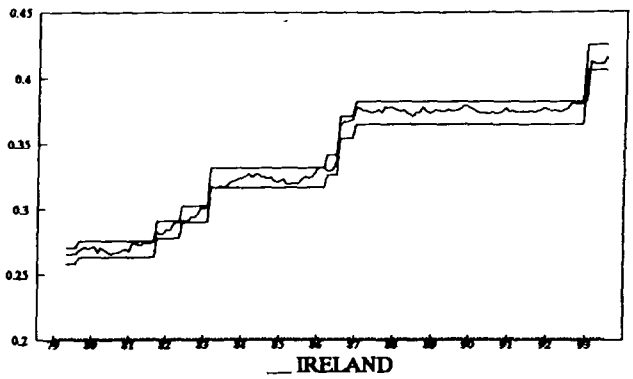
NORWAY



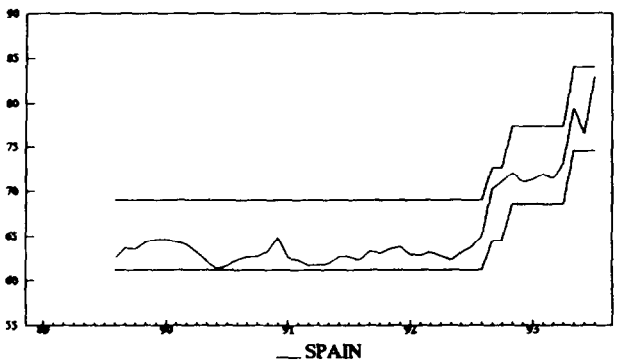
SWEDEN



DENMARK



IRELAND



SPAIN

(*) The exchange rates for Denmark, Ireland and Spain are expressed as the price of the deutsche mark in terms of the local currency. The exchange rate for Norway and Sweden are expressed as the price of the basket and the ECU in terms of the local currency for the basket period and the ECU period, respectively. The discountinuity in the exchange rate between the basket and the ECU period for Norway and Sweden is purely expositional, and does not imply an exchange rate depreciation arising from a switch to the ECU-link.

not be maintained for extended periods of time in the wake of deepening recession in these countries. As argued in Eichengreen and Wyplosz (1993), the duration of interest rate increases is critical for the impact of high money market rates on the economy. If the defense of currencies requires high money market rates for long periods of time, which is the only way the central bank can credibly stem speculative attacks, the impact of such rates on the economic activity, banking system, retail interest rates, and fiscal budgets can be substantial. It is precisely due to this fact that central banks were (or perceived to be) unwilling to tolerate further increases in interest rates and allowed for changes in their exchange rate arrangements.

While individual central banks lost a substantial part of their foreign exchange reserves in defense of their parities, they were in general not effective in preventing the subsequent regime changes as resources available to central banks were hardly enough to meet the massive demands of buyers of foreign exchange (i.e., speculators). However, it is important to note that both Denmark and France received massive intramarginal support from other central banks in periods of heavy pressure on their currencies, which helped them avoid a realignment in their respective currencies.

In addition to these measures, Spain and Ireland at times used various kinds of exchange controls to prevent speculative capital flows. Exchange controls in Spain, which focused mainly on short-term capital movements, had been successively reduced since March 1990 and dismantled in February 1992, ahead of the schedule laid out by the EC. Spain reintroduced exchange controls on September 23, 1992 in order to limit the potential amount of speculative foreign exchange transactions. Such transactions were made very expensive by the imposition of a 100 percent compulsory one-year non-interest bearing deposit requirement on lending of pesetas to nonresidents. This in effect eliminated speculative short selling of the peseta by foreigners. In addition, domestic institutions and Spanish residents were prevented from using the short-term credit markets to short the peseta. All restrictions were removed after the second devaluation of the peseta, on November 22, 1992.

In line with the movement toward a single European market in 1992, Ireland pursued a policy of gradually reducing its exchange controls. In 1989, restrictions on the amount that Irish residents could invest abroad were lifted. During the September currency crisis, existing exchange controls were reinforced as banks were forbidden to lend to non-Irish financial institutions for less than a year and foreigners were not allowed to use forward contracts, which had been one of the most popular tools of currency speculation. All exchange controls were lifted on January 1, 1993 in line with the requirements of the European Community.

Several analyses of the effectiveness of foreign exchange controls has shown that in the case of Ireland and Spain, these controls have been effective in buying some time against the massive currency speculation. 1/ On the other hand, Mathieson and Rojas-Suarez (1993) argue that even when capital controls drive a wedge between the levels of domestic and international interest rates, they may only temporarily break the correlation between these rates over time. Furthermore, while controls and restrictions can temporarily surprise speculators, significant interest rate differentials between domestic and external markets could induce individuals to engage in speculative activity through other channels, such as portfolio investment and use of trade credits. 2/

III. The Model

This section describes the model used to evaluate the role of economic fundamentals and speculative factors in generating tensions in the European foreign exchange markets. In the first subsection, we model the systematic relationship between economic fundamentals and the probability of a regime change. In the second subsection, we derive the probability of a regime change as a function of speculative factors and fundamental variables.

1. Evaluating the impact of macroeconomic fundamentals

The model used to evaluate the influence of macroeconomic fundamentals on exchange market pressures is an extension--by Blanco and Garber (1986)--of the basic analytical framework proposed by Krugman (1979) and formalized by Flood and Garber (1984) and Obstfeld (1984). It is a stochastic version of the monetary approach to exchange rate determination, in which we consider a small open economy whose government and the monetary authority are committed to maintain the exchange rate within an adjustable peg system. The model is described by the following equations:

1/ See Bartolini (1993), Eichengreen and Wyplosz (1993) and Galy et al. (1993). Bartolini (1993) shows that overall, the behavior of the onshore-offshore interest differential provides evidence that residual exchange controls in Ireland have been essentially non-binding since mid-1990, with the exception of the period September-December 1992 when the Central Bank of Ireland reinforced the already-existing controls. Eichengreen and Wyplosz (1993) argue that controls allowed domestic interest rates to be nearly 80 (annualized) percentage points lower than what they would have been without controls, measured by the deviation from the covered interest parity (p. 100). Galy et al. (1993) show that capital controls were instrumental in reconciling the domestic and external objectives of monetary policy in Spain over the 1980s. While there is no concrete evidence on the effectiveness of such controls used in Spain during the currency crisis of late 1992, it is claimed that they helped authorities to temporarily prevent excessive capital outflows (see Fieleke (1993)).

2/ See Browne and McNelis (1990).

$$(1) \quad m_t^d - p_t = \beta + \Omega y_t - \alpha i_t + w_t$$

$$(2) \quad m_t^s = \log(D_t + R_t)$$

$$(3) \quad i_t = i_t^* + Ee_{t+1} - e_t$$

$$(4) \quad p_t = p_t^* + e_t + u_t$$

$$(5) \quad m_t^d = m_t^s$$

where, m, p, y are the logarithms of the money stock, domestic price level, and real output, respectively, i the domestic nominal interest rate, w a stochastic disturbance to money demand, D the domestic credit component of the money stock, R the foreign reserves of the central bank, i^* the foreign nominal interest rate, p^* the logarithm of the foreign price level, and e and u the logarithms of the nominal and real exchange rates, respectively. e is defined as the units of the domestic currency required to buy a unit of the foreign currency, and a rise in e implies a depreciation of the domestic currency. u is defined such that an increase implies a real appreciation of the currency. E represents the expectation conditional on information available in the current period. The subscripts d and s denote demand and supply, respectively.

Equation (1) specifies the transactions and asset motives for holding real money balances. Equation (2) defines the money stock as the sum of domestic credit and the book value of the central bank's foreign reserves. Equation (3) is the uncovered interest parity condition, which states that the interest rate differential between the domestic and foreign country is given by the expected rate of depreciation of the currency, thus implying perfect substitutability between domestic and foreign assets (i.e., absence of a risk premium). Equation (4) allows for deviations from purchasing power parity by the existence of a non-zero term, u_t, which denotes the real effective exchange rate. Finally, Equation (5) gives the condition for money market equilibrium.

The money market equilibrium condition determines the path of foreign reserves of the central bank under a fixed exchange rate system. Foreign reserves are used to offset any excess supply of domestic credit or any changes in the components of Equation (1) to maintain the money market equilibrium. When reserves that are used to maintain this equilibrium are exhausted, the exchange rate must adjust. The central bank must abandon the prevailing fixed exchange rate by either devaluing or allowing its currency to float. The rate which would clear the market when the central bank stops

defending its fixed parity can be obtained by using these five equations. Following Blanco and Garber (1986), we argue that this rate provides the lower bound for the new value of the fixed exchange rate after a devaluation or for the value of the exchange rate following the switch to a flexible exchange rate system. This rate is referred to as the "shadow exchange rate" and calculated in two steps. First, substituting Equations (3) and (4) into Equation (1) and using the equilibrium condition (5), we obtain the path of the floating exchange rate, $\tilde{e}_t$:

$$(6) \quad h_t = -\alpha E\tilde{e}_{t+1} + (1+\alpha)\tilde{e}_t \ , \ \textit{where},$$

$$(7) \quad h_t = \log(D_t + R_c) - \beta - \Omega y_t + \alpha i_t^* - p_t^* - u_t - w_t \ .$$

$\tilde{e}_t$ is the exchange rate which clears the market when the foreign reserves of the central bank reach the critical level, R_c. 1/ As specified by Equation (7), h_t represents the state of the economy as a function of market fundamentals, such as domestic credit, foreign exchange reserves, real output, foreign interest rates and prices and real exchange rates, as well as some stochastic disturbances to money demand. It is usually assumed that market fundamentals follow a first order autoregressive process: 2/

$$(8) \quad h_t = \theta_1 + \theta_2 h_{t-1} + v_t \ ,$$

where, v_t is a white noise process with normal density function $g(v)$, zero mean and variance σ^2. 3/ By using Equation (8) and the method of undetermined coefficients, Equation (6) can be solved to obtain the solution for the floating exchange rate:

$$(9) \quad \tilde{e}_t = \mu\alpha\theta_1 + \mu h_t \ , \quad \mu = \frac{1}{1 + \alpha - \alpha\theta_2} \ .$$

1/ The critical level of reserves could be zero, negative or positive. In perfect capital markets, the central bank can create foreign reserves by borrowing from international markets, which might result in a negative critical reserve level.

2/ Blanco and Garber (1986) tried second-order autoregressive process for this variable, and found that the coefficient of the second lag of the variable was not significantly different from zero.

3/ Assuming normality of the disturbance term allows for negative values for the growth of the variable h_t. An alternative (as it is used in Flood and Garber (1984) and Goldberg (1991)) is to assume exponential distribution which restricts the growth of this variable to positive values only.

Next, it is assumed that the shadow exchange rate is given by the value of the floating exchange rate plus a non-negative term whose magnitude is dependent on the size of the disturbance to the fundamentals that forced the regime change,

$$(10) \quad \hat{e}_t = \tilde{e}_t + \delta v_t \ , \quad \delta \geq 0 \ .$$

Equations (7)-(10) imply that the level of the shadow rate reflects the underlying fundamentals of the economy. Given this rate, we approximate the probability of a regime change by that of a speculative attack: the speculators decide to attack the central bank's foreign currency reserves if and only if they find it profitable. That is, if speculators operating in the current period expect the shadow exchange rate to exceed the actual fixed rate, they purchase the central bank's foreign exchange reserves. If speculative attacks deplete the central bank's reserves to a critical level and thus cause the central bank either to devalue or to let the currency float, then speculators make a profit equal to the non-negative difference between the shadow and the actual fixed rates for each unit of reserves they purchase from the central bank, provided that the market exchange rate falls outside the old fluctuation bands. Then, using Equations (8), (9) and (10), the one-step-ahead probability of a regime change, π_t, can be approximated by computing the probability that the shadow exchange rate next period will exceed the prevailing fixed exchange rate, $\bar{e}$: 1/

$$(11) \quad \pi_t = pr(\hat{e}_{t+1} > \bar{e}_t) = pr(\mu\alpha\theta_1 + \mu h_{t+1} + \delta v_{t+1} > \bar{e}_t)$$
$$= pr(v_{t+1} > k_t) = 1 - F(k_t) \ , \ where$$
$$k_t = [1/(\mu + \delta)] \ [\bar{e}_t - \mu\alpha\theta_1 - \mu(\theta_1 + \theta_2 h_t)] \ ,$$

where $F(k_t)$ is the cumulative distribution of the process $\{v_t\}$. This probability is expected to peak before or at the period in which the regime change is materialized. We use Equation (11) as a basis for the estimation of the probability of a regime change, calculated as a function of economic fundamentals and the prevailing fixed rate:

$$(11') \quad \pi_t = f \ (h_t, \overline{e_t}) ,$$

where f is a nonlinear function, and h denotes economic fundamentals as specified in Equation (7).

1/ In the case of the ERM, $\bar{e}$ can be considered as the upper bound of the fluctuation margin for the currency (i.e., the lowest value to which the currency is allowed to fall).

2. Evaluating the impact of speculative factors and economic fundamentals

Typically, periods immediately prior to a regime collapse are characterized by the existence of high domestic interest rates and increased deviation of the spot exchange rate from its central parity. Bertola and Svensson (1990) suggested an alternative devaluation model which calculates the expected rate of devaluation as a function of interest rate differentials and the deviation of the exchange rate from the central parity. In this setup, rational investors are assumed to form expectations about future changes of the exchange rate which come from two sources: anticipated movements of the exchange rate within the fluctuation band, and expected shifts of the band itself (i.e., a change in the central parity of the currency). Under the assumption of uncovered interest rate parity, an estimate of market expectations of realignments can be obtained by subtracting from the interest rate differential an estimate of the expected depreciation within the fluctuation band.

Formally, in log terms, the exchange rate of currency i with respect to the anchor currency can be written as,

$$(12) \qquad e_{it} = [e_{it} - c_{it}] + c_{it}$$

$$= e^{*}_{it} + c_{it} \ ,$$

where the first term on the right hand side of the equality denotes the deviation of the exchange rate from its central parity, c_{it}. Taking the difference and then the expectation of Equation (12) conditional on the information available at time t gives,

$$(13) \qquad E_t \left[\Delta e_{i,(t+\Delta t)}\right] = E_t \left[\Delta e^{*}_{i,(t+\Delta t)}\right] + E_t \left[\Delta c_{i,(t+\Delta t)}\right] .$$

Assuming that uncovered interest parity holds, the interest rate differential between country i and the country of the anchor currency is written as,

$$(14) \qquad \left[i_{it}^{(\Delta t)} - i_{t}^{*(\Delta t)} \right] \Delta t = E_t \left[\Delta e_{i,(t+\Delta t)}\right] .$$

where, i^{*} refers to the interest rate of the anchor country. Combining (13) and (14) gives,

$$(15) \qquad E_t\,[\Delta c_{i,(t+\Delta t)}] = [\, i_{it}^{(\Delta t)} - i_t^{*(\Delta t)} \,]\,\Delta t - E_t\,[\,\Delta e^{*}_{i,(t+\Delta t)}\,] \,.$$

This equation states that the expected rate of realignments can be obtained from interest rate differentials and the estimates of the expected changes in the position of the exchange rate with respect to the central parity. Rose and Svensson (1991) and Svensson (1993) use the following regression forms to estimate the changes in the deviation of the exchange rate from the central parity:

$$(16) \qquad \Delta e^{*}_{i,(t+\Delta t)} = \beta_{i0} + \beta_{i1}\, z_{it} + \epsilon_{it} \,,$$

where, z_{it} is a set of variables that might help explain anticipated changes of the exchange rate within the band. Empirical tests of this approach has shown that these changes are best predicted by the current position of the exchange rate within the band (i.e., the probability of a regime change or a realignment is larger the greater is the deviation of the current value of the exchange rate from the prevailing central parity). Consistent with this approach, we first calculate the probability of a regime change as a function of speculative factors only. These speculative factors include interest rate differentials and the deviation of the exchange rate from the central parity. 1/

In addition to interest rate hikes, central banks conduct intra-marginal interventions in order to defend their currencies. Therefore, in periods prior to a crisis, reserves typically fall, reflecting the weakening of the public's confidence in the sustainability of the fixed parity. Falling reserves invite further speculative attacks as speculators doubt the ability of the central bank to defend its currency. In order to capture this self-fulfilling aspect of speculative pressure on the currency, we also include the level of foreign exchange reserves among the speculative proxies.

Using implications of Equations (15) and (16), we estimate the probability of a regime change as a function of speculative proxies that reflect the existence of exchange market pressures:

1/ However, it should be noted that this approach does not take into account decisions by the central banks to keep the exchange rate at a particular position within the band. For example, some authorities, e.g., the United Kingdom, aimed to stay near the bottom of the band, while some, such as Spain, above the middle of the band.

(17) $\pi_t = g$ (*speculative proxies*),

where g is a nonlinear function. Finally, we extend Equation (17) by assuming that anticipated future changes of the exchange rate within the band are a function of economic fundamentals, as well as the current position within the band:

(18) $\pi_t = \psi$ (h_t , $\overline{e_t}$; *speculative proxies*)

where ψ is a nonlinear function. The particular form of Equations (11'), (17), and (18) for empirical testing is provided in the next section.

IV. Empirical Analysis

In this section, we test the implications of the theoretical model described in the previous section. First, we treat the central bank's decision regarding a change in its exchange rate regime as a discrete variable, which takes on only two values: one, when there is a regime change--either a discrete devaluation or a switch to flexible rates--zero when the existing fixed parity is maintained. We then estimate the one-step-ahead probability of a regime change as a function of a set of explanatory variables using a probit model, which is commonly used in estimation of models with qualitative dependent variables. In our framework, the predicted value of the dependent variable can be interpreted as the probability that the central bank will change its exchange rate regime:

$$Prob(Y=1) = F(X,b),$$
$$Prob(Y=0) = 1 - F(X,b),$$

where, Y denotes the central bank's decision, X denotes a set of explanatory variables, b denotes the vector of parameters that reflect the impact of changes in X on the probability, and F denotes the cumulative normal density function. 1/

1/ Conventional estimation techniques are not appropriate in the analysis of models with a qualitative dependent variable since the variable can only take on a limited range of values. In our framework, the estimated probability of a regime change can only take on values between zero and one, however, it is quite possible to have estimated probabilities outside the 0-1 range if conventional techniques are used. Using the cumulative normal function, the probit models yields estimated probabilities, which will by construction lie within the 0-1 range.

Using this approach, we first estimate the one-step-ahead probability of a regime change as a function of the market fundamentals and the prevailing fixed rate. These market fundamentals include the level of domestic credit, real effective exchange rate, foreign nominal interest rate, foreign reserves, real output, foreign price level, and the prevailing central rate as specified by Equation (11).

An increase in the current level of domestic credit, which is not sterilized by central bank intervention, is expected to increase the probability of a devaluation in the following period by increasing inflationary pressures through increases in the money supply or through lower real interest rates. If on the other hand, the central bank sterilizes, the decline in foreign exchange reserves will nonetheless reduce the ability of the central bank to defend its fixed parity and will still invite speculative attacks.

An increase in the real effective exchange rate indicates a loss of external competitiveness, inducing expectations of an exchange rate adjustment and resulting in a higher probability of a regime change. An extension of the basic currency crisis model, as described in Agénor et al. (1993), includes an equation in which net exports are assumed to be a decreasing function of the real exchange rate and the level of output. An appreciation of the real exchange rate (indicated by an increase in the index) is expected to worsen the trade balance and, hence, increase the likelihood of a policy change. The inclusion of the real exchange rate in the estimation accounts for this indirect effect. Alternatively, we include the trade balance in the estimation to account for the direct impact of a deterioration in the trade balance on the central bank's exchange rate regime.

The model implies that the higher the critical level of reserves below which the central bank is unwilling to allow its reserves to fall, R_c, the higher is the probability of a regime change. This critical level is generally unknown to the public. Due to the difficulty in quantifying this reserve level, we instead use the actual level of reserves. This can be justified by the fact that periods prior to an exchange market crisis are often associated with a rapid loss of reserves, as individuals hedge themselves against the risk of an exchange rate depreciation. Thus, the lower the level of foreign exchange reserves the higher is the probability of a regime change.

Higher foreign interest rates, other things being constant, lead to capital outflows and exert pressure on the domestic currency. On the other hand, an increase in the level of output signals stronger economic performance and reduces the pressure on the domestic currency. The monetary model, described in Section 3 by Equations (1)-(5), assumes that the economy is at its full employment level. Willman (1988) attempts to incorporate deviations from full employment by endogenizing output as a function of real interest rates and real exchange rates. Such an extension aims to incorporate short-run movements in economic activity. Alternatively, we

include the unemployment rate as an explanatory variable in the empirical analysis to take into account such deviations from the full employment level of output. A high level of unemployment is expected to pressure the central bank to reconsider its exchange rate policy and thus increases the probability of a regime change.

A higher price level in the anchor country, other things being constant, reduces inflation differentials and thus the probability of a devaluation. Finally, an increase in the existing fixed rate implies an adjustment of the exchange rate with respect to economic fundamentals and thus decreases the probability of a further devaluation.

Following the above discussion, Equation (11') can be written as,

$$(11'') \qquad \pi_t = f\left[D_t \, , \, u_t \, (X_t - M_t) \, , \, R_t \, , \, i_t^* \, , \, y_t \, (ur_t) \, , \, P_t^* \, , \, c_t \right]$$

where $(X_t - M_t)$ denotes the trade balance, ur_t the unemployment rate, and c_t the current central parity. By estimating the probability of devaluation using these variables, we attempt to capture the systematic relationships between the realized regime changes and economic fundamentals. Thus, using this approach, we evaluate whether the pressure on the currency is justified by economic fundamentals alone.

Second, in order to capture directly the existence of speculative pressures on the currencies we use short-term interest rate differentials, the deviation of the spot exchange rate from the central parity, and the level of foreign exchange reserves in computing the probability of a regime change. We expect the probability of a regime change to rise with an increase in interest differentials and deviations of the exchange rate from the central parity, and to fall with an increase in the level of foreign exchange reserves available to the central bank to defend its currency. The estimated version of Equation (17) is then given by:

$$(17') \qquad \pi_t = g\left[(i_t - i_t^*) \, , \, (E_t - C_t) \, , R_t \right]$$

where, $(E_t - C_t)$ denotes the deviation of the spot rate from the central parity.

Finally, we combine Equations (11") and (17') to estimate the probability as a function of both speculative proxies and economic fundamentals. This formulation provides an extension to the model of Blanco and Garber (1986) by adding speculative proxies to economic fundamentals in the estimation of the probability of a regime change:

$$(18') \qquad \pi_t = \psi \left[D_t,\ u_t\,(X_t - M_t),\ R_t,\ i_t^*,\ y_t\,(ur_t),\ P_t^*,\ c_t,\ (i_t - i_t^*),\ (E_t - C_t) \right]$$

We also introduce some time and country specific variables in the estimation process. As discussed in Section 2, Ireland and Spain have used capital controls in order to prevent speculation against their currencies. To take into account such policies, we incorporated a dummy variable--denoting the periods during which controls were in effect--in the estimation process. The coefficient of this variable turned out to be statistically insignificant. In addition, we also tested the hypothesis that the general relaxation of exchange controls in most of the ERM countries by the early 1990 was one of the factors that has increased the vulnerability of the ERM and lead to speculative attacks on the European currencies. The inclusion of a dummy variable to account for this general regime change turned out to have a positive but statistically insignificant coefficient for all countries in the sample. 1/

It has also been observed that currencies come under speculative pressures during periods of political uncertainties. Such uncertainties particularly arise during or ahead of national elections or important political decisions which might have significant economic implications. Speculators have been observed to engage in one-way bets on currencies during such periods, particularly when they have doubts about the commitment of the new government to the prevailing exchange rate policies. The 1982 devaluation of the Swedish krona and the most recent devaluation of the Irish pound and the Spanish peseta were associated with their national elections in September 1982, December 1992, and April 1993, respectively. In addition, the Danish referendum imposed uncertainties about the future of the EMU causing tensions in the ERM. In order to account for the speculative pressures associated with such events, we incorporated a dummy variable for each country in our empirical analyses. The coefficient of this variable, however, also turned out to be statistically insignificant and did not affect the results.

V. Estimation Results

In this section we present the empirical findings. A note of caution is warranted as regards these findings in that in general these are conditional results based on historical data; their use in predicting future regime changes are subject to margins of error through the model specification.

1/ However, a more comprehensive evaluation of the effectiveness of capital controls requires a more thorough analysis of incentives and impediments to short-term capital flows, which is beyond the scope of this paper.

The estimation covers the periods of adjustable peg exchange rate regimes in each country. Since devaluations are observed only rarely, we used pooled data for Denmark, Ireland, Spain, Norway, and Sweden by including country dummies. A significantly positive coefficient for a country dummy indicates that the devaluations are more likely in this particular country, holding the other variables in the model constant. The estimation of the pooled data for the whole sample period, however, gave quite poor predictions for the probability of devaluations. This is not surprising, however, given that during the initial years of the operation of the EMS, there were significant divergences among these countries in their economic objectives and performances, and factors affecting their exchange rate adjustments were quite different. Consequently, we estimated the probabilities for each country individually, except for Norway and Sweden, for which the estimation was done jointly. 1/ The results of the probit analyses and the corresponding estimated one-step-ahead devaluation probabilities for individual countries are given in Tables 2-5 and Charts 2-5, respectively. 2/

The probability of devaluation for the Danish krone and the Irish pound were estimated for the period 1979:5-1993:3 and 1979:5-1993:2, respectively. During this period the krona was devalued on three occasions (in September and November 1979 and February 1982) against most ERM currencies. Similarly, the Irish pound was devalued three times (in March 1983, August 1986 and January 1993) against all the other ERM currencies. The central rates of the krona and the pound vis-à-vis the deutsche mark were reduced on five other occasions as a result of general realignments within the ERM. 3/

The empirical findings, which are summarized in Tables 2 and 3 and Charts 2 and 3, indicate that the probability associated with all three devaluations of Denmark and Ireland, as well as their October 1981 realignment, is attributed to the deteriorating economic fundamentals. Even though the effective devaluation on October 1981 is the result of a general realignment within the system, involving a revaluation of the deutsche mark, fundamentals of both countries predicted it fairly well, since their initial years in the mechanism were associated with economic imbalances, such as high inflation differentials vis-à-vis Germany, sharply

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1/ The decision to jointly estimate the devaluation probabilities for these two countries was dictated by a very small number of devaluations in Sweden, and can be justified given the similarity in their economic environment.

2/ These tables present the results of those estimations which provided the best predictions. Hence, they exclude some of the variables listed in (11''), (17'), and (18'). Also, in some cases two-period lagged variables gave better results.

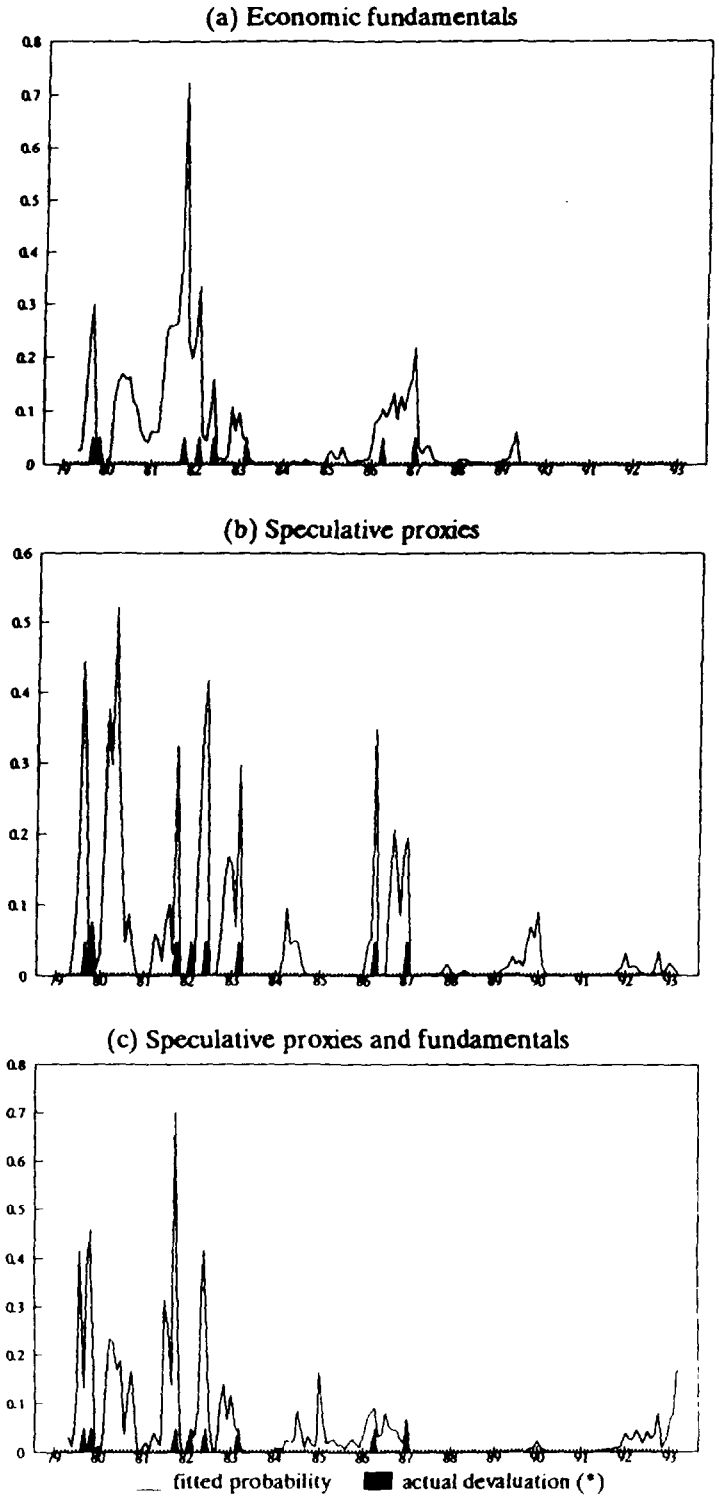
3/ We refer to these three devaluations as "actual" and other five realignments as "effective" devaluations since in some of these realignments, the respective currencies were revalued against some other ERM currencies, but still incurred a depreciation vis-à-vis the deutsche mark.

Table 2. Denmark: Empirical Results 1/

	Economic fundamentals (a)	Speculative proxies (b)	Fundamentals and speculative proxies (c)
Constant	-185.906 (-1.51)	12.037 (1.71)**	51.15 (1.52)
Time dummy	-10.467 (-0.06)		
c_t Central parity	-31.849 (-2.57)*		-31.46 (-2.62)*
$Log(D_t)$ Domestic credit	1.049 (0.23)		7.23 (2.44)*
ur_{t-1} Unemployment rate	0.082 (0.16)		0.25 (1.25)
u_t Competitiveness	17.044 (1.51)		-8.87 (-1.26)
p^*_t German price index	36.010 (1.25)		
$Log(R_t)$ Reserves	-2.473 (-2.25)*	-1.518 (-2.18)*	-1.680 (-1.55)
E_t-C_t Position within the band		26.484 (2.77)*	
$i_t-i^*_t$ Interest differential		0.188 (1.84)**	0.300 (2.54)*
Log L	-21.85	-20.53	-22.23
R^2	0.217	0.216	0.205
Number of observations (Number of devaluations)	167 (8)	167 (8)	167 (8)

1/ T-ratios are given in parentheses. * and ** denote statistically significant t-statistics at the 5 percent and 10 percent levels, respectively.

Chart 2. Denmark: Probability of Devaluation



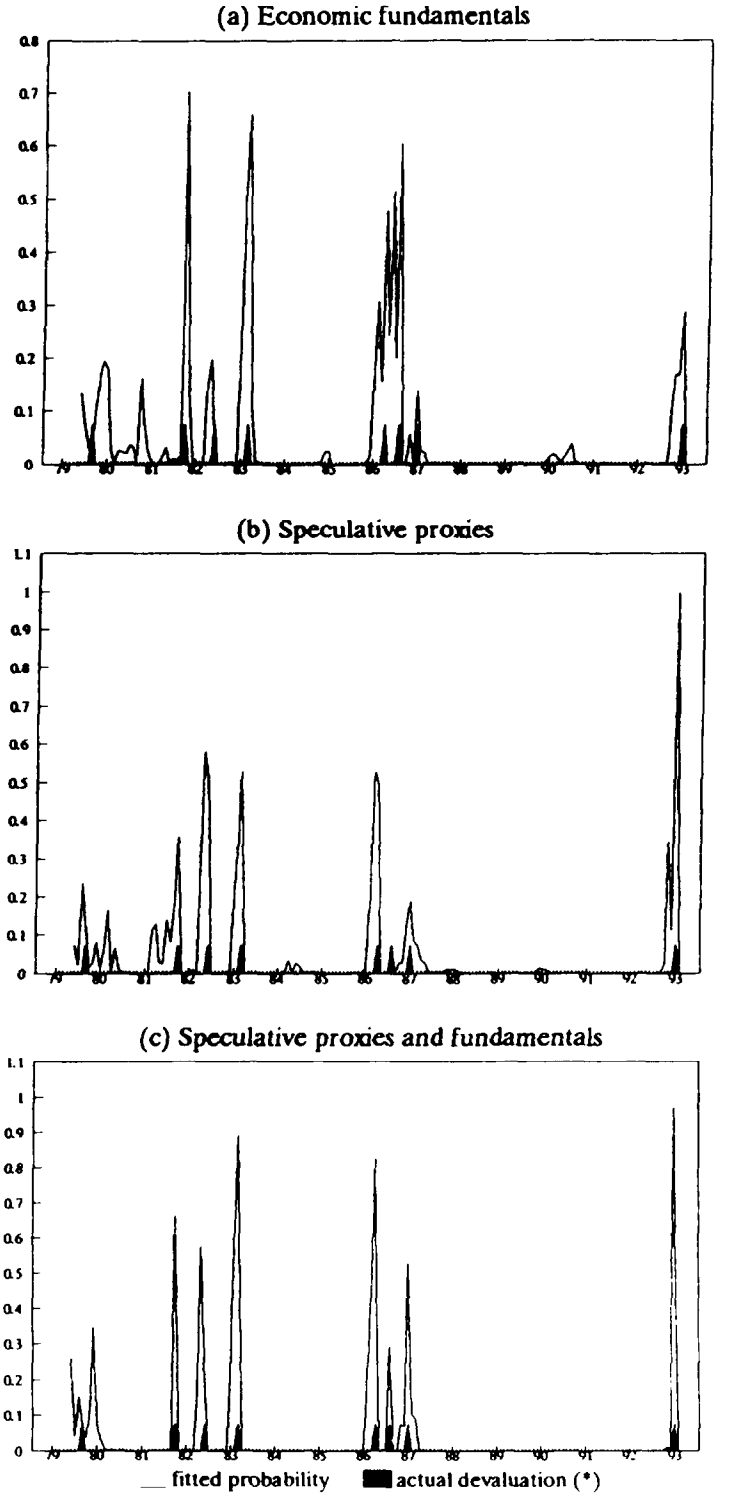
(*) Actual devaluation marks periods in which a devaluation took place.

Table 3. Ireland: Empirical Results 1/

	Economic fundamentals (a)	Speculative proxies (b)	Fundamentals and speculative proxies (c)
Constant	-103.575 (-1.923)**	-1.146 (-0.201)	-42.742 (-0.619)
c_t Central parity	31.430 (2.582)*		22.020 (1.213)
$\log(D_t)$ Domestic credit	17.459 (2.071)*		17.621 (1.466)
ur_{t-1} Unemployment rate	0.041 (0.218)		
u_t Competitiveness	28.864 (2.405)*		36.988 (1.922)**
p^*_t German price index	-46.997 (-1.840)**		-68.949 (-1.640)**
$\text{Log}(R_t)$ Reserves	-0.934 (-0.493)	-0.356 (-0.475)	0.201 (0.052)
E_t-C_t Position within the band		-33.613 (-2.919)*	-40.656 (-1.388)
$i_{t-1}-i^*_{t-1}$ Interest differential		0.168 (2.068)*	0.169 (1.587)
Log L	-17.80	-16.20	-11.45
R^2	0.354	0.377	0.521
Number of observations (Number of devaluations)	165 (8)	165 (8)	165 (8)

1/ T-ratios are given in parentheses. * and ** denote statistically significant t-statistics at the 5 percent and 10 percent levels, respectively.

Chart 3. Ireland: Probability of Devaluation



(*) Actual devaluation marks periods in which a devaluation took place.

rising unemployment rates, and a rapid expansion of domestic credit. In line with the predictions of the model, the probability of devaluation is found to be decreasing in the central parity (in terms of the domestic currency), and increasing as a function of the level of domestic credit, the unemployment rate, as well as the loss of foreign exchange reserves and competitiveness.

While having the expected positive sign, the coefficient of the unemployment rate was found to be statistically insignificant for both countries. Although not very significant for Denmark, the loss of competitiveness has a significant positive impact on the probability of devaluation of the Irish pound. Furthermore, the level of foreign reserves has a significant negative impact on the probability of devaluation for the krona, but not for the pound. It is also interesting to note that the increase in the German price level has the expected negative impact on the pound's probability of devaluation, while it has a positive impact on that of the krona. As shown by Charts 2 and 3, fundamental variables generate high probabilities for Ireland's three actual devaluations and the 1981 realignment: 66 percent, 60 percent, 29 percent, and 70 percent, respectively. Corresponding probabilities for Denmark's three actual devaluations and the 1981 realignment are 30 percent, 2 percent, 34 percent, and 73 percent, respectively. As can be seen in Charts 2 and 3, the model not only predicts the devaluations fairly well but also false predictions of a devaluation are limited mainly to the 1980-81 period for both countries. This was to be expected because this period is characterized by frequent market tensions due to unfavorable economic fundamentals.

The charts also indicate that the effective devaluations of both currencies, which arise from general realignments within the ERM, are better explained by the speculative proxies. 1/ The coefficients of interest rate differentials and the deviation of the spot exchange rate from the central parity have the expected positive sign, and are statistically significant. 2/ This result is consistent with our expectations, since these realignments mainly took place as a result of heavy speculative pressures on the other weak currencies of the ERM and/or a strong upward pressure on the mark, as opposed to correcting economic imbalances in these countries. These pressures reflected the increased sensitivity of market participants to continued divergences among ERM members in their external

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1/ The second actual devaluation of the krona on November 1979 is also better explained by the inclusion of interest differentials.

2/ The coefficient of the latter is negative for Ireland, since the exchange rate was expressed as the price of the pound in terms of the mark. That is, an increase in deviation from the central rate indicates an appreciation, and the absence of a downward pressure on the pound. A similar argument follows for the coefficient of the central parity, where an increase in the central rate in the case of Ireland implies an overvaluation of the pound, which might increase the probability of a future devaluation.

current account performances, which led to unequal pressures on some ERM currencies through international capital flows in periods of dollar weakness.

For both countries, the period after 1987 represents a significant improvement in economic performance. In particular, inflation differentials with Germany have become negative since end-1990, trade accounts have been in surplus, fiscal deficits have been reduced significantly and progress was made in reducing the public debt in the case of Ireland. On the other hand, unemployment has risen since 1990 in Ireland and since 1988 in Denmark. Furthermore, real effective exchange rates have been appreciating since 1991, and in the case of Ireland, a sharp appreciation took place with the recent depreciation of the sterling. While devaluation probabilities based on fundamentals have been essentially zero for Denmark after the 1987 realignment until now, speculative proxies yield positive probabilities during occasional periods of tensions within the ERM (particularly in 1989-90, 1992-93, as well as earlier in 1984-85) amidst devaluations by other ERM currencies and the appreciation of the mark. In the case of Ireland, economic fundamentals predict the January 1993 devaluation by a probability of about 30 percent, while the inclusion of speculative factors increases the estimated probability to 97 percent.

The probability of devaluation for the Spanish peseta was estimated for the period 1989:8-1993:5. During this period, the peseta was devalued three times, on September 1992, November 1992 and May 1993, within the ERM. The model performs well in predicting these devaluations, and false predictions are limited and concentrated in the ERM crisis period. The empirical findings, which are summarized in Table 4 and Chart 4, indicate that the speculative pressure and all three devaluations were the result of the conflict between domestic and external objectives and thus explained by deteriorating economic fundamentals. In particular, the worsening of the trade balance, the rise in the unemployment rate, the expansion of domestic credit and the loss of foreign exchange reserves predict the first and the third devaluations of the peseta with about 70-80 percent probability. Also, as in the case of Denmark, the rise in the German price level is found to have a significant positive impact on the devaluation probability of the peseta. The speculative pressure on the peseta, as captured by the deviation of the spot rate from its central parity, however, appears to be the key factor in explaining its second devaluation (by about 90 percent probability).

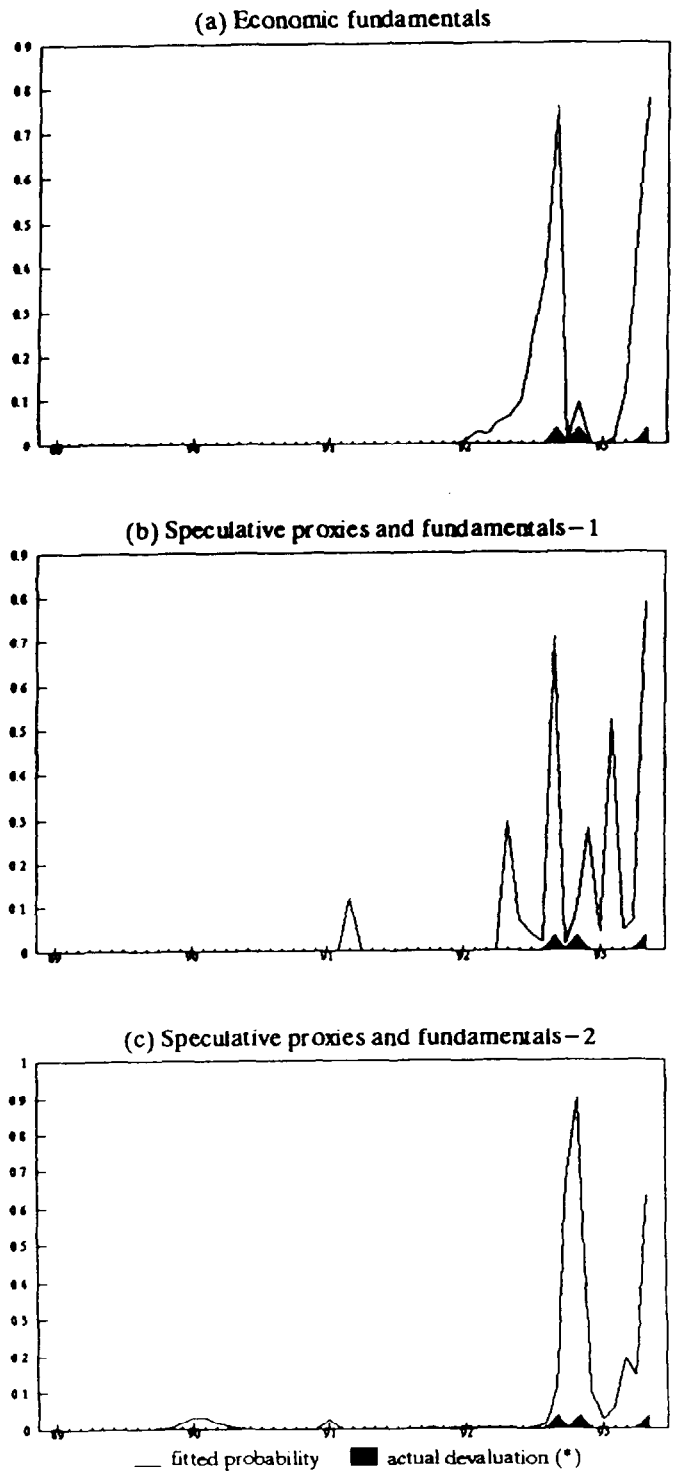
The probability of a regime change for Norway and Sweden was estimated by pooling their data over 1982:3-1992:12 and 1979:3-1992:11, respectively. During these periods, the Norwegian krone was effectively devalued four times, and the Swedish krona was devalued twice against their respective currency basket indices. The subsequent ECU-link of both currencies was suspended during the Fall 1992 currency crisis. The estimation results are summarized in Table 5 and Chart 5.

Table 4. Spain: Empirical Results 1/

	Economic fundamentals (a)	Fundamentals and speculative proxies (b)	Fundamentals and speculative proxies (c)
Constant			-7.03 (-1.39)
c_t Central parity	-80.20 (-1.78)**		
$Log(D_{t-1})$ Domestic credit	27.32 (1.75)**		
ur_t Unemployment rate	2.09 (1.93)**	1.61 (2.00)*	0.32 (1.24)
$Log(R_t)$ Reserves		-2.80 (-2.03)*	
$E_t - C_t$ Position within the band			0.82 (2.21)*
$X_{t-1} - M_{t-1}$ Trade balance		-0.04 (-1.90)**	
Log L	-4.71	-4.85	-4.57
R^2	0.51	0.49	0.49
Number of observations (Number of devaluations)	47 (3)	47 (3)	47 (3)

1/ T-ratios are given in parentheses. * and ** denote statistically significant t-statistics at the 5 percent and 10 percent levels, respectively.

Chart 4. Spain: Probability of Devaluation



(*) Actual devaluation marks periods in which a devaluation took place.

The results show that the devaluations by Norway and Sweden and their subsequent suspension of the ECU-link were mainly attributed to the deterioration of economic fundamentals. In particular, the loss of international competitiveness, the subsequent worsening of their trade balance, and the decline in industrial production have significant and positive impact on the probabilities of a regime change. 1/ As was the case in Denmark and Spain, the significant fall in foreign exchange reserves and the increase in the German price level increased the probability of a regime change for Norway and Sweden. The increase in domestic credit extended by the central bank has a positive but insignificant impact on the probability. When this variable was replaced with total domestic credit extended by the banking system, the effect of the level of domestic credit turns out to be significant but negative, which may well be due to the massive banking crisis and the subsequent credit crunch that both countries experienced in the early 1990's. During the recent currency crisis, speculative proxies indicate the existence of pressure on both of these currencies. The deterioration of the economic fundamentals, particularly the loss of international competitiveness and reserves, and the rise in the German price level, successfully predict the suspension of the ECU link for both countries. In addition, the hike in the short-term interest rate differential vis-à-vis Germany effectively predicts the regime change of Sweden in 1992.

As can be seen in Chart 5, the model yields some false positive probabilities of devaluations in the case of Norway, especially in the 1983-84 period, associated with the rising unemployment and loss of competitiveness during the period. However, the magnitude of these false predictions is very small compared to the correct predictions. The false predictions for Sweden are limited.

Since 1987, the EMS has enjoyed a much greater degree of success in achieving its goals of exchange rate stability. As countries commenced fiscal and monetary discipline, monetary policies and inflation rates began to converge to those in Germany and exchange rates began to stabilize. Given these factors and our special interest in explaining the recent European currency crisis, we ran a joint estimation of the probabilities for all countries in the period 1989-1993, which marks the entrance of Spain to the ERM. As no realignments took place in Denmark during this period, the estimation procedure is not able to provide any probability estimates for the devaluation of the Danish krone. Given that its inclusion did not affect the results for the other countries, we excluded Denmark from the sample for the post-1989 period. The estimation results are given in Table 6 and Chart 6. 2/

1/ Norway's third realignment was due to a change in the definition of the currency basket and is not predicted by the model.

2/ As the number of explanatory variables used has to be equal to the number of positive values for the dependent variable (i.e., the number of regime changes) we were not able to combine economic fundamentals and speculative factors in the same equation.

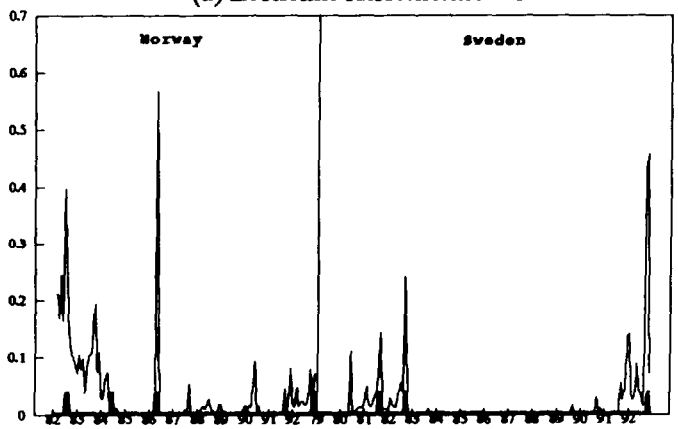
Table 5. Norway and Sweden: Empirical Results 1/

	Economic fundamentals (a)	Economic fundamentals (b)	Fundamentals and speculative proxies (c)
Constant	-96.94 (-2.35)*	-368.05 (-2.70)*	-126.29 (-2.39)*
Norway	2.79 (2.56)*	-12.13 (-1.83)**	3.96 (2.77)*
$Log(D_t)$ Domestic credit		-17.43 (-2.11)*	
$dccb_t$ Central bank credit	0.04 (0.44)		
ur_{t-1} Unemployment rate		-0.619 (-1.31)	
y_t Output	-4.77 (-2.21)*		-5.06 (-2.15)*
u_t Competitiveness	10.14 (1.69)**	16.78 (2.72)*	12.34 (1.69)**
p^*_t German price index	20.45 (2.65)*	90.79 (2.39)*	28.34 (2.96)*
$(X-M)_t$ Trade balance	-0.002 (-1.68)**	-0.003 (-2.42)*	-0.002 (-1.76)**
$Log(R_t)$ Reserves	-2.37 (-2.44)*	-1.52 (-1.49)	-3.93 (-2.78)*
$i_{t-1}-i^*_{t-1}$ Interest differential			0.12 (1.06)
Log L	-24.89	-19.66	-20.16
R^2	0.13	0.20	0.29
Number of observations (Number of devaluations)	295 (8)	295 (8)	295 (8)

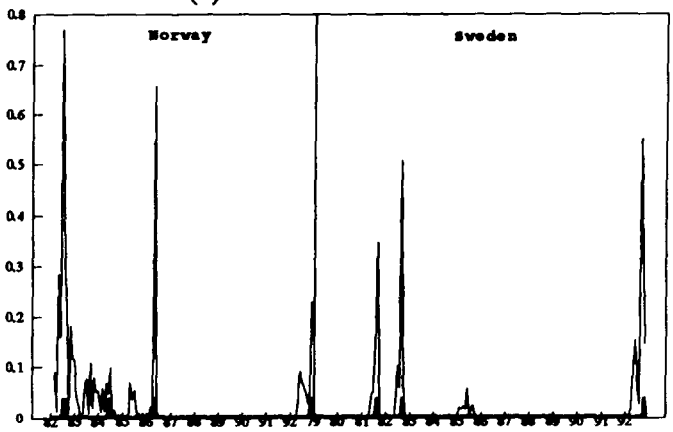
1/ T-ratios are given in parentheses. * and ** denote statistically significant t statistics at the 5 percent and 10 percent levels, respectively.

Chart 5. Norway and Sweden: Probability of a Regime Change

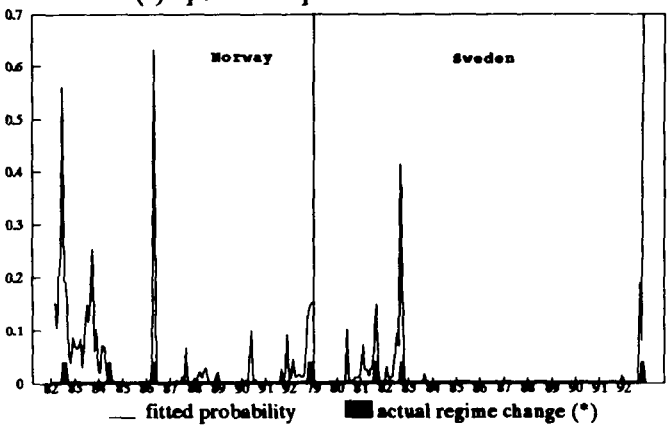
(a) Economic fundamentals – 1



(b) Economic fundamentals – 2



(c) Speculative proxies and fundamentals



(*) Actual regime change marks periods in which a devaluation or a switch to flexible rates took place.

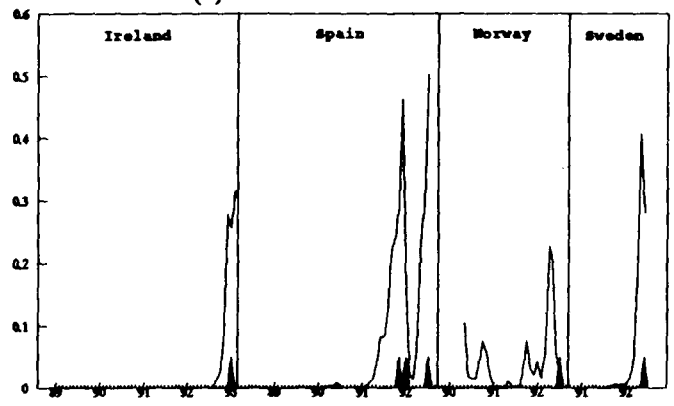
Table 6. The Post-1989 Period: Empirical Results 1/

	Economic fundamentals (a)	Economic fundamentals (b)	Speculative proxies (c)
Constant	-447.3 (-2.18)*	-158.8 (-2.18)*	-1.82 (-2.96)*
Ireland	3.36 (1.35)	8.17 (2.21)*	-2.02 (-1.16)
Norway	5.25 (1.43)	19.2 (2.35)*	-0.25 (-0.36)
Sweden	2.56 (1.40)	14.8 (2.47)*	-4.25 (-0.01)
p^*_{t-1} German price index	75.3 (2.26)*		
ur_{t-2} Unemployment rate		0.84 (2.46)*	
u_{t-2} Competitiveness		29.07 (2.09)*	
u_{t-1} Competitiveness	18.05 (1.48)		
$i_{t-2}-i^*_{t-2}$ Interest differential			0.16 (1.99)*
$E_{t-1}-C_{t-1}$ Position within the band			0.96 (2.60)*
Log L	-13.91	-15.08	-9.69
R^2	0.24	0.21	0.51
Number of observations (Number of devaluations)	137 (6)	137 (6)	137 (6)

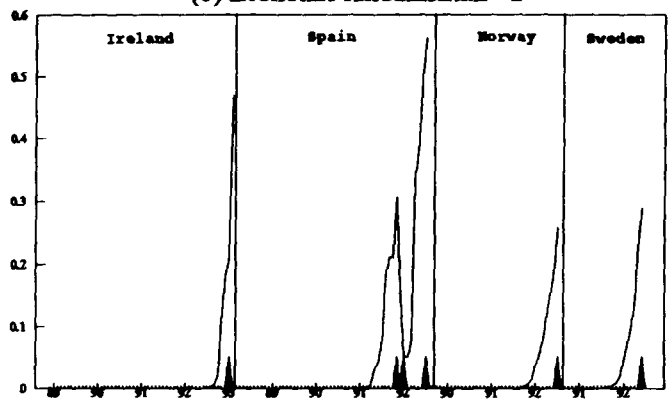
1/ T-ratios are given in parentheses. * denotes statistically significant t statistics at the 5 percent level.

Chart 6. The Post-1989 Period: Probability of a Regime Change

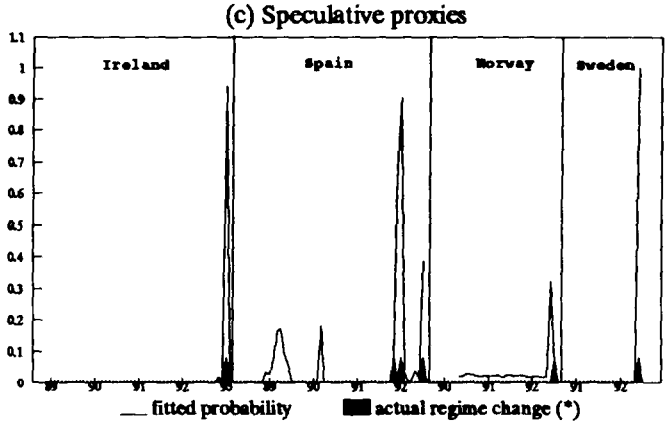
(a) Economic fundamentals–1



(b) Economic fundamentals–2



(c) Speculative proxies



(*) Actual regime change marks periods in which a devaluation or a switch to flexible rates took place.

The most significant factors in explaining the devaluations that took place during the 1989-93 period are the trends in Germany's price level, increases in unemployment rates in the wake of a deep recession in Europe, and the loss of export competitiveness for all four countries. While declining inflation differentials vis-à-vis Germany were expected to reduce the pressure on these currencies, the empirical results suggest, contrary to the predictions of the theoretical model, a positive relationship between the German price level and the devaluation probabilities. This empirical finding may be attributed to other factors not captured directly by the model, which takes into account the long-term impact of a rise in the German price level and predicts a reduction in the probability of devaluation for other currencies, when such rises are perceived by the market to be persistent. The response of the Bundesbank to the inflation that resulted from German unification was a tightening of the monetary policy, and it would seem reasonable to consider that market participants perceived the price shock as temporary and the tight monetary policy as more enduring. Tensions in the European currency markets were subsequently created as accompanying tight monetary policies adopted by other European central banks were perceived as unsustainable with the background of deepening recession, unacceptably high unemployment rates, and vulnerable fiscal and financial systems. It is important to note that deteriorating economic fundamentals generated significantly positive probabilities of devaluations for all countries prior to and during the September currency crisis and prior to their respective regime changes. Furthermore, substantial increases in short-term interest rates during the crisis generated sharply higher probabilities for Ireland, Spain, and Sweden.

VI. Concluding Remarks

The crisis periods of the ERM are associated with significant differences among countries in their objectives and economic performance, and in their policy strategies. This situation eventually resulted in considerable tensions in the working of the system in periods when perceptions of market participants had the potential to become self-fulfilling or were in line with economic fundamentals, or both. Exchange rates have been subject to frequent realignments when economic fundamentals were not consistent with the fixed exchange rate system, as confirmed in this paper. Exchange rate adjustments were thus one of the main policy tools used to correct short-term imbalances. The post-1987 period, in contrast, was characterized by significant improvements in economic fundamentals and an increased degree of convergence in economic performance --except in the most recent period--and in monetary policies. During this period, very few realignments took place, reflecting the efforts toward greater exchange rate stability and eventual achievement of monetary union, in line with the requirements of the Basle/Nyborg agreement of September 1987 which, inter alia, agreed on less frequent and smaller realignments. The efforts toward monetary union affected the exchange rate developments not only in the ERM member countries, but also in other European countries committed to different fixed exchange rate mechanisms, in a manner that increased the incidence of speculative pressures on individual currencies.

In this paper, we have attempted to identify the systematic relationships between exchange rate realignments on one hand and macroeconomic fundamentals and speculative factors on the other. Our empirical results show that both factors were important in generating the crises and the subsequent regime changes in the European currency markets. In particular, the worsening of the trade balances of the countries in the sample, increases in the German price level, the significant rise in the rate of unemployment, the level of domestic credit, as well as the loss of foreign exchange reserves and external competitiveness are shown to increase the probability of a regime change. 1/

The results also indicate that in the pre-1987 period, frequent adjustments were made in response to short-term imbalances and existence of market pressures on currencies within the system. Economic fundamentals better predict the actual devaluations, while general realignments (that is, effective devaluations) are better explained by speculative proxies.

In the post-1987 period, there were no realignments until the 1992/93 currency crisis. In particular, no realignment was made at the beginning of 1990, when a revaluation of the mark was needed within the ERM to absorb the German unification shock. Our results confirm the view that the speculative pressures and subsequent regime changes during the 1992/93 currency crisis were the results of the growing conflict between differing requirements for economic recovery in Europe and the sustainability of the fixed exchange rate system. The rise in the German price level after the unification could be sufficient for the needed real appreciation of the mark in the absence of a general realignment within the ERM or a fiscal adjustment, but the Bundesbank's commitment to price stability also required a tightening of the German monetary policy. As in any fixed exchange system, monetary policies in Germany and in the rest of the EMS could not be determined independently. Tensions in the European currency markets were subsequently created as the accompanying tight monetary policies were perceived by the market participants as unsustainable in the midst of a deepening recession, unacceptably high unemployment rates, and weak fiscal balances and financial systems.

These pressures were intensified as some countries experienced losses in competitiveness vis-à-vis those trade partners which abandoned their fixed exchange rate parities. For Ireland, Denmark, and Norway, the deterioration of economic fundamentals and thus the speculative pressure on their currencies was mainly created by such external factors. In contrast, the already existing domestic problems (such as widening public

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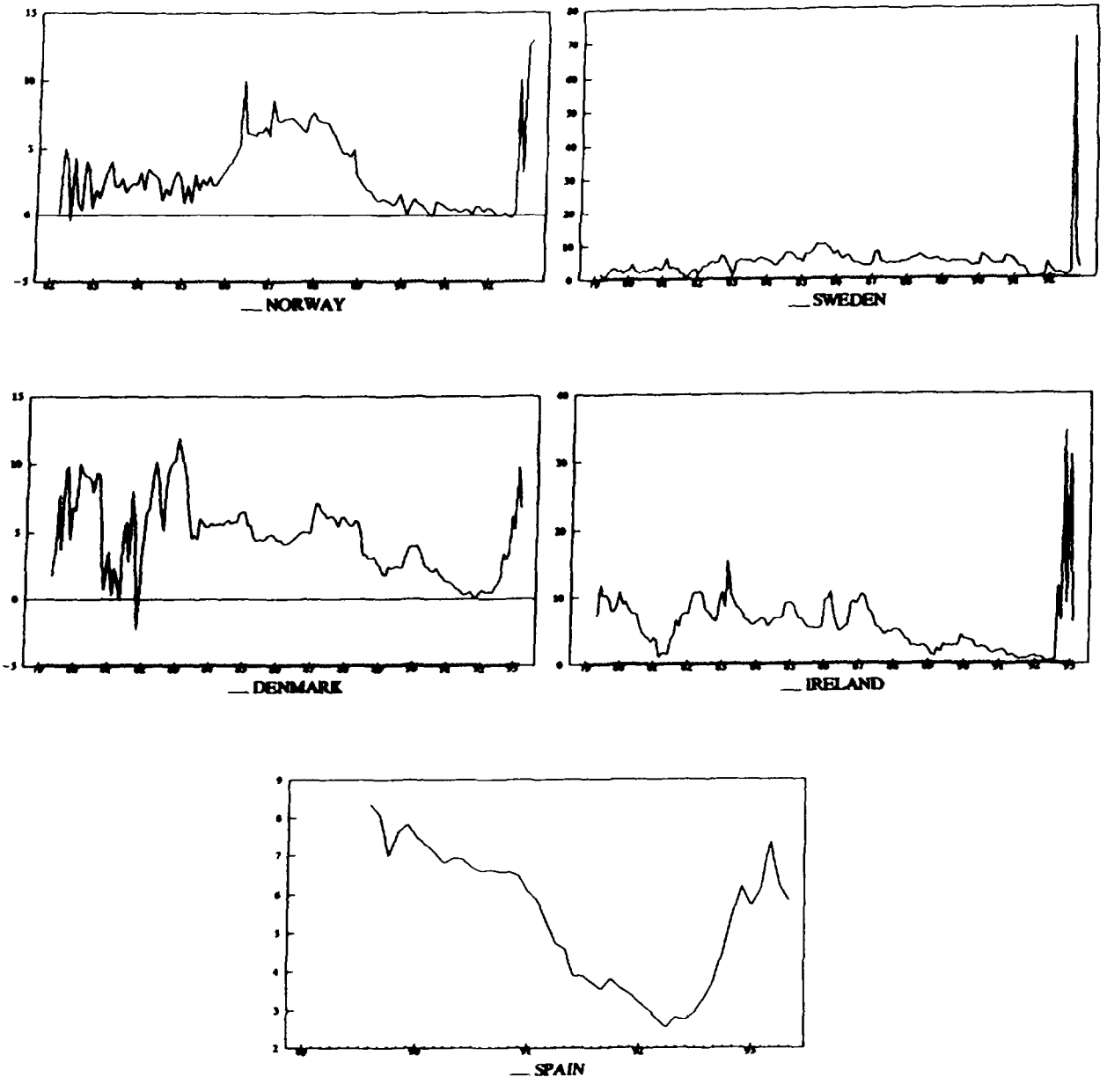
1/ Our findings are broadly consistent with the previous empirical work. Edin and Vredin (1993) also found a systematic relationship between fundamentals and the probability of a regime change for some of the Nordic currencies in 1979-89 period. Caramazza (1993) found similar results for the French franc. On the other hand, Thomas (1993) showed only a weak relation between economic fundamentals and devaluation risk for the franc and the lira, while he identified the position within the band as the most significant explanatory variable.

sector deficits and weak financial systems) intensified the degree of speculative pressure on the currencies of Spain and Sweden, and thus led to subsequent regime changes. Our results confirm that regardless of the source of the deterioration, market participants perceived the existing parities of the currencies in these five countries as inconsistent with their underlying economic fundamentals. Furthermore, defensive interest rate policies to maintain existing parities have proven ineffective, as such policies were perceived by the market to be internally unsustainable.

APPENDIX I

Indicators of Economic Performance in the Sample Countries

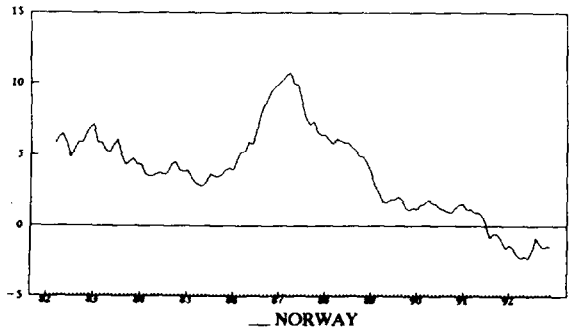
Short-Term Interest Rate Differentials*

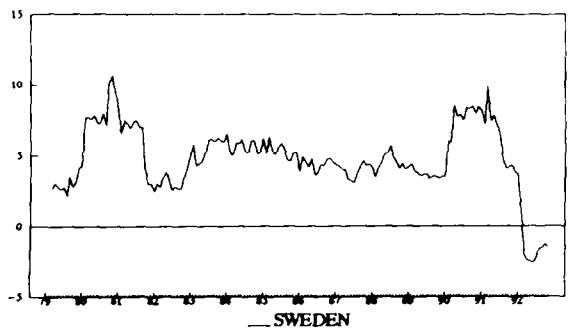


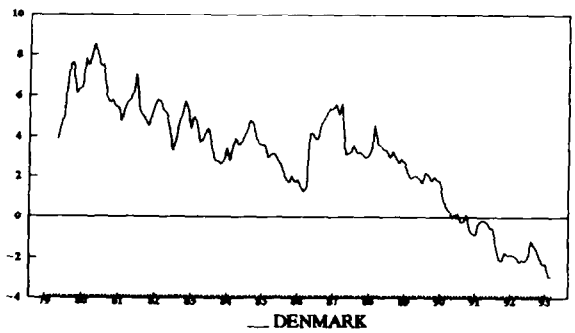
(*) Differentials are vis-a-vis German short-term rates for Denmark, Ireland, Spain and Sweden. For Norway, they are vis-a-vis short-term basket interest rate for the basket period, and short-term ECU interest rate for the ECU period.

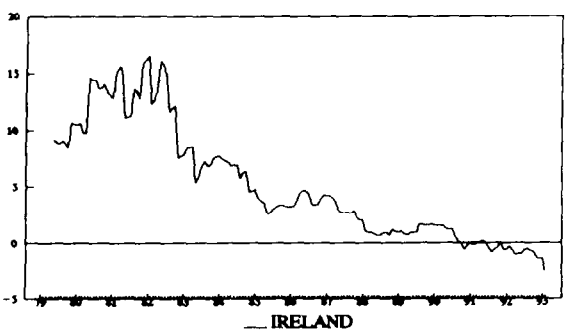
APPENDIX I

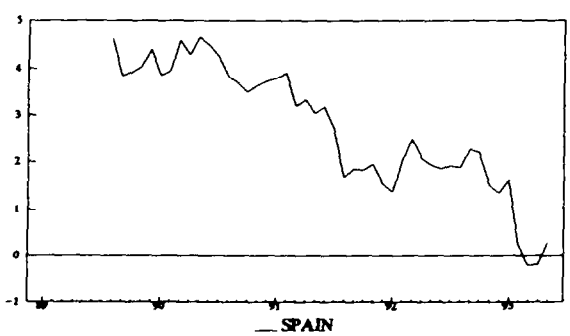
Inflation Differentials with Germany







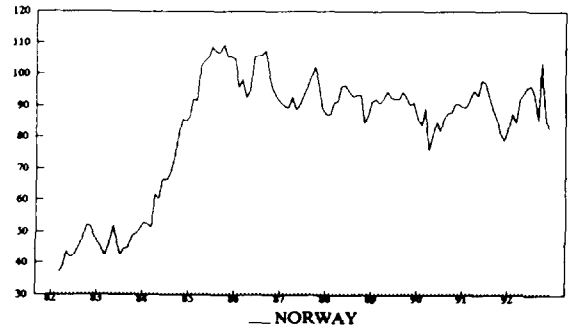


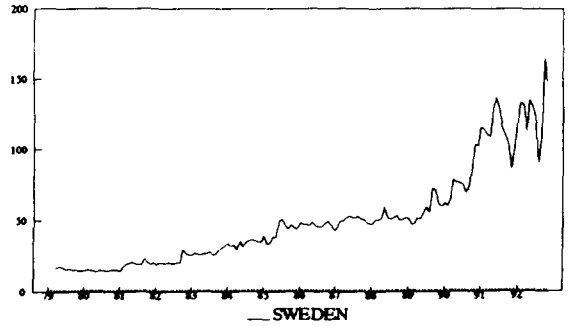


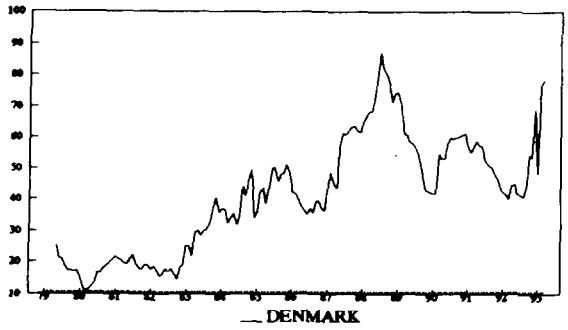
APPENDIX I

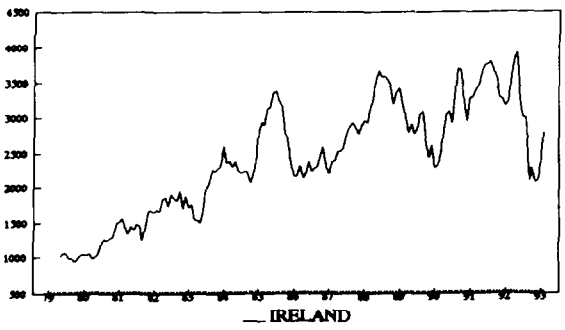
Foreign Reserves (Minus Gold)

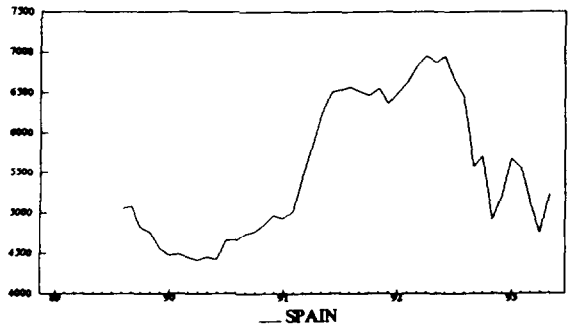
(In billions of local currencies*)









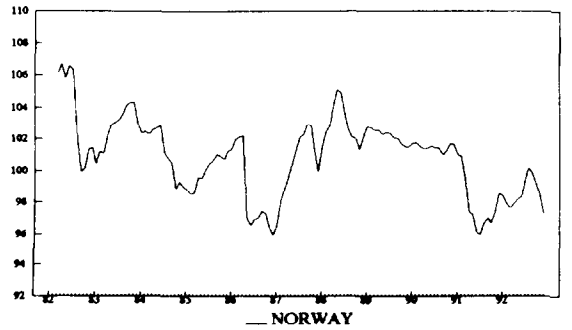


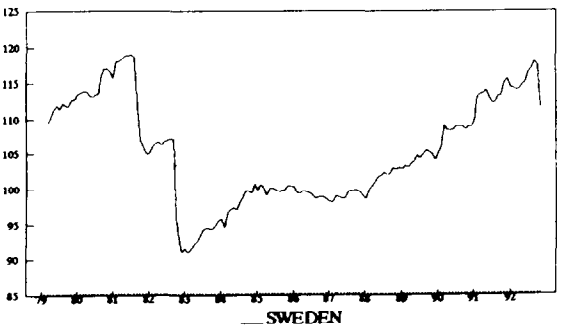
(*) millions of Irish pounds in the case of Ireland.

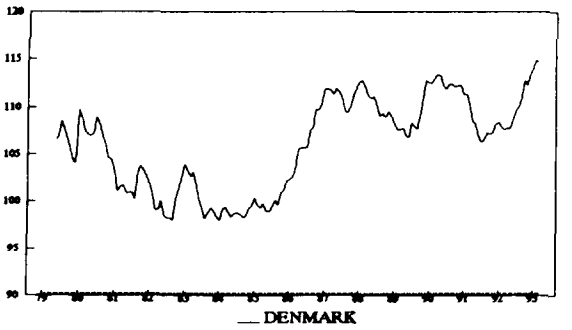
APPENDIX I

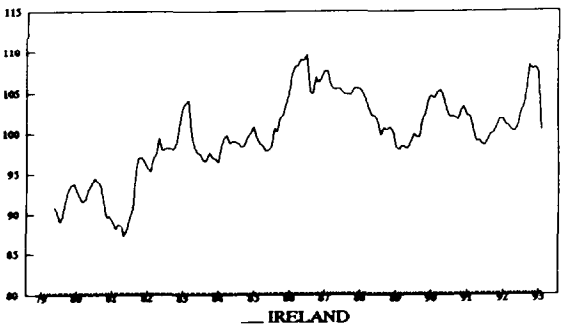
Real Effective Exchange Rates

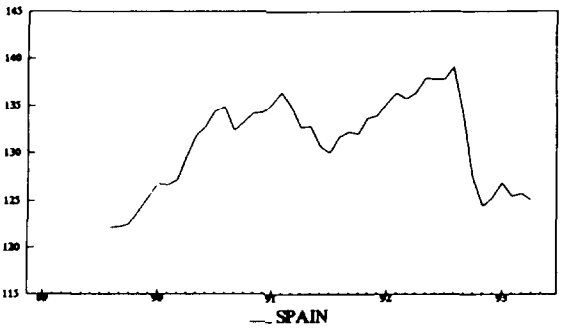
(1985=100)







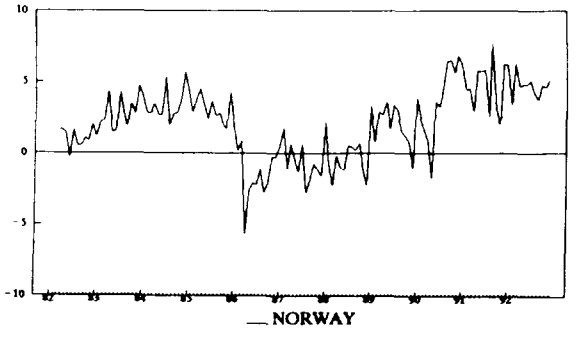




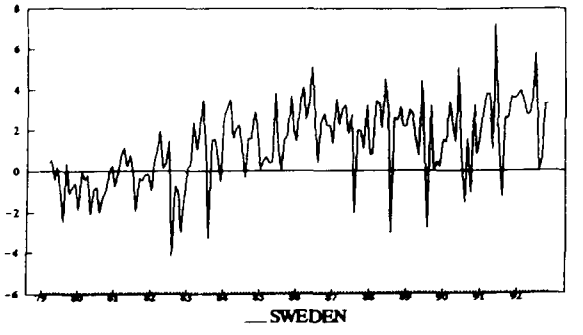
APPENDIX I

Trade Balances

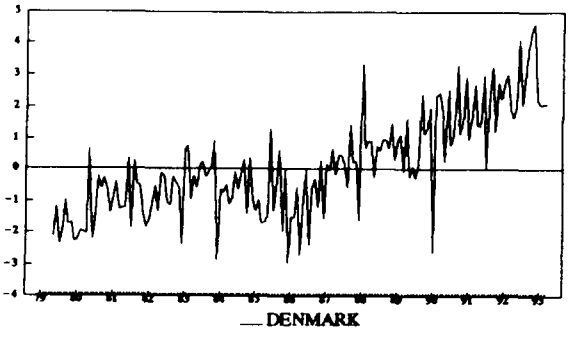
(In billions of local currencies*)



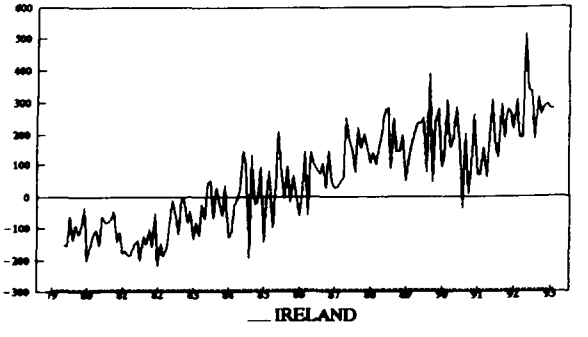
NORWAY



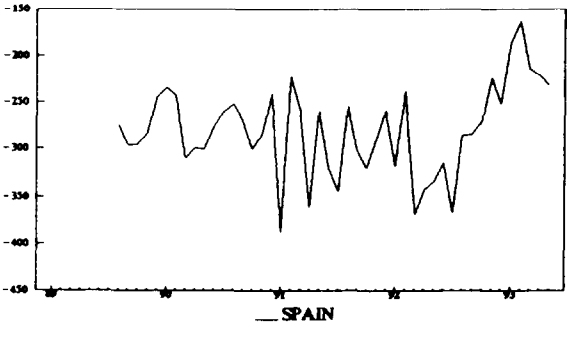
SWEDEN



DENMARK



IRELAND



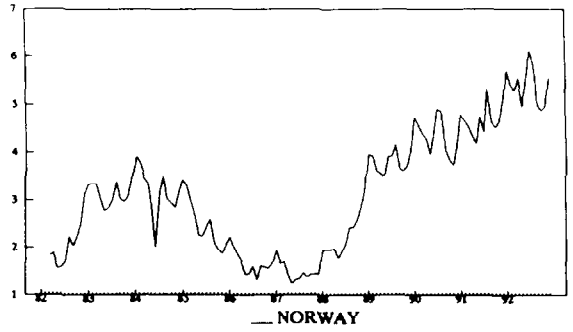
SPAIN

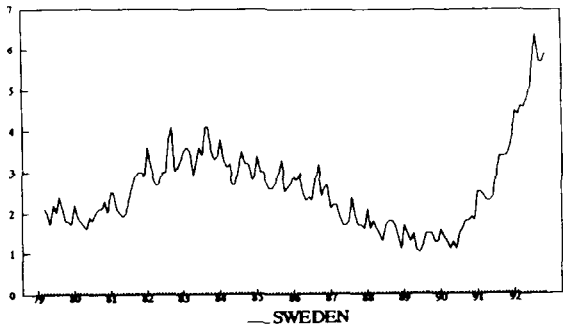
(*) millions of Irish pounds in the case of Ireland.

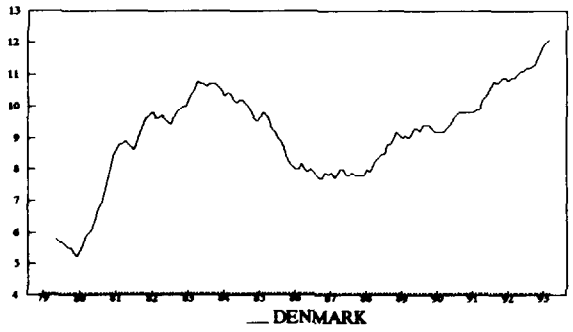
APPENDIX I

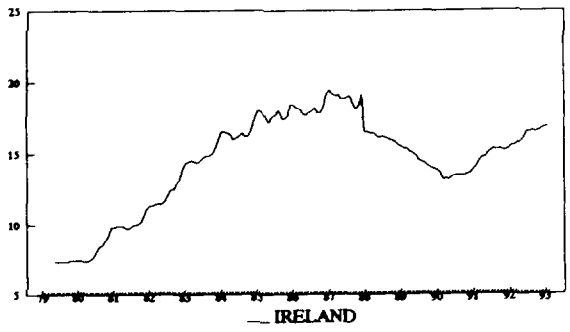
Unemployment Rates

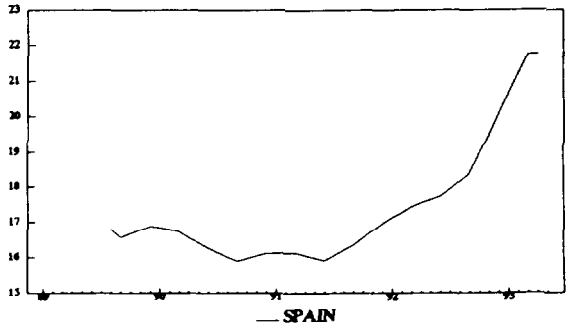
(In percent)







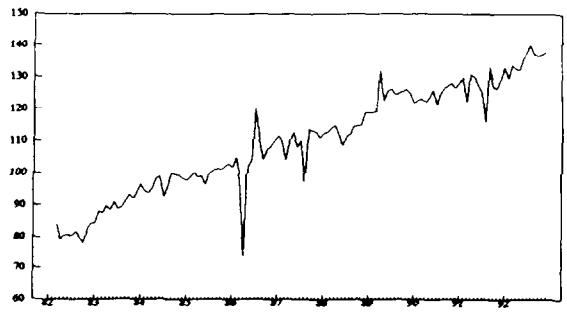




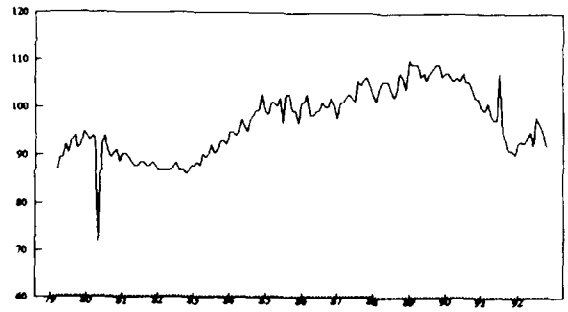
APPENDIX I

Industrial Production

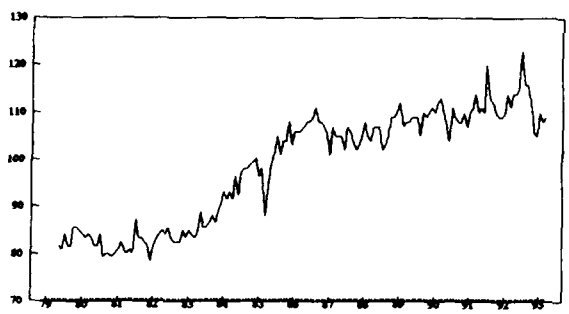
(1985=100)



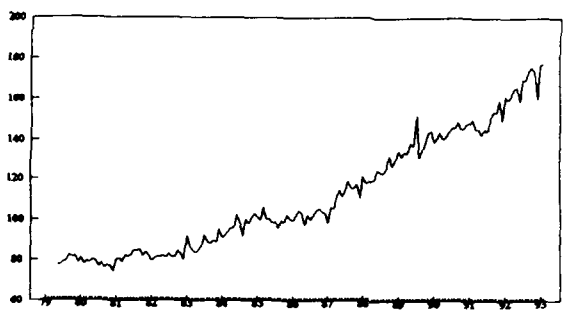
__ NORWAY



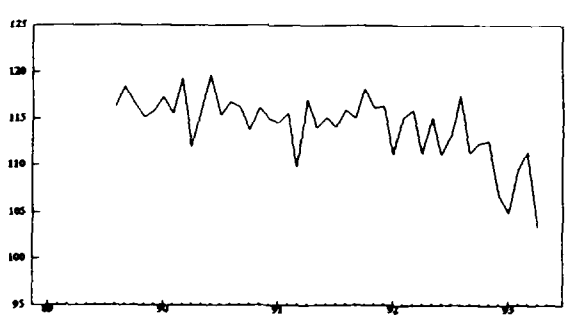
__ SWEDEN



__ DENMARK



__ IRELAND



__ SPAIN

Description of the Data

This appendix provides the description of the monthly data used in the empirical analyses.

E: The level of the end-of-period spot exchange rate. In case of Denmark and Spain, it is the price of the deutsche mark in terms of the Danish krone and the Spanish peseta. In case of Ireland, it is the price of the Irish pound in terms of the mark. In case of Norway and Sweden, it is the official basket index for the basket period and the price of the ECU in terms of the Norwegian krone and the Swedish krona for the ECU period. Sources: IFS, International Monetary Fund, Norges Bank, and Riksbank.

e: The log of the end-of-period spot exchange rate, *E*.

C: The level of the bilateral central parity for the Danish krone, the Irish pound, and the Spanish peseta vis-à-vis the deutsche mark, for Denmark, Ireland, and Spain, and the central parity vis-à-vis the currency basket and the ECU for the Norwegian krone and the Swedish krona for the basket and the ECU periods, respectively. Sources: Norges Bank, Riksbank, Ungerer, Hauvonen, Lopez-Claros and Mayer (1990), and Foreign Exchange Outlook by the Vefa Group.

c: The log of the central parity, *C*.

i: Short-term domestic money market rates. Source: IFS (line 60b), International Monetary Fund.

i^*: Short-term money market rate for Germany in case of Denmark, Ireland, Spain, and Sweden, and short-term basket interest rate for the basket period, and short-term ECU interest rate for the ECU period, in case of Norway. Sources: IFS, International Monetary Fund, and Norges Bank.

R: The central bank total reserves minus gold (in domestic currency converted at the end of period spot exchange rate). Source: IFS (line 11.d), International Monetary Fund.

D: Total domestic credit (in domestic currency). Source: IFS (line 32), International Monetary Fund.

dccb: Net domestic credit extended by the central bank. Source: IFS, International Monetary Fund.

y: The log of industrial production index. Source: IFS (line 66.c), International Monetary Fund.

ur: The unemployment rate as percent of labor force. Sources: Norges Bank, OECD-Main Economic Indicators, the Danish Statistical Bureau, and OECD-Main Economic Indicators.

u: The log of the real effective exchange rate index based on relative consumer prices. Source: IFS, International Monetary Fund.

p^*: The log of the German consumer price index was used for all countries. Source: IFS, International Monetary Fund.

X-M: The trade balance or net exports (in domestic currency). Source: IFS (line 70-line 71), International Monetary Fund.

time dummy: Takes the value 0 and 1 before and after 1989:6, respectively.

Denmark: Intercept dummy for Denmark.

Ireland: Intercept dummy for Ireland.

Norway: Intercept dummy for Norway.

Spain: Intercept dummy for Spain.

Sweden: Intercept dummy for Sweden.

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