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INTEREST RATE VOLATILITY REGIMES AND EXCHANGE RATE BEHAVIOR IN A TARGET ZONE

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Interest Rate Volatility Regimes and Exchange Rate Behavior in a Target Zone*

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Abstract

The fluctuation of a bilateral exchange rate in a target zone is often chosen as part of official agreements between two or more countries (such as in the European Monetary System – EMS) or of informal unilateral monetary policy packages a country adopts for itself. The defendability of such a regime in the face of asymmetric shocks is always an issue. In this paper, we examine a long period in the life of the EMS and we argue that the increase in volatility in the *interest rates* could help identifying periods of possible impending crisis for the *exchange rates*. Our framework provides a way to put to test the quality of the reaction by monetary authorities and to relate perceived weakness to subsequent episodes of realignment in the central parity.

We examine ten years of Italian Lira one month Eurodeposit daily between 1983 and 1993 addressing three empirical questions:

1. Is interest rate volatility a measure of the perceived degree of vulnerability of the institutional agreements and hence a good predictor of the timing of realignments?
2. Does the adoption of a new central parity always bring about an immediate increase in the level of credibility?
3. Are there episodes in which an increase in volatility is successfully countered and hence does not lead to a realignment?

We analyze these questions in the framework of a Markov Switching ARCH model which accommodates the volatility clustering features in the interest rates and the presence of economically interpretable regimes.

1 Introduction

The history of the Exchange Rate Mechanism (ERM) within the European Monetary System (EMS) is marred by periodic crises which at times have led to the realignment of the bilateral central parities among the participants. The aim of the ERM was[1] mainly one of exchange rate stabilization and proved to be a good training ground to understand what is needed to converge to a monetary union such as EMU. It has been argued by several authors (Giavazzi and Giovannini, 1989) that stabilization and convergence of exchange rates could happen only at the expenses of an increased volatility in interest rates and interest rate differentials (convergence on which was in fact inserted as one of the Maastricht parameters). Since the issue of British participation and of Union enlargement is still open the problem deserves some further attention. More in general, it can be placed in the framework of the speculative attack literature (see Eichengreen *et al.*, 1996) and the study of its determinants: a study which follows a similar methodology to ours is Martinez Peria (1999).

In this paper, we argue that the increase in the volatility of interest rates, although persistent, was not permanent. In the variety of shocks monetary authorities had to face, their reaction and their capability of coordinating with one another was put to test, sometimes resulting in a currency devaluation, other times providing grounds for successful gains of credibility and the defense of the band. When analyzing short term interest rate data for the countries involved the typical volatility clustering of financial data can be detected, which could be modeled with a GARCH type parameterization. Yet, a relevant question is whether interest rate volatility within the EMS had a peculiar behavior given the needs of exchange rate management. Hamilton and Susmel's (1994) proposal of including a scale difference in the parameters of a ARCH–type conditional variance model in correspondence to a change in regime (Switching Regime ARCH - SWARCH) is appealing to this end. In fact, it allows for magnified impacts of shocks on volatility and faster absorptions of shocks than the standard GARCH, a feature which mimics the inception of crises and the return to a low volatility regime, and which we put to test to model the markets' reaction to public announcements about

[1]It still is for Denmark and Greece whose currencies fluctuate in (differently sized) bands with respect to the Euro.

monetary policy. Other authors have considered the presence of switching regimes in a target zone (Driffil *et al.*, 1994), nonlinearities in exchange rates (BP/DM - Garratt *et al.*, 1998). Kugler (1994) analyzes the effects of regime switches on the term structure of interest rates.

In detail, we examine a series of ten years of Lira one–month Eurorates data between 1983 and 1993 and estimate its conditional variance with a SWARCH model. The division of the sample period in volatility regimes allows us to look at the behavior of the ITL/DM exchange rate within these regimes and to address three related questions:

1. Is interest rate volatility a measure of the perceived degree of vulnerability of the institutional agreements and hence a good leading indicator of the timing of exchange rate realignments?

2. Does the adoption of a new central parity always bring about an increase in the level of credibility and hence a change in regime characterized by rapid absorption of volatility?

3. Are there episodes in which an increase in volatility is successfully countered and hence does not lead to a realignment in central parity?

Our results show that all questions can be answered affirmatively, and that in particular we manage to isolate three periods of high volatility for the interest rates: the first starts well before the April 7, 1986 revaluation of the DM and lasts past that realignment, the second coincides with the adoption of the Basel-Nyborg agreements in 1987 which is not accompanied by a realignment, but marks a reform of the EMS and the inception of a period of greater stability, and the September 1992 episode which starts at the end of April of that year and lasts into 1993.

The structure of the paper is as follows: in section (2) we recall the main features of Hamilton and Susmel's approach to set up the notation. In section (3) we perform a model specification search over possible lag lengths and choices of probability density functions for daily Italian Lira Eurorates, estimating the regimes associated with interest rate volatility. In section (4) we use the identified regimes to examine the evolution of the ITL/DM exchange rates within these regimes interpreting the economic significance of the statistical evidence. Finally, we draw some concluding remarks.

2 The SWARCH Model

Volatility clustering is an empirical feature of financial data: second moments of series are well modeled by a GARCH type model (Bollerslev *et al.*, 1994) in which recent innovations and estimates of conditional variance determine the current estimate of conditional variance.

Let us consider Ω_t, the information set available at time t, and the representation for the returns of a series y_t around its constant mean α:

$$\begin{aligned} y_t &= \mu + \epsilon_t \\ \epsilon_t|\Omega_{t-1} &= v_t\sigma_t \end{aligned} \tag{1}$$

Although more parsimonious and more widely used representations exist, we recall here Engle's (1982) original ARCH(p) model where

$$\sigma_t^2 = \omega + \alpha_1\epsilon_{t-1}^2 + \ldots + \alpha_p\epsilon_{t-p}^2 \tag{2}$$

This or any other GARCH-type model can be shown to have a difference equation representation where the largest root λ is very close to 1, suggesting that the persistence of shocks in the conditional variance is very high. This feature translates into a high persistence profile of the multi–period ahead forecasts, which is difficult to reconcile with the observed fast absorption of the news by the markets. Moreover, the estimate of the persistence parameter λ is often not robust in sub-samples, so that a value of λ close to one could be attributed to the presence of changes in regime (Lamoureux and Lastrapes, 1990).

The SWARCH specification (Hamilton and Susmel, 1994) is motivated by this possibility and it is an extension to conditional variance models of the Markov Switching regimes for the mean (Hamilton, 1994). Let us recall that the regime for the volatility is determined by the values assumed by a latent discrete state variable s_t (for simplicity, in two states, the values 0 and 1), the dynamics of which is ruled by a Markov chain. In this framework, the conditional variance of the disturbance ϵ_t is assumed independent of the state of the process, that is,

$$\epsilon_t = \sqrt{1 + gs_t}u_t \tag{3}$$

with the conditional variance of u_t follows an ARCH(p) specification as in (2) above. The scale factor $g \geq 0$ is activated only if $s_t = 1$ and produces an upward shift in h_t when in regime 1.

Having assumed that the states of the world are two, the transition probability matrix for s_t will be $\mathbf{P}$:

$$\mathbf{P} = \begin{pmatrix} p_{00} & 1 - p_{11} \\ 1 - p_{00} & p_{11} \end{pmatrix}$$

with p_{00} and p_{11} to be estimated, together with $\mu, \omega, \alpha_1, \ldots, \alpha_p$ and g.

3 MS Regimes for Lira Eurorates

The historical evolution of the European Monetary System has pinpointed the fundamental role played by the credibility of economic and monetary policies by the various countries in managing the exchange rate regime. The successive crises and the reforms realized until the crisis of 1992-3 are a witness to the increasing weight given by the markets to the internal consistency between macroeconomic goals and sustainability of monetary policies. In particular, the crises which struck various currencies (among which the Italian Lira) in September 1992 and others later on, at the end of July 1993 show the constraints imposed on the evolution of monetary policy by the development of market expectations *non credibly* contrasted.

In order to analyze such dynamics, the Markov switching approach proposed by Hamilton is particularly useful. In fact in the mechanisms at work behind target zones like the one in the EMS, there is a continuous interaction between the monetary policy authorities and the markets. The policy maker controls the exchange rate in two different ways: she defines the monetary policy fixing short-term interest rates and at the same time, if needed, intervenes buying or selling currencies on the foreign exchange markets. The markets, on their part, express a judgement on the adequacy and credibility of the policy maker's actions, forming the prices at which the currency is exchanged and defining the market interest rates. It is interesting to notice that in many situations of currency crisis the most relevant dynamics is observed more on the interest rate structure (and hence on forward rates) than on spot exchange rates which are compressed at the depreciation bound of the band.

There exist various suggestions to detect periods of potential crisis for a currency within the EMS, most of which are based on the uncovered interest rate parity accompanied by some corrections (Svensson). In what follows we will depart substantially from that route, in that we will follow the evolution of a daily series of short-term interest rates, and we will model the behavior of its conditional variance through a SWARCH model since we think that it has the potential to isolate the different dynamics relative to different levels of credibility. In this framework, we can accommodate sudden changes in the level of the variable, preceded or followed by important oscillations corresponding to periods in which the markets are discounting the (possibly temporary) difficulties in defending the central parity. This variability may return to more reasonable values once an effective defense of the parity has been carried out or a new central parity has been announced.

The dynamics in the conditional variance can put forward a measure of the impact that the uncertainty about the future of the system can have on the evolution of the interest rates. By the same token, the speed at which currency crises develop and hence the need to work with high frequency data make it difficult to adopt the standard MS approach where both means and variances are switching *across* but constant *within* regimes. Moreover, the evolution of the interest rate series (Fig.1) shows a behavior which combines the typical characteristics of jumps-in-mean with a SWARCH profile. Thus, caution has to be exerted in commenting the results, since the classification of a period to a high volatility state could mask a jump in first- rather than second-order moments. We will return on this point later on, when we will comment on the episodes between 1985 and 1986, at the end of 1987, at the end of 1990 and in September 1992.

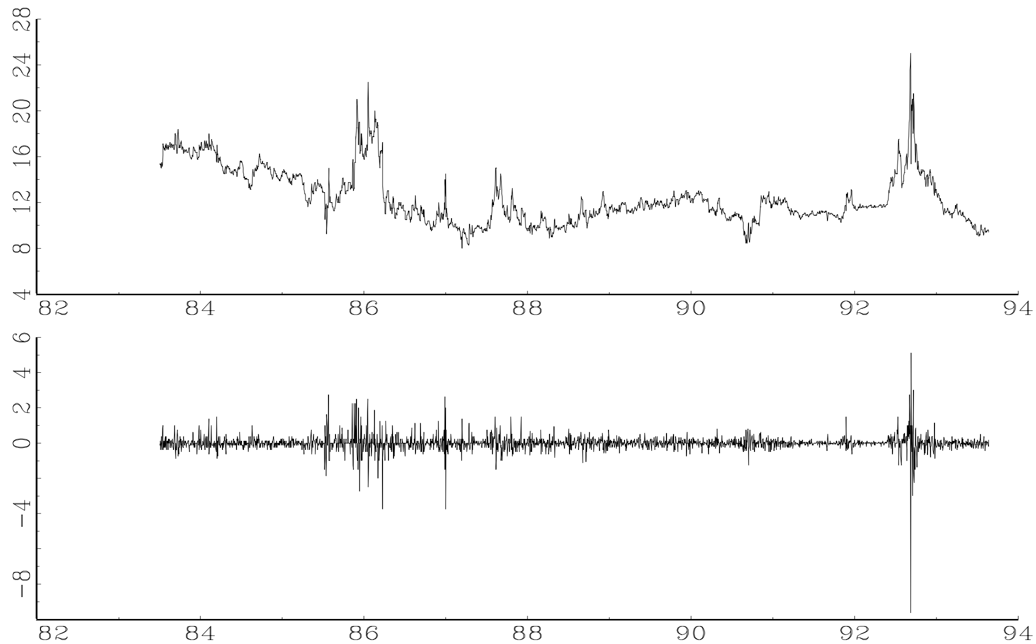

Figure 1: One-month Lira Euromarket Rates: Levels and First-differences.

We will concentrate on daily bid interest rates on one-month ahead Lira Eurodeposits and apply a SWARCH model. We will focus on a long period between July 13, 1983 and August 26, 1993 which includes several turbulent periods during which the pressure on the Lira surfaced heavily in the monetary markets. Some of these crises gave rise to realignments (five) and the most serious one in September 1992 lead to the Lira abandoning the EMS.

Given the nonstationarity of levels, we work on a first differenced series (without logs - Fig. 1b) which exhibits the typical behavior of a financials series with volatility clustering.

A visual inspection of the series shows that there exists a first phase (until the end of 1988) characterized by episodes of high volatility. A second phase (until 1992), where the volatility is less pronounced, follows until the crisis of September 1992 and its aftermath. This kind of behavior (already pointed out in the literature – Giavazzi and Spaventa, 1990), corresponds to the evolution of institutional agreements within the EMS, justifying an approach based on regimes. The advantage of the SWARCH approach is to let the statistical properties of the data suggest various regimes present in the series, allowing also to identify the probabilistic structure of the transition from one regime to another.

3.1 The Two Regime Model

This class of models is difficult to estimate with a large data set, hence we chose to get some initial estimates using the observations from July 13, 1983 to May 10, 1991 (excluding the later, more turbulent, period). We will examine the episodes characterized by a the sudden passage from situations of low to high volatility and vice versa. A number of crises occurred in this period, with devaluations in the central parity and by sudden jumps in the volatility of the interest rates. As far as the Lira exchange rates are concerned, this period was marked by a gradual acquisition of credibility marked by no realignments past 1987; following the tightening of the fluctuation band in January 1990, the end of this sample is marked by an increase in the volumes exchanged on the Euromarket, and an even higher stability which not necessarily corresponded to an interest rate stability.

The exclusion of the deep crisis of 1992 from the sample allows us to assume the presence of two states (recall that testing for the number of regimes within Markov Switching models is plagued by the problem of nuisance parameters – in this case p_{00} and p_{11} – unidentified under the null hypothesis, see Hansen, 1997, and Andrews and Ploberger, 1994) labelled low and high volatility states, respectively. The specification search in this context was limited to a choice of the probability density function and the lag length for the ARCH process[2] For the latter, a choice of $p = 2$ is fairly stable in not leaving autocorrelation in the standardized squared residuals across specifications (Hamilton, 1996): hence we will be estimating

$$\sigma_t^2 = (1 + g s_t)(\omega + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 \epsilon_{t-2}^2).$$

As for the choice of pdf's, we explored two possibilities, the Gaussian and the Student's t. The results are overwhelmingly in favor of the Student's t, on a number of grounds: in terms of better explanatory power (the log-likelihood function for the t – with unrestricted degrees of freedom – is estimated at

[2]Contrary to Hamilton and Susmel's (1994) results there is no evidence of autoregression for the mean nor of leverage effects for the conditional variance – the estimated constant $\hat{\mu}$ is not significant across specifications.

-232.28, while the log-likelihood corresponding to the normal – restricting the degrees of freedom to be infinite – is estimated at -311.93), in terms of the significance of the parameters of the ARCH specification (the normal pdf has trouble detecting the value and significance of the parameters on lagged squared innovations) and finally, and most interestingly, in terms of the detection of the regimes through the smoothed probabilities (calculated on the entire sample) associated with one regime. Figure 2 shows such probabilities estimated with the Student's t (upper panel) and with the normal (lower panel) distributions for the innovations. Clearly, the normal distribution provides very unstable results while the Student's t is capable of isolating six episode of high volatility (two of which are longer lived than the others) the interpretation of which is deferred to the next section. Since the estimated degrees of freedom are equal to 2.6081 (very close to 2 value for which the unconditional variance is infinite), the t distribution manages to classify days with mildly high innovations as large values sampled from a low volatility distribution, while the normal pdf, having less density in the tails, (wrongly) recognizes them as values sampled from a high volatility distribution.

The estimated g (7.09 with a s.e. 1.34) points to a seven-fold scale factor for the conditional variance in the regime of high volatility. The expected persistence in the low volatility state can be derived from $\hat{p}_{00} = 0.9943$ through the expression $(1 - \hat{p}_{11})^{-1}$ is equal to 166 working days, while $\hat{p}_{11} = 0.9705$ indicates an expected permanence in the state of high volatility equal to 33 days. These results are in line with prior expectations that surges in the conditional volatility are shortly lived (the normal predicted an expected permanence in each state equal to 16, respectively, 3 days).

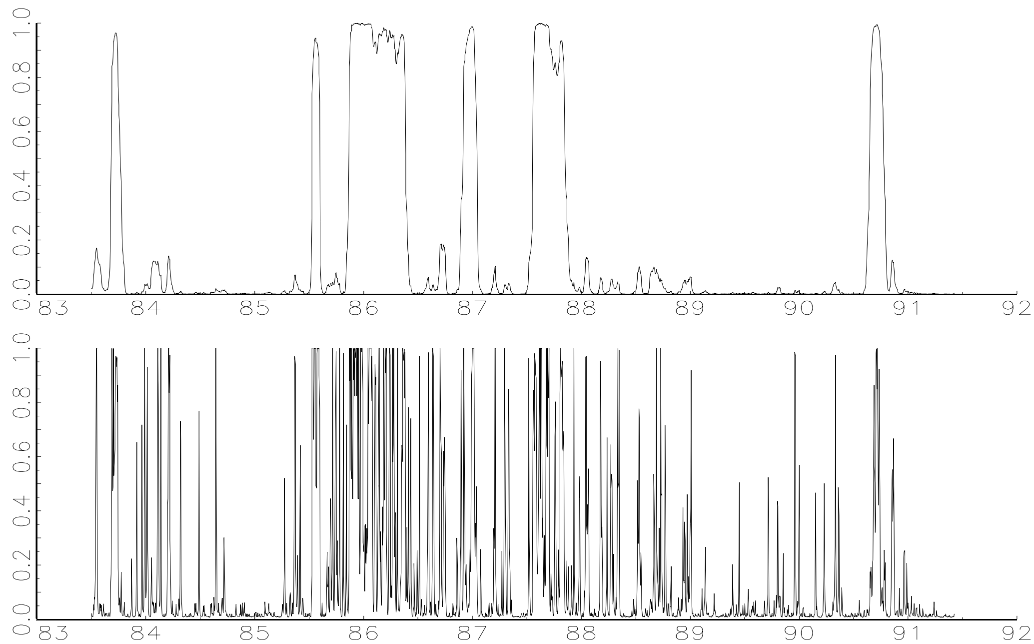

Figure 2: Smoothed Probabilities Obtained with a Student's t and with a Normal p.d.f. (two states).

3.2 The Three Regime Model

When the sample period is extended to include the unprecedented September 1992 episode, there is a clear need to extend the number of regimes to three. As a matter of fact, estimation of a SWARCH-t(2,2) on the entire sample did not converge. We maintain the Student's t pdf for maximum likelihood estimation and, as suggested by Hamilton and Susmel (1994) we reduce problems in convergence by imposing some meaningful zero restrictions in the transition probability matrix. Stylized facts suggest that the effect of the inception of currency crises on interest rates is quite abrupt (hence we force to zero the probability of passing from the medium to high volatility regimes p_{23}) and that an existing crisis is not absorbed immediately (hence we set to zero the probability of passing from the state of highest to the state of lowest volatility p_{31}).

The estimation results with the three regime model confirm the non significance of the constant term, the absence of an autoregressive component in the mean, and the absence of leverage effects in the variance. The retained model is a SWARCH-t(3,3)

$$\sigma_t^2 = (s_{1t} + g_2 s_{2t} + g_3 s_{3t})(\omega + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 \epsilon_{t-2}^2 + \alpha_3 \epsilon_{t-3}^2)$$

for which (standard errors in parentheses)

$\hat{g}_2$	$\hat{g}_3$	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$
9.46	39.49	0.0093	0.3356	0.1681	0.1907
(3.48)	(18.32)	(0.0035)	(0.1461)	(0.1030)	(0.0765)

with estimated degrees of freedom equal to 2.51, still significantly different from 2.

The transition probability matrix is equal to

$$\begin{pmatrix} 0.977 & 0.004 & 0.000 \\ 0.006 & 0.996 & 0.011 \\ 0.015 & 0.000 & 0.989 \end{pmatrix}$$

from which it is clear that the persistence in each state is high and that, given a regime of low volatility, there is a higher probability to switch to state 3 than to state 2, in agreement with the expectations for the problem at hand. The likelihood value for this model is -114.60 well above the value that was obtained with two regimes.

With three regimes, therefore, we manage to identify a higher permanence of the Italian interest rates in a state of medium volatility (expected period equal to 303 days) with three significant episodes of very high volatility (between November 11, 1985 and May 30, 1986, between July 7, 1987 and November 19, 1987, and between June 3, 1992 and December 30, 1992) where the conditional volatility is 40 times higher than the lowest volatility state and 4 times higher than the medium volatility state. The latter has an expected stay in the regime of 83 days, while the lowest expected persistence is in regime 1 (44 days). This is clear also from the inspection of Fig. 3 reporting the smoothed probabilities associated with each state.

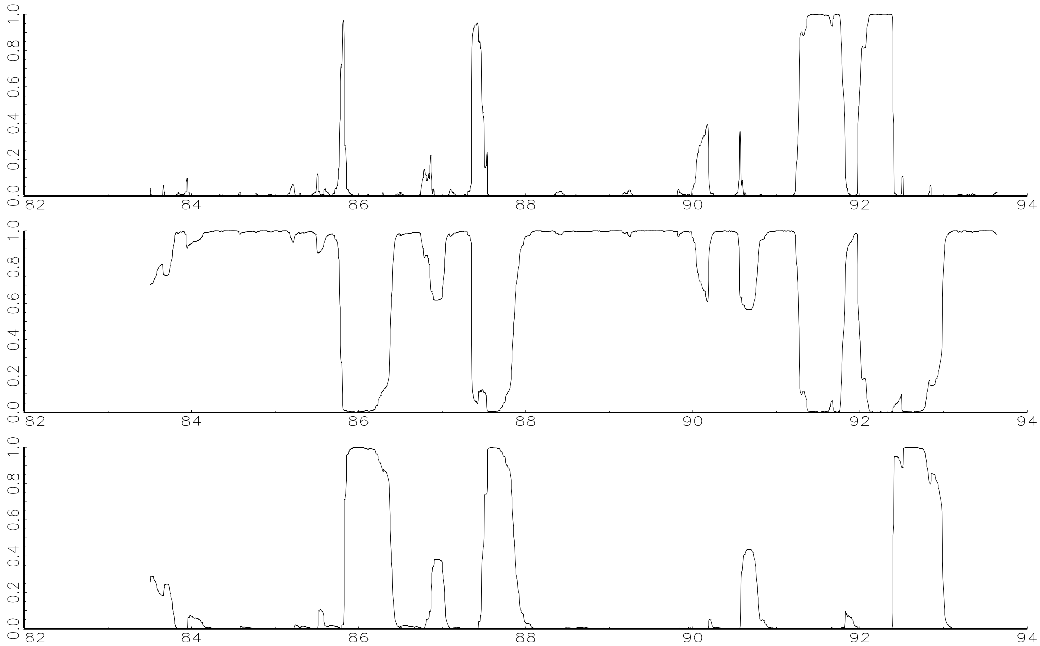

Figure 3: Smoothed Probabilities with Three States (Low, Medium and High Volatility).

4 An Economic Interpretation of the Results

We can now interpret the results from an economic point of view by including the behavior of other variables into the analysis and by considering the phases isolated by the SWARCH model, both in the case of two and three regimes.

One possible explanation of the changes in volatility of the Italian rates can be found by looking at their relationship with the German rates on the same maturity, given the strict dependence of the Italian monetary policy from the German policy in a semi-fixed exchange rates. However, the analysis on the German rates did not show an effect of transfer of volatility towards the Italian rates. Being a country–specific effect, therefore, the hypothesis about the higher volatility episodes in the interest rates is that they were connected to the exchange rate mechanism in the EMS. Given that the Lit/DM exchange rate at times was flattened against the upper limit of the fluctuation band, its latent volatility was transferred to interest rates.

We explored this hypothesis by analyzing the behavior of the exchange rate between the dates marking the beginning and the end of the estimated high volatility regime for the interest rate. We need to consider that during the phase of appreciation of the dollar *vis-à-vis* the Deutsche Mark and the other European currencies (1983-85), the tensions within the EMS were relatively less important. In the two regime hypothesis, a switch in volatility was estimated to have occurred on July 11, 1985, 13 days prior to a strong devaluation of the Lira *vis-à-vis* the DM (-6%), but it is not confirmed by the estimation with three regimes. Evidently the jump in volatility in that occasion was not as high (and persistent) as later episodes. The period of higher volatility which is common to the two model estimates is the one going from November 11, 1985 to May 30, 1986. In that occasion the Dollar had already showed signs of weakening since the beginning of the year, a process which increased after September 22, with the Plaza agreements. The first months of 1986 were marked by a high level of uncertainty accompanying the political elections in France and by a peak on April 7, with the revaluation of the DM *vis-à-vis* the Lira and the French Franc (3%). The increase of volatility between 1986 and 1987 which includes a further appreciation (3%) of the DM (January 12, 1987) is accompanied by a switch in regime in the two states estimation, but it is not strong enough to be classified as extreme in the three states estimation.

The high volatility in the final part of 1987 coincides between the two estimates as generating a switch to the higher volatility regime. It coincides with the Basel-Nyborg agreements (September 12-13). However, we must recall that, during 1987, the high instability among the European currrencies and the apparent incapability by the Lira to keep a stable course relative to the central parity for long periods had raised questions about the usefulness and the sustainability of the exchange rate mechanism. From this point of view, after ten years of experience with semi-fixed exchange rates, the Basel-Nyborg agreements had defined more strict and credible intervention instruments and had stated a strong and renewed determination by the European monetary policy makers to pursue the road to convergence. This reform (known as the "new EMS") dissipated doubts and started a phase of exchange rate stability which lasted until 1992.

This stability is indeed exhibited by the Lit/DM exchange rate, although some occasional tensions on the interest rates surface here and there. This is the case, for example, of an episode towards the end of 1990 which is classified as high volatility by the two state procedure, although, again, it was not strong enough to enter the third regime under the extended estimation. This is a period characterized by a distinct attempt by the Bank of Italy to push interest rates downwards, through a cut in the discount rate from 13.50% to 12.50% and also through the gradual reduction of the repo rates from values around 13% at the beginning of 1990 to 7% during the month of September. In this period the Lira was taking advantage of a strong position which had been exploited to better position the currency relative to the tightening of the band margins operated in January 1991.

Finally, the last period is the one that includes the crisis of September 1992 which is included only in the three regime model and needs not extensive comments.

In Figure 4 we present some additional details about the exchange rate behavior during the three periods detected as very high volatility in the three state model. In two cases, the increase in the interest rates volatility is accompanied by a realignment. The very interesting result, which validates our claim that SWARCH can be used as a measure of credibility, is that the increase in volatility has been strongly anticipatory with respect to the realignment itself. By the same token, the impending crisis leading to the realignment cannot be detected with an analysis of the exchange rate which has a distorted behavior due to the presence of the band limits. Also, note that the periods classified by SWARCH as phases of high turbulence are not only characterized by an increase in volatility in the interest rates but also by jumps in the levels of interest rates and the exchange rates.

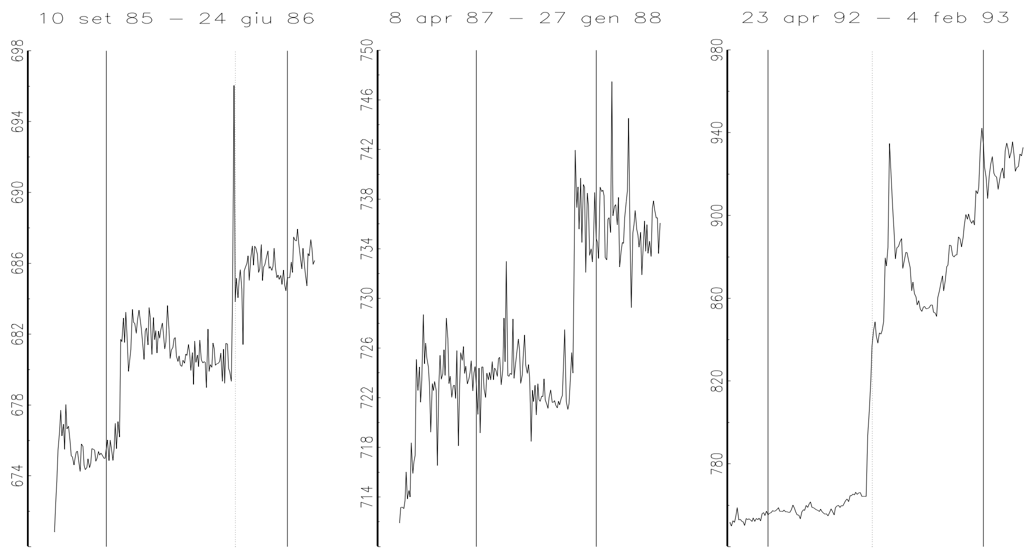

Figure 4: Exchange Rate Lit/DM during the Three Periods of High Volatility.

Admittedly, our regime classification was carried out by considering the smoothed probabilities (computed conditional on the entire sample period) and hence depends on a certain degree of hindsight. As a true *ex ante* measure one might want to consider the filtered probabilities (which we show in Fig. 5 for the three state model), i.e. the probabilities to be in one state at time t conditionally on the observations just up to time t. In such a case the identification of the states would be much less unquestionable, although the attribution of each day to a regime depends on how close to 1 the estimated probability is chosen to be. The more erratic profile in Fig. 5 relatively to Fig. 3 shows that, as expected, outliers have a stronger impact on the filtered probabilities than on the smoothed ones. However, the strength of our results stays unchanged, since the identification of the turbulent period emerges with clarity even from the analysis of filtered probabilities.

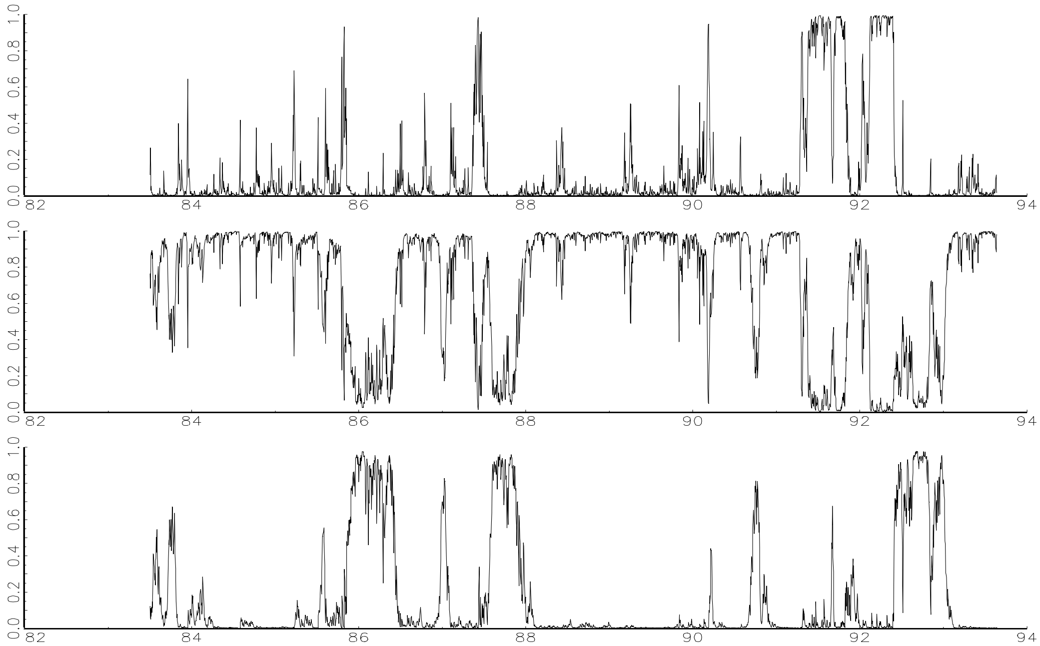

Figure 5: Filtered Probabilities with Three States (Low, Medium and High Volatility).

5 Conclusions

The elements which we have gathered from this SWARCH-based analysis of exchange rate and interest rate behavior seem to suggest relevant insights about the way the exchange rate mechanism of the EMS has worked for the Italian Lira.

In this context the SWARCH approach proved adequate to capture some events of diminished credibility by the monetary authorities, the effects of which surface clearly in the behavior of financial time series.

The extent to which our results signal a very high volatility regime is fairly robust to the use of filtered or smoothed probabilities and hence can be used as an *ex ante* measure of crisis. Situations that required a realignment in the past are correctly identified with our method and the estimated dates of the switch in volatility are quite anticipatory of the impending crisis. This is apparent both in the two state and the three state estimations. In the extended sample where new and previously unobserved levels of volatility occurred, the detection of two regimes becomes obsolete and needs to be supplanted by an increase in the number of regimes to three. By so doing some periods previously attributed to the high volatility regime (in a two state world) are reclassified between the medium and the high volatility regimes.

In particular, the evidence produced here is interesting because it is obtained with daily data (and hence is well suited to the monitoring needs of both the markets and the policy maker) and because it shows how situations in which a situation of distress for the exchange rate is correctly identified in terms of suddenly increased volatility in short-term interest rates.

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