ESSAYS ON EXCHANGE RATE TARGETS AND INTEREST RATES

by

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"...L'essere umano impegna la lotta con le circostanze ambientali, con gli amici cui resta agganciato. A volte sormonta le difficoltà, a volte ne viene sopraffatto. Il mondo altro non vede che il suo lottare, e naturalmente lo fraintende..."

Karl A. Menninger

"La vera felicità
Non consiste nello stuolo degli amici,
Ma nel pregio e nella buona scelta."

Ben Jonson

to Rony
Essays on exchange rate targets and interest rates
by
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ABSTRACT

After the breakdown of the Bretton Wood System, several
countries have specified limits to exchange rate fluctuations,
rather than maintain fixed exchange rates.
The Exchange Rate Mechanism of the European Monetary System
(EMS), for example, prevents the exchange rate between most
pairs of countries from deviating by more than 2.25% from the
relevant central parity.
The existence of target zone exchange rates regimes gives
rise to many questions. For instance, do target zones exchange
rate give Central Banks some degree of monetary independence?
And in particular, can the adoption of a target zone regime, as
in the case of the EMS, facilitate the disinflation effort of
a country? i.e. Can the monetary authorities decide to peg
the exchange rate to a country, whose reputation is of being
a credible inflation fighter, and make easier the process of
disinflation? Has the adoption of a target zone really changed
the exchange rate policy of the countries? To
answer to these questions I have focused my attention on the
EMS and in particular on the experience of Italy.
The first chapter answers the first two questions, which
are, in fact, crucial to understand the large fall in the
inflation rate among the member countries of the EMS. The role
actually played by the "EMS rule" in the disinflationary
process has not been demonstrated yet since the disinflation,
since the early 1980's, has also been substantially outside
the EMS. Furthermore we have not seen a complete convergence
of inflation rates among the member countries.
The idea that joining the EMS must have helped the
countries in their disinflationary effort rests on the
assumption that exchange rate targets are more credible than
monetary targets. But, since the inception of the EMS and
until recently, the central parities have been realigned
periodically and relative large exchange rate movements have
been associated with these realignments. Hence, if the
adoption of a target zone has not really changed the exchange
rate management policy of the countries, i.e. if the nominal
exchange rate band has not been credible, the EMS has played no role. And indeed the data indicate that the bands do not represent a firm commitment to intervention. In fact, after 1979, the French Franc/Deutschmark and the lira/Deutschmark bilateral exchange rates were realigned six and seven times, respectively. It is only after 1987 that the tendency of the franc and the lira to devalue against the mark subsided.

To analyze if the EMS has affected the anti-inflation reputation of the policy-makers, i.e. if the probability that the public assign to the policy-makers pursuing anti-inflationary policies has increased in Italy after 1979, I have analyzed and estimated a simple model.

In the model of slow adjustment of expectations developed, in the first chapter, the public is not sure how strong is the commitment to a fix central parity and revise his expectations as time passes. However the public is aware that there will always be instances when the monetary authorities will want to use the exchange rate under extreme circumstances. This means that the expectations of an exchange rate change will not asymptotically converge to zero. In the presence of wage and price stickiness, and if the private sector is not fully convinced of the switch of regime, this behavior can generate intra-EMS price level divergences. The empirical evidence of this argument has been assessed by showing that the decision to join the EMS has produced a shift in expectations. I have then analyzed expected price series, wage inflation and the unions contractual wage platforms in the period between 1979-1990.

The results obtained demonstrate that the mechanism of inflation expectations have changed after 1987. The empirical estimation of a wage equation in the manufacturing, but not in the public sector, supports this result. It is in fact after 1987 that the Italian monetary authorities have decided not to use the exchange rate as a mean to recover the lost competitiveness.

These results have strengthened my beliefs that the exchange rate management policy in Italy has not changed soon after the decision of joining the EMS. During the 70's one of the objectives of the monetary authorities became that of anticipating, with a devaluation of the exchange rate, the national wage contractual agreements so to alleviate there incidence on the costs bore by the firms in the export sector. Competitiveness had been searched through devaluations. It is my opinion that the same strategy has been followed even after the decision of joining the EMS and that the authorities have not followed a target zone for the nominal exchange rate but an informal and not announced one for the real exchange rate. Therefore, in the second chapter, I have developed a simple model in which a target zone on the exchange rate is announced but an informal target zone for the real exchange rate is followed. The probability that the monetary authorities will intervene to recover the lost competitiveness is increasing in
the real exchange rate deviation from its target level. This behavior induces, in a country with a high inflation, a devaluation of the nominal exchange rate when is still within the nominal exchange rate band. This seem to reproduce the experience of the lira: since 1979 the lira has undergone seven realignments and those have always been implemented when the currency was within the band. This hypothesis has implications for the behavior of the interest rates on financial instruments at different maturities and denominated in different currencies, which depend on the way in which devaluation risk is expected over time. If the expected rate of devaluation increases over time the differential yield curve will be upward sloping for some maturities and hump shaped for longer maturities.

In the third chapter, I have simulated devaluation expectations, using several methods with increasing sophistication and precision. I have referred to the literature on the target zone and I have estimated expected rates of devaluation by subtracting estimates of expected rates of exchange rate depreciation within the band from the interest rate differentials. Since formal tests on the stability of the coefficients indicate that the parameters of the estimated equation have changed over time, I have investigated the possibility of an endogenous regime shift in the series of expected devaluation. I have then examined how devaluation expectations can be explained by a set of macrovariables. My results indicate that the real exchange rate appreciation and wage inflation have a significant positive effect on devaluation expectations in the period 1979-1988, but they lose their explanatory power after 1988. This results confirms our belief that the devaluation of the lira has been a tool to recover the lost competitiveness, even after 1979.

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CHAPTER ONE
LEARNING ABOUT A CHANGE IN REGIME
the EMS once more

I. INTRODUCTION

In his first Annual Report, after the currency crisis that lead to the decision of closing the exchange market for over a month in 1976, the Governor of the Bank of Italy affirmed that "...the decision of closing the exchange market has been taken in the period just before the negotiation for the renewal of the national wage contracts. Wage contracts are now based on an inflationary platform, able to destroy every possible compatibility of the old level of the exchange rate with the new cost of labor..". He then suggested to modify the wage indexation mechanism and to follow a restrictive monetary policy to contain inflation.

At the beginning of 1977 it was clear that radical stabilization measures were inevitable to avoid that domestic inflation and currency depreciation reinforce each other, and in 1979 Italy joined the EMS , after a long debate: "...the EMS initiative, once it was seen to be irreversible, was bound to alter the set of conditions affecting expectations and the behavior of the economic variables...Not joining may have been taken as a declaration of impotent inferiority and worsen that climate: commitment to disinflate outside the system would
appear less credible."¹

After the early 80's inflation differential with Germany fell from double digit figures to 4-5% points.

The disinflation experience of Italy and of other countries in the EMS leaves an important question open: Can the transition from flexible to fixed exchange rates facilitate the disinflation effort of a country? i.e. Can the monetary authorities decide to peg the exchange rate passively to a country, whose reputation is of being a credible inflation fighter, and make easier the process of disinflation?

The answer to these questions is crucial to understand the large fall in the inflation rates among the member countries of the EMS.

The role actually played by the "EMS rule" in the disinflationary process has not been yet demonstrated and there is still no consensus among the economists on how far this development should be attributed to the EMS itself. Disinflation since the early 1980's has also been substantially outside the EMS, and "...no evidence has been brought that membership played a critical role ... or even that exchange rate targets were vitally important. There is a good story in the credibility associated with exchange rate commitments, but how about the U.S. where disinflation was very

¹ Spaventa (1991)
substantial?.."².

Notwithstanding the substantial disinflation, we have not seen a complete convergence of inflation rates among the member countries. France succeeded in bringing down inflation to 3% in 1991 but the same cannot be said of Italy, as Table (1) shows. And recently in Italy emerging change in the real exchange rate and in the external competitive position have confirmed the presence of long lasting nominal rigidities and price costs divergencies that are arousing once again expectations of realignments.

A story of insufficient credibility and incomplete adjustment is confirmed by the interest rate differentials of EMR countries vis a' vis the Germany that have remained high while ex post return differential vis a vis the DM have systematically exceeded maximum permitted changes in the exchange rates within the band indicating the presence of a risk or credibility premia.³

The purpose of this paper is to analyze if the EMS has affected the anti-inflationary reputation of the policy-makers, i.e. if the probability that the public assign to the policy-makers pursuing low-inflation policies has increased in Italy after 1979.

We will follow the argument that place in the slow

² Dornbusch (1990)

³ Giovannini (1990)
adjustment of expectations of the individuals, in the presence of wage and price stickiness, a plausible explanation of intra-EMS price level divergences. When the monetary authorities stuck to a fixed exchange rate, the private sector was not fully convinced by the change in regime. The beliefs of the private sector has been revised optimally only when the authorities increasingly committed to a fixed exchange rate parity.

This "popular" explanation of intra-EMS price level divergences "...has been accepted too readily, especially as an explanation of the inflation, wage growth data...". In particular, so far, no evidence has been produced in favor of the hypothesis of a change in the expectations of the individuals.

This paper provides new evidence in favor of this hypothesis by analyzing expected price and wage behavior in Italy in the period between 1975 and 1991.

In the model of slow adjustment of expectations here developed the public is not sure how strong is the commitment to a fixed exchange rate parity and revises its expectations as time passes. However the public is aware that there will always be instances when the monetary authorities will want to use the exchange rate under extreme circumstances. This means that the expectations of exchange rate changes would not

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4 Froot and Obstfeld (1991)
necessarily asymptotically converge to zero. The learning paradigm has been mixed with the use of the exchange rate as an "escape clause".

The way to assess the empirical evidence of this argument is to show that the decision to join the EMS has produced a shift in expectations.

Empirical analyses of policy credibility in the EMS have often used the prediction error method: they consider the model prediction of the inflation rate arguing that a disinflationary policy has been credible if such prediction overestimate actual values of the inflation rate during the relevant regime period, simply because this models were unable to take account of such regime changes. By using this method Giavazzi e Giovannini (1988) were able to detect a structural instability in the process of formation of prices and wages in Italy after 1984. Unfortunately their finding was not supported by statistical tests. However, this is not a satisfactory test of the credibility hypothesis because the prediction error might explain anything not considered explicitly in the model. This method is useful to test the credibility hypothesis only when the residuals are due solely to the absent credibility variable.

Christensen (1987) avoids that problem by including the credibility policy variable itself in the model and tests its
A different approach has been followed more recently by Barrel-Darby-Donaldson (B.D.D)(1990). Under the hypothesis that labor market structure may have changed either because the perception of wage bargainers have changed or because legal and institutional framework in which wage bargains are made has changed, B.D.D. focus on the impact of the formation of EMS on wage and price behavior.

Wage bargainers have to form expectations about the future in an uncertain environment. Since there are many shocks both to output and to prices that have to be taken into account when forming expectations, wage bargainers have to extract a signal from the shocks. The degree of signal extraction may depend on the reputation of the authorities. A change in reputation will change both the expectations formation mechanism used and the structural relationship in the wage-price system.

It is then possible to expect the estimated equations to show a structural break. And indeed, when they work with

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5 Christensen estimates a modified Fisher interest rate model in order to analyze whether the stabilization of the exchange rate has led to lower nominal interest rate. If the stabilization of the exchange rate induces lower inflation expectations and lower nominal interest rates a necessary condition to sustain high credibility is that the variance of the exchange rate is positively correlated with the interest rate. He implements this test.
Italian data, they do find that both the impact and the long-run effect of unemployment on wages appear to be greater in the 1980's than they were in the 1970's.

The result obtained by B.D.D. is mostly due to the reform in the labor market that lead to the possibility of dismissing workers in the eighties, while this was impossible in the seventies, and is difficult to interpret it, as they instead do, as a change in the expectation formation mechanism due to the Italian authorities commitment to the EMS in 1979.

We would rather prefer to interpret it as a demonstration that EMS membership might have helped by providing a justification for "unpopular" policies.

More recently A. Weber (1991) has measured the effect of the EMS on some countries' credibility analyzing the extent to which belief concerning a policy conform to official announcements about this policy. Credibility is here viewed as a measure of the degree to which policy-makers tie their hands on future policies by issuing policy announcements. The basic idea is that a policy announcement should receive a heavier weight in private-sector forecasts the greater is the policy-makers credibility. Since data on people expectations' before and after the announcements are not available Weber uses as a proxy the least squares predictions on known announced and realized target variables. His empirical estimates of credibility inevitably depend on the choice of the proxy for the unobservable expectations.
The approach we have followed in this paper is completely different. We have used a more "direct" method of assessing credibility by analyzing expected price series, wage inflation and the unions' contractual wage platform in the period between 1975 and 1990.

The availability of survey data on price expectations allows not to rely on an ad hoc assumed mechanism of price expectation. Since agents form their expectations every period, on the basis of past and present information and on the basis of their beliefs about the future, expectations conditional on info data set change when the signal extraction mechanism change.

To search for the most likely point in time in which a shift in regime occurred the econometric procedure adopted here is the non linear approach introduced by Hamilton, which is a non linear filter with antecedents in the work of Goldfeld and Quandt(1973), Nefti(1982), Cosslett and Lee (1985). This technique allows not only to identify a regime change but also to assign probabilities that the process changed to an alternative and specific regime.

The results obtained demonstrates that the mechanism of inflation expectations have changed after 1987. The empirical estimation of a wage equation in the manufacturing, but not in the public sector, supports this result.
2. THE MODEL SET-UP

Our approach is in the spirit of the staggered wage contract model of Fisher (1977), Taylor (1980) and Calvo (1982). I will consider an overlapping contract model with forward looking expectations and incomplete information:

\[ y_t = -a_1(e_t - p_t + p_t^*) - a_2(w_t - p_t) \]  (1)
\[ y_t = b_1(e_t - p_t + p_t^*) - b_2 r_t \]  (2)
\[ r_t = i_t - \pi_{t+1,t} = i_t - (\phi_{t+1,t} - \phi_t) \]  (3)
\[ \phi_t = \alpha p_t + (1 - \alpha)(e_t + p_t^*) \]  (4)
\[ \pi_t = \phi_t - \phi_{t-1} \]  (5)
\[ i_t = i_t^* + (e_{t+1,t} - e_t) \]  (6)
\[ w_{t+1} = \mu w_t + (1 - \mu) q_t \]  (7)
\[ q_t = (1 - \mu) \sum_{i} \mu_i \phi_{t+1,i,t} \]  (8)
\[ e_{t+1,t} - e_t = (p_{t+1,t} - p_t) - (p_{t+1,t}^* - p_t^*) \]  (9)

Equation (1) is a standard supply schedule giving output negatively related to the real wage and augmented with a real exchange rate effect. The real exchange rate affects both the aggregate supply in eq.(1) and the aggregate demand in eq.(2). An appreciation tends to increase an excess supply.

The CPI in eq.(4) is affected by the exchange rate through the price of finished goods imports while eq.(6) is

\[ A \text{ similar specification of the wage equation has been used by Levine-Pearlman (1990)} \]
the familiar uncovered interest parity condition.

Equation (7) gives wages as a geometrically declining average of past contracts prices \( q_t \). These in turn are equal, as eq.(8) shows, to the expected weighted average price level over the future, formed at time \( t \).

\[ \mu \] measures the degree of wage stickiness.

The probability that the contract will last for \( n \) period is equal to \( (1 - \mu) \mu^{n-1} \) and the expected contract length is \( l = \Sigma_n (1 - \mu) \mu^{n-1} = 1 / (1 - \mu) \).

The model is completed by eq.(9) which define the exchange rate policy of the government: the nominal exchange rate is adjusted to restore the level of competitiveness\(^7\).

Suppose that people at a particular point in time come to believe that the exchange rate policy of the government has changed. This initial believe could come from an announcement of the government or from a formal act, for example the choice of joining the EMS. To keep the solution and the discussion simple we suppose that until time \( t < 0 \) the government follows the strategy defined above, keeping the real exchange rate fixed. When \( t > 0 \) the rule followed by the government instead change and

\[ ^7 \text{A good representation of the exchange rate policy of the authorities in the EMS could have been better synthesized by a modified version of eq.(9):} \]

\[ e_{t+1,t} = k[(p_{t+1,t} - p_t) - (p_{t+1,t}^* - p_t^*)] \quad (9'). \]

Eq.'(9) is an extreme version of eq.\((9')\) but our specification choice does not change our results. See Giavazzi-Spaventa(1991).
\[ e_{t+1,t} - e_t = 0 \]  
(10)

i.e. the government decides to fix the nominal exchange rate living the real exchange rate fluctuate.

Additional assumptions are that:

1. the market knows the parameters of the potential new process
2. the information set of the government is complete in that all parameters and the state of the system are known
3. individuals can at no stage directly observe the state of the system.

Under these assumptions the expected exchange rate is defined as:

\[ e_{t+1,t} - e_t = (1 - \theta_t) [(p_{t+1,t} - p_t) - (p_{t+1,t}^* - p_t^*)] \]  
(11)

where \( \theta_t \) is the probability attached by the individuals that the authorities will follow the second rule.

Given \( \theta_t \), and thus the expected depreciation, we can solve the model for the wage rate and the expected price level.

The uncovered interest parity condition (6), using (11) becomes:

\[ r_t = r_t^* - (\alpha \theta_t / L) [(\phi_{t+1,t} - \phi_t) - (p_{t+1,t}^* - p_t^*)] \]  
(12)

where \( L = 1 - \theta_t (1 - \alpha) \)
Prices are set as to equate demand and supply:

\[ p_{t,t-1} - p_{t,t-1} = (a_1 + b_1)(1 - \theta_t) [(\phi_{t,t-1} - \phi_{t-1}) - (p_{t,t-1} - p_{t-1}^*)] + (a_1 + b_1)(p_{t,t-1} - p_{t-1}^*) L + a_2(w_{t,t-1} - w_{t-1}) L - b_2(r_{t,t-1} - r_{t-1}) / PL \]

(13)

where \( P = a_1 + a_2 + b_1 \)

Substituting this expression in equation (5) and using (12) we can write expected inflation as:

\[ (\phi_{t,t-1} - \phi_{t-1}) = \theta_t(a_1 + a_2 + b_1 + b_2 \alpha - a_2 \alpha)(p_{t,t-1} - p_{t-1}^*) + a_2 L(w_{t,t-1} - w_{t-1}) - b_2 L(r_{t,t-1} - r_{t-1}^*) + b_2 \alpha \theta_t(p_{t+1,t-1} - p_{t,t-1}^*) / D \]

(14)

where \( D = a_2 + b_2 \alpha \theta_t + \theta_t(a_1 + b_1) \)

**Result 1:** For a given wage inflation, the higher is the perceived probability of being in the new regime the lower will be the expected domestic price inflation.

**Proof:** From eq.(13) and eq.(14) it is easy to verify that \( (p_{t,t-1} - p_{t-1}) \) and \( (\phi_{t,t-1} - \phi_{t-1}) \) are decreasing in \( \theta_t \).

See Appendix for an analytical proof.

Contractual inflation will be equal to:

\[ q_{t-1} - q_{t-2} = (1 - \mu) \Sigma \mu^I(\phi_{t+1} - \phi_{t+1-1}) = (1 - \mu) [\pi_{t,t-1} + \Sigma \mu^I(\pi_{t+1,t-1} - \pi_{t+1,t-1,t-2})] \]

(15)

and wage inflation:
\[ w_t' = \mu w_{t-1} + (1-\mu)^2[ \sum_i \mu^i (\pi_{t+i,t-1} - \pi_{t+i-1,t-2}) + \pi_{t-1}] \]

(16)

where \( w_t' \) = wage inflation

The higher the expected future inflation rate the higher will be the wage inflation.

The two key parameters that affects the convergence of inflation towards zero are \( \theta_t \) and \( \mu \).

**Result 2:** If \( \theta_t=0 \), i.e. if the private sector assumes that the government continues to keep the real exchange rate constant, the expected inflation rate is higher than the foreign one even when \( \mu \), the degree of wage stickiness, is equal to zero.

**Proof:** When \( \theta_t=0 \) and \( \mu=0 \) by eq. (16)

\[ w_t = \pi_{t-1} + (\phi_{t-2} - \phi_{t-1,t-2}) \]  

(16')

Substituting (16') in (14), under the hypothesis that the foreign interest rate is expected to remain constant, we obtain: \( \pi_{t,t-1} = a_2 \pi_{t-1} + a_2 (\phi_{t-2} - \phi_{t-1,t-2}) \)

Agents inflation expectations for time \( t \), formed at time \( t-1 \), are based on past inflation adjusted for a forecast error. But by hypothesis \( \pi_{t-1} > \pi_{t-1}^* \).

**Result 3:** If \( \theta_t=1 \), i.e. the private sector recognizes the shift of the government towards a fix nominal exchange rate policy, the expected domestic inflation rate converges to the expected
foreign inflation rate only when $\mu$, the degree of wage stickiness, is equal to zero.

**Proof:** Let $\theta_t=1$ and $\mu=0$. Again substituting (16') in (14), under the hypothesis that foreign interest rate are expected to remain constant, we obtain:

$$\pi_{t,t-1} = \pi_{t,t-2}^* + a_2 (\phi_{t-1} - \phi_{t-1,t-2})$$

expression that tells us that individuals form their expectations of tomorrow domestic inflation on the basis of the expected foreign inflation rate. The expectation is adjusted for a forecast error.

If $\mu \neq 0$ the convergence of the expected domestic inflation rate to the expected foreign inflation rate is a function of the degree of wage stickiness, i.e. of $\mu$.

3. LEARNING ABOUT THE CHANGE IN REGIME

Until here we have treated the probability $\theta_t$ as a fix parameter. If we let the private sector learn through time we can obtain more interesting results.

A convenient way to parametrize this evolution is to suppose that the market assessed probabilities follows a Markov process. The transition matrix to the Markov process can be written as:
\[ A = \begin{pmatrix} 1-q & q \\ z & 1-z \end{pmatrix} \]  

(17)

where

\[ \text{Prob}[S_t = 1 / S_{t-1} = 1] = z \]
\[ \text{Prob}[S_t = 0 / S_{t-1} = 1] = 1-z \]
\[ \text{Prob}[S_t = 0 / S_{t-1} = 0] = q \]
\[ \text{Prob}[S_t = 1 / S_{t-1} = 0] = 1-q \]

People believe that the probability of going from the state, that we now call 0, in which the real exchange rate is kept fixed to the state 1 in which the nominal exchange rate is kept constant, is equal to 1-q. People recognize also the possibility that the government decides to shifts back to the previous regime and we define with (1-z) the assessed probability that the government reverts to the first process.

The structure of the information is important here. We suppose that the individuals fix the wages at the beginning of time \(-t\)- for time \(-t+1\)- and form inflation expectations after having observed the inflation today, knowing all the past history.

People do also recognize the possibility of changes in regime and incorporate this into their forecast for the future.

To obtain the best forecast of \(\theta_t\) market participants combine their prior beliefs together with the observation of the inflation rate each period to update their posterior
probability according to Bayes' rule.

Given a certain prior about the probability of being in regime 1 or 0 based on past information

\[ \text{Prior}(S_{t-1}) = \frac{z \text{Post}(S_{t-1}=1) + (1-q)(1-\text{Post}(S_{t-1}=1))}{(1-\text{Prior}(S_{t-1}))\text{Post}(S_{t-1}=0)} \]  \hspace{1cm} (18)

with

\[ \text{Prior}(S_{t-1}=1) = \text{Prob} \left[ S_{t-1}=1 / \pi_{t-2} \ldots \pi_0 \right] \]  \hspace{1cm} (19)

\[ \text{Post}(S_{t-1}=1) = \text{Prob} \left[ S_{t-1}=1 / \pi_{t-1} \ldots \pi_0 \right] \]  \hspace{1cm} (20)

agents calculate the density function of \( \pi_t \):

\[ f(\pi_t/\pi_{t-1}\ldots\pi_0) = \text{Prior}(S_t=1)f(\pi_t/S_t=1) + (1-\text{Prior}(S_t=1))f(\pi_t/S_t=0) \]  \hspace{1cm} (21)

with

\[ f(\pi_t/S_t=1) = \exp(-\frac{1}{2})[a_1^2+a_2^2+b_1b_2\alpha-a_2^2\alpha - a_2L(w_{t-1} - w_{t-1}) + b_2L(r_{t-1} - r_{t-1}) - b_2\alpha(\phi_{t-1} - \phi_{t-1}) + b_2\alpha\theta_i(p_{t-1} - p_{t-1})] / D \]  \hspace{1cm} (22)

where \( i = 0, 1 \) and \( D = a_2 + b_2\alpha\theta_i + \theta_i(a_1 + b_1) \)

\[ L = 1 - \theta_i(1 - \alpha) \]

and update their prediction using Bayes' rule:

\[ \text{Post}(S_t=1) = \frac{f(\pi_t/S_t=1)\text{Prior}(S_t=1)}{f(\pi_t/S_t=1) + (1 - \text{Prior}(S_t=1))f(\pi_t/S_t=0)} \]  \hspace{1cm} 24
Result 4. If people recognize the possibility that the government will revert to the old rule, devaluing the exchange rate, expected inflation tomorrow will not be equal to the expected future foreign inflation rate.

Proof: The proof of this statement comes straightforwardly from observing expression (18). In fact even if, at the end of period \((t-1)\), \(\text{Post}(S_{t-1}=1) = 1\) we do not necessarily obtain that the prior probability of being in state \(1\), at the beginning of time \(t\), is equal to 1 but we obtain that \(\text{Prior}(S_t=1) = z\). When the private sector recognizes that the government can revert to the old rule he assign a positive probability to the event of a devaluation tomorrow equal to

\[ e_{t+1,t} - e_t = (1-z)(p_{t+1,t} - p_t) \]  

(23)

and expected inflation will not be equal to the expected foreign inflation rate.

Eq. (23) resembles the use of the exchange rate as an "escape close" as in the model of Flood and Isard\(^8\).

The behavior of the probabilities depend upon the actual observation of the process. The more the real exchange rate tends to appreciate the higher is the probability attached by

\(^8\) In the model of Flood and Isard (1988) the monetary authorities retain the possibility of overriding the monetary rule if and only if the shock in the economy is large.
the individuals that the exchange rate policy, i.e. the inflationary stance of the government, follows the new process.\(^9\)

Before considering the estimation results we want to discuss the behavior of the interest rate.

Eq. (12) define the uncovered interest parity in real term as

\[
  r_t = r_t^* - (\alpha \theta_t / L) [(\phi_{t+1,t} - \phi_t) - (p_{t+1,t}^* - p_t^*)]
\]

where \( L = 1 - \theta_t (1 - \alpha) \)

Let's consider what happens if the shift in regime of the government is not credible and the people attach a probability \( \text{Prob}(S_t = 0 | S_{t-1} = 0) = q = 1 \) of remaining in the old regime. Then

\[
e_{t+1,t} - e_t = (p_{t+1,t} - p_t) - (p_{t+1,t}^* - p_t^*)
\]

and \( r_t = r_t^* \) i.e. the real interest rates in the two countries equate.

If instead the shift is perfectly credible and people attach a probability \( z = 1 \) of remaining in the new regime forever then

\[^9\] It could also be possible to argue that the more the currency is appreciated the higher is the probability that the government is, let's say, "pushed" to revert to the old policy. This counter effect could be taken into consideration by making \((1-z)\), the probability of reverting to the old process at time \( t \), not constant as above but a function of the degree of the exchange rate appreciation.
\[ r_t = r_t^* - [\pi_{t+1},t - \pi_{t+1},t^*] \] (24)

and the real interest rate is lower in the country with the higher inflation rate. It seems that we obtain exactly what is called the "Walter critique to the EMS": an inflationary economy that enters the EMS without capital controls is forced by financial arbitrage to lower nominal interest rates; but the lower interest rates stimulate the economy and exacerbate inflation.

Only if the peg is not credible, Sir Alan Walters argues, will this tendency for inflation to diverge be checked.

In reality if we look at expression (24) we do not obtain this perverse effect.

In this case, as we have seen above, \( \theta_t = 1 \) and, when \( \mu = 0 \), the domestic inflation rate converge to the foreign inflation rate. When the peg is credible the nominal interest rate and the inflation rate move by exactly the same amount and the effects Walters predicts do not occur.

4. ESTIMATION PROCEDURE AND RESULTS.

a. Expected inflation

The extent to which counterinflation reputation, here defined as the probability that policy makers consistently pursue low inflationary policies, has increased in the
countries that have joined the ERM has been recently studied by Alex Weber (1991). The Bayesian procedure he adopts consists in finding out how inflation could be forecasted over each sub periods by computing inflation forecasts as a probability weighted average of four alternative forecasting models and evaluating the relative success of each of these forecasts over time. The strength of counterinflation reputation can be measured by the weight attached to the "low inflation " forecast. The critiques that have been moved to the above procedure rest mainly on the ad hoc nature of the model of the inflation expectations mechanism. In fact Weber uses as a proxy for the unobserved expectations least squares predictions on known announced and realized target variables.

We have followed a different approach, estimating a modified version of eq.(14) using data on expected price inflation provided by the survey conducted in Italy by the economic magazine Mondo Economico since 1952. The advantage of having a series of data on expected prices is that we do not need to specify an ad hoc mechanism of price expectations\(^{10}\).

We can rewrite eq.(14) as:

\(^{10}\) These surveys date back to 1952 and are not qualitative surveys. The interviewee can provide an appropriate answer not being asked for an exact estimate but having only to choose from among a number of pre-selected intervals which he expects will contain the rate of price change for the next quarter. The respondents are "qualified" and "informed" businessmen in production,commerce, the banking and the financial world, and economic experts.
\[(\phi_{t,t-1} - \phi_{t-1}) = \theta_t (a_t + a_2 + b_1 - a_2 \alpha) (p_{t,t-1} - p_{t-1}^*) + a_2 L (w_{t,t-1} - w_{t-1}) - b_2 L (i_{t,t-1} - i_{t-1}) + b_2 a L (\phi_{t+1,t-1} - \phi_{t,t-1}) / D^{11}\] (25)

where \( D = a_2 + b_2 a \theta_t + \theta_t (a_1 + b_1) + b_2 L \)

The estimated equation is the below equation (26):

\[
\pi_{t,t-1} = c_{1_1} w_{t-1} + c_{2_1} w_{p_{t-1}} + c_{3_1} \pi_{t-1}^* + c_{4_1} (\phi_t - \phi_{t-1}) + c_{5_1} (\phi_{t+1,t-1} - \phi_{t+1}) + c_{6_1} (i_{t-1} - i_{t-1})^{12}
\] (26)

with

\( \pi_{t,t-1} \): log-change in the consumer price index expected at the end of the quarter \((t-1)\) for quarter \(t\)

\( w_{t-1} \): wage inflation in the manufacturing sector

\( w_{p_{t-1}} \): wage inflation in the public sector

\( i_{t-1} \): nominal interest rate on three month T-Bills

\( \pi^* \): foreign prices

where we have differentiated the role played by wage inflation in the public sector and in the manufacturing sector in the formation of domestic inflation expectations.

The model analyzed in the previous section predicts that the paths of the wage rate and of expected inflation follow two different processes depending on the probability attached by the individuals to the change in regime.

\[\text{Eq. (25) is obtained by substituting eq. (13) in eq. (5) without using the uncovered interest parity condition (6). In fact Italy has maintained controls on capital movements until 1990.}\]

\[\text{12 Since we do not have a series of data on } \pi_{t+1,t-1} \text{ we have supposed that agents forms expectations of the inflation at time } t \text{ using the following rule: } \pi_{t+1,t-1} = \pi_{t+1,t-1} + r (\pi_t - \pi_{t,t-1}) \text{ and we have substituted this expression in eq. (25) obtaining eq. (26)}\]
In particular, as \( \theta \rightarrow 1 \) individuals should assign more weight, in forming their expectations, on foreign prices and domestic prices should move closer to them.

To search for the most likely point in time in which a policy shift could have occurred the econometric procedure adopted here is similar to the non linear approach introduced by Hamilton, which is a non linear filter with antecedents in the work of Goldfeld and Quandt (1973), Nefti (1982), Cosslett and Lee (1985). The estimation procedure is the following: we start at \( t=1 \) with the unconditional probability \( \beta \), which we set equal to the limiting probability of being in state 1 of the Markov process described in (17),

\[
\beta = \frac{1-q}{[(1-z)+(1-q)]} \tag{27}
\]

Then, by using (18)-(22) we construct the sample log-likelihood

\[
\ln[f(\pi_t, \pi_{t-1}, \ldots, \pi_1)] = \sum_t \ln[f(\pi_t/\pi_{t-1}, \ldots, \pi_1)] \tag{28}
\]

which can be maximized numerically with respect to the unknown parameters.

From the estimation we can obtain the probability that the process was in regime 1 at date \( t \) on the basis of the information available at the time, \( P(S_t=1/\pi_t, \ldots, \pi_1) \), which is

30
defined the "filter" inference about the probable regime at date t. Alternatively, we can use the full sample of ex-post available information \((\pi_1, \ldots, \pi_T)\) to draw inference about the state of the process at some date \(t\), \(P(S_t = 1/\pi_1, \ldots, \pi_T)\), which is defined as the "smoothed" inference about the regime at date \(t\).

The drawbacks of the Hamilton filter is that the probability of the switch in regime is modelled as a constant. An interesting extension would be to allow the probability to depend on some alternative variable.

Table (2) reports maximum likelihood estimates. The estimates shows that inflation expectations has been "driven" by the wage in the manufacturing sector until mid-eighties, period after which in the public sector it has been experienced an autonomous wage push that has increased expected inflation.

Fig. (1) plots expected price inflation. Fig. (2) plots the smoothed probability that the process was in regime 1 at each date of the sample; that is, \(P(S_t = 1/\pi_1, \ldots, \pi_T)\) is plotted as a function of \(t\). This inferences uses the full sample of observations of \(\pi_1, \ldots, \pi_T\) and the maximum likelihood estimates of the parameters to draw inference about the state of the process at each date \(t\).

If we accept that the process had switched between the two regimes when \(P(S_t = 1/\pi_1, \ldots, \pi_T) > 0.5\) it is easy to see a

---

13 Hamilton (1990)
change in regime after 1987, when the monetary authorities decided to resist any temptation to devalue the lira.

As predicted by the model expected foreign inflation becomes more significant in the formation of expected domestic inflation in the second period.

The estimated probabilities indicate that when the system is in state 1 is likely to stay in that state.

The detected change in regime is well after the structural break found by Giavazzi and Giovannini (1989). This should not appear strange. After Italy had joined the EMS the lira has been devalued seven times and the monetary authorities only recently have decided not to use the exchange rate as a mean to recover the lost competitiveness.

3.2 From expected inflation to wages.

The analysis of the Italian price and wage inflation is also the analysis of the unions' contractual strategy and of the evolution of the relations and the agreements among unions, employers' associations and the government.

Indexation of wages to inflation has been at the center of the negotiations between the unions and the government since the earlier seventieth leading to a formal agreement called the "Scala Mobile". The agreement defined a coefficient of coverage of wages to inflation which has varied considerably during the whole period. In 1975-1977 the degree
of coverage of the Scala Mobile increased, making the pass through of prices to inflation more rapid. The Bank of Italy estimates shows that the proportion of change in wages "caused" by the scala Mobile rose from 60% in 1975 to 80% in 1978.

In 1978, at the Congress held at Eur (Rome), one of the three most important unions, the Cgil\textsuperscript{14}, expressed the need for a strategy of more moderate salaries in order to sustain the government and his fight against inflation. But the decision of the Communist party to resign from the parliamentary majority in 1979 determined the refuse of the Cgil to pursue this new strategy.

In 1983, after a year of negotiation and debate over the indexation mechanism the government, the unions and the employer's association reached an agreement that reduced the coefficient of indexation from 1 to 0.85 percent.

The agreement was characterized by the highest level of centralization ever experienced and by a high level of political involvement of the unions. It was seen as a signal of a change in the system of industrial relations and the beginning of a neo-corporativism, i.e. of a new system of trilateral negotiations. The aim of the government was to reduce the inflation rate to 13% in 1983, 10% in 1984 and 7% in

\textsuperscript{14} The three most important unions are: the Cgil, whose majority of members are communists, the Uil, whose majority of members are socialists and republicans, the Cisl, whose majority of members are christian democrats.
1985. The government promised as a return to lower the fiscal pressure on the wages.

At the beginning of 1984 the situation worsened again creating new conflicts between the unions and the government. The employer association pushed the government to open again the negotiation with the union to lower the degree of coverage of the Scala Mobile. But in this case the three unions decided to adopt different strategies. The Cisl and Uil decided to negotiate with the government but inside the Cgil the communist, but not the socialists, assumed an anti-governmental position.

The government decided\textsuperscript{15} to intervene directly by issuing a decree with the force of law. The decree of San Valentino, as it was popularly called, signed a formal breakdown of the negotiations with the unions and also a crisis of representativeness of the unions.

It is in this scenario that the big reform of the Scala Mobile was accepted in 1985. The frequency of adjustment of wages to prices were reduced from quarterly to half yearly and the rule of indexation was modified so to let low wages be fully compensated and wages above a certain minimum partially indexed or not indexed at all.

And it is after then that we detect a switch in regime in the estimated equations of wage inflation in the manufacturing sector.

\textsuperscript{15} February 1984
I have estimated wage inflation in the manufacturing sector and in the public sector separately.

Among the specification we have explored, the one which appears to fit the data better is the following:

\[ w_{m,t} = d_{11} \pi_{t-1} + d_{21}(1 - \tau_t) \pi_{t,t-1} + d_{31} t + d_{41}(w_{t-1} - p_{t-1}) + d_{51} u_{t-1} \] (29)

\( \tau_t \): the degree of indexation, is not a constant.

\( u_t \): unemployment rate

\( t \): time trend, a proxy for productivity growth.

The period of estimation is 1975:3-1990:04.

Eq. (29) differs from eq. (16) only for an error correction term and for the coefficient of indexation of the nominal wages\(^{16}\).

The specification (29) implies that when \( \tau_t \), the coefficient of indexation, has been lowered wages have been set on the basis of inflation expected for time \( t \).

Estimates of equation (29) are reported in table (3). The difference between the two regime is clear cut.

Fig. (3) plots wage inflation in manufacturing. Fig. (4) plots the smoothed probability that the process was in regime 1 at each date of the samples.

The change is apparent in the first quarter of 1987, but, as can be seen, the probability attached to the shift in regime is not equal to 1. It is not puzzling the fact that we

\(^{16}\) We have estimated (29) by letting \( \mu = 0 \) since in previous estimations the coefficient of the lag wage inflation was not significantly different from 0.
do not see a change in regime right after 1985 but only in 1987. When we compute the degree of coverage of the Scala Mobile we need to take into consideration that the cost-of-living bonus is paid only at the beginning of the following semester.

If we look at the coefficients of the equation estimated the most important difference seems to be in the role played by price expectations in the two periods and by the coefficient of the unemployment. In state 0, wages are more "backward looking": $\pi_{t-1}$, the lagged price inflation appears to be the most important variables that explain wage inflation in this period.

The unemployment rate seems not to have a big influence in explaining wage inflation.

This result is not puzzling. In fact the government during the eighties had played a crucial role in the process of restructuring of industry. While during the seventieth it was impossible for the firms to fire workers. Between 1980-1985 1 million workers were displaced from industry. The government introduced a wage compensation mechanism (CIG) that preserved almost entirely displaced worker's wage, but also worked to reduce the impact of unemployment on the labor market.

The unemployment rate seems to have a higher effect in mitigating wage inflation in the second period. Moreover while the lagged inflation ($\pi_{t-1}$) is not significant it
becomes important in explaining expected wage inflation $\pi_{t,t-1}$, i.e. the expectations of inflation for the period $t$ formulated using information at time $t-1$. If we maintain the hypothesis that wage are set the period before being paid we can conclude that in the second period wages are more "forward looking".

A different story seems to be told by wages in the public sector.

In fact more evident, since 1979, has become the division of the Italian economy in two different "macro-sectors". The first "protected" from international competition (construction, public and private services) and the second "not protected", i.e. exposed to the international competition (manufacturing and food industry). These two sectors had had a complete divergence in prices and wages.

When in the second half of the eighties the monetary authorities has abandoned the devise of devaluing the lira to restore the lost competitiveness the non protected sector have tried to limit costs and price inflation. And as demonstrated above the wage in the manufacturing sector has shown a different behavior after 1987.

Instead strong autonomous wage push pressures developed in the public sector which is also increased in terms of weight on total employment. In the public sector the number of employed people went from 2.363.000 in 1970 to 3.616.000 in 1989 while total employment in manufacturing declined from
Moreover between 1980 and 1986 the average weight of employment compensation on public expenditure has reached 21.5%.

The equation estimated for the public sector

\[ \text{wma}_{it} = f^1_i \pi_{t-1} r_t + f^2_i (1 - r_t) \pi_{t-1} + f^3_i t + f^4_i (w_{t-1} - p_{t-1}) + f^5_i u_{t-1} + f^6_i h_{t-1} \quad (30) \]

\(r\): the degree of indexation, is not a constant.
\(u\): unemployment rate
\(t\): time trend, a proxy for productivity growth.
\(h\): hours lost in strikes and wage conflicts.

The period of estimation is 1975:3-1990:04.

Eq. (30) differs from eq. (29) only for the variable \(h\) that measure the hours lost in strikes and wage conflict in the public sector. Estimates of eq. (30) are reported in table (4).

The smooth probability that the process was in regime 1 at each date of the sample is plotted in Fig. (6).

A change in regime is apparent at the end of 1986. But the new regime is characterized by a higher level of wage inflation and, what is more striking, the variable \(h\), hours lost in the previous period in strikes and conflicts in the public sector, is the most important variable that explains the public sector wage inflation after 1986.

The increase in wage inflation has not been accompanied by an increase in productivity, which is one of the most important problems of the Italian public sector.

Wage growth has been fuelled by imitative behavior inside the public sector while the unemployment rate has not
helped much in mitigating wage growth.

4. CONCLUSION

Has the European Monetary System helped member countries to disinfla\text{t}e during the 80's? The main focus in this paper is on the reputation effect of the EMS, defined here as the probability which the public assign to the consistent pursue of a low inflationary policy. It is derived by learning over time from the actual behavior of the monetary authorities. The way to assess the empirical relevance of the learning process is to show that the decision to join the EMS has produced a shift in expectations. This paper provides new evidence in favor of this hypothesis by analyzing expected price and wage behavior in Italy in the period between 1975 and 1990.
APPENDIX

Let's consider equation (13):

\[
p_{t,t-1} - p_{t-1} = \left(a_0 + b_0 \right) (1 - \theta_t) \left[ (\phi_{t,t-1} - \phi_{t-1}) - (p_{t,t-1}^* - p_{t-1}^*) \right] + \left( a_1 + b_1 \right) (p_{t,t-1}^* - p_{t-1}^*) L_t + a_2 (w_{t,t-1} - w_{t-1}) L - b_2 (r_{t,t-1} - r_{t-1}) / PL
\]

(13)

where \( P = (a_0 + a_2 + b_1) L \) and \( L = 1 - \theta_t (1 - \alpha) \)

To understand which is the effect on expected domestic inflation of an increase in the perceived probability that we are in the new regime we need to differentiate (13) by \( \theta_t \).

\[
d(p_{t,t-1} - p_{t-1}) / d\theta_t = \alpha \left[ (\phi_{t,t-1} - \phi_{t-1}) - (p_{t,t-1}^* - p_{t-1}^*) \right] (b_2 - a_1 - b_1) / PL^2 < 0
\]

expression which is negative since \( (b_2 - a_1 - b_1) < 0 \).

DATA APPENDIX

The data used in this paper are:

\( \pi_{t,t-1} \) : expected inflation.
Source: survey data by Mondo Economico

\( \text{wm}', \text{wpa}' \): wage inflation in the manufacturing and in the public sector.
Source: ISTAT

\( i \) : nominal interest rate on three month T-Bills
Source: Banca Commerciale Italiana

\( \pi^* \) : weighted average of foreign prices used by the Bank of Italy as a measure of foreign competitiveness
Source: Bank of Italy

\( r \) : degree of indexation
Source: Bank of Italy

\( u \) : unemployment rate adjusted for CIG
Source: Bank of Italy

\( h \) : hours lost in strikes and wage conflicts.
Source: ISTAT

\( p \) : consumer price index
Source: Bank of Italy
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<th>Italy</th>
<th>U.K.</th>
<th>Germany</th>
<th>France</th>
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<tr>
<td>1981</td>
<td>19.5</td>
<td>11.9</td>
<td>6.3</td>
<td>13.3</td>
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<tr>
<td>1985</td>
<td>9.2</td>
<td>6.1</td>
<td>2.2</td>
<td>5.8</td>
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<td>1991</td>
<td>6.12²</td>
<td>4.1¹</td>
<td>3.5²</td>
<td>2.6¹</td>
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Source: Bank of Italy. Annual Report 1991

¹ September 1991– September 1990
² October 1991– October 1990
Table 2

a) Maximum Likelihood Estimates of Parameters and Asymptotic Standard Errors

Expected inflation Estimation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
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<tbody>
<tr>
<td>$c_{11}$</td>
<td>0.3580</td>
<td>0.07348</td>
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<tr>
<td>$c_{21}$</td>
<td>0.0340</td>
<td>0.0424</td>
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<tr>
<td>$c_{31}$</td>
<td>0.2227</td>
<td>0.141644</td>
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<td>$c_{41}$</td>
<td>0.2433</td>
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<tr>
<td>$c_{51}$</td>
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<td>$c_{61}$</td>
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<td>$c_{12}$</td>
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<td>$c_{22}$</td>
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<td>$\sigma_2$</td>
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$p$  
$q$
Table 3

a) Maximum Likelihood Estimates of Parameters and Asymptotic Standard Errors

Inflation Wages in the Manufacturing sector

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
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<td>$\sigma_1$</td>
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<td>$d_{22}$</td>
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<tr>
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**Table 4**

a) Maximum Likelihood Estimates of Parameters and Asymptotic Standard Errors

<table>
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<th>Parameter</th>
<th>Estimate</th>
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</tr>
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<td>$f_{11}$</td>
<td>0.04728</td>
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<td>$f_{21}$</td>
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<td>0.04071</td>
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<td>$f_{31}$</td>
<td>0.2001</td>
<td>0.43396</td>
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<td>$f_{41}$</td>
<td>-0.14298</td>
<td>0.09591</td>
</tr>
<tr>
<td>$f_{51}$</td>
<td>0.3127685</td>
<td>0.41041</td>
</tr>
<tr>
<td>$f_{61}$</td>
<td>0.0007109</td>
<td>0.00108</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>0.0257227</td>
<td>0.00123</td>
</tr>
<tr>
<td>$f_{12}$</td>
<td>0.19437</td>
<td>0.02531</td>
</tr>
<tr>
<td>$f_{22}$</td>
<td>0.00371</td>
<td>0.003608</td>
</tr>
<tr>
<td>$f_{32}$</td>
<td>-2.6526</td>
<td>1.47</td>
</tr>
<tr>
<td>$f_{42}$</td>
<td>-0.54757</td>
<td>0.19274</td>
</tr>
<tr>
<td>$f_{52}$</td>
<td>-1.98066</td>
<td>0.95685</td>
</tr>
<tr>
<td>$f_{62}$</td>
<td>0.0078946</td>
<td>0.00274</td>
</tr>
<tr>
<td>$\sigma_2$</td>
<td>0.0147992</td>
<td>0.00295</td>
</tr>
</tbody>
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Figure 1. Expected Inflation
Figure 2. Probability $S_t=1$
Figure 3. Wage Inflation in Manufacturing
Figure 4  Probability $S_t=1$
Figure 5 Wage Infl. in Public Sector
Figure 6  Probability $S_t=1$
CHAPTER TWO INTEREST RATES AND COMPETITIVENESS

I. INTRODUCTION

Special attention has been devoted in international financial theory to the properties of exchange rate dynamics within a target zone. However, observation of the data suggest the source of inconsistency between the standard model of exchange rate target zone and reality: in the EMS, within band exchange rate movements have been dwarfed by relative frequent and relative large realignment.

The experience of the lira is particularly interesting. Since Italy has joined the EMS in 1979 the lira has undergone seven realignments and those have always been implemented when the currency was within the band.

The recent literature has begun to formalize these facts, making explicit and more realistic assumptions as to the behavior over time of the exchange rate. Svensson (1991) has developed a model in which the target zone is defended by infinitesimal interventions and devaluations of fixed size occur with constant probability intensity; Bertola and Caballero (1990) argue that repeated interventions should affect the likelihood and/or the size of realignments and propose a stylized model in which the level of reserves affects the position and shape of the relationship between expected depreciation and the exchange rate. Bertola and
Svensson (1991) allow for stochastic fluctuations in the size and in the likelihood of devaluations.

These papers have given a notable contribution but they have been unable to capture the experience of countries like France and especially Italy where devaluations have been a tool to restore competitiveness.

In the present paper we develop a simple model in which a target zone for the nominal exchange rate is announced but the authorities follow an informal and not announced target zone for the real exchange rate. The term informal means that the real exchange rate can perforate any exogenously given ceiling or floor with non zero probability. The probability that the monetary authorities will intervene to recover the lost competitiveness is increasing in the real exchange deviation from its target level. This behavior induces, in a country with a high inflation, a devaluation of the nominal exchange rate when it is still within the band.

This hypothesis have implications for the behavior of the interest rates on financial instruments at different maturities and denominated in different currencies, which depend on the way in which devaluation risk is expected over time. If the expected rate of devaluation increases over time then the differential yield curve will be upward sloping for some maturities and hump shaped for longer maturities.

The plan of the paper is as follows. Section II present some stylized facts that justify our
hypothesis of an informal target zone on the real exchange rate. We will concentrate our attention on the experience of France and especially of Italy. In section III a survey of the most important empirical implications of target zone models is developed. We distinguish a first generation and a second generation of target zone models.

Section IV develops a simple target zone model in which, following Miller and Weller (1990, 1991) we introduce a form of price inertia. As shown by Sutherland (1992) this hypothesis does not change most of the qualitative results of the traditional target zone models but allows us to consider the possibility of departure of the exchange rate from a Purchasing Power Parity condition. It also implies that a change in nominal exchange rate and nominal interest rates lead to changes in the same direction in the real exchange rate and in the real interest rates.

Section V concludes.

II. FACTS

In the early 1970's supply shocks affected all European economies. Nominal wages and unit labor costs increased in all major countries.

In Italy the effect of the oil shock was stronger than in other countries due to the greater dependence on imported oil. The increase in labor costs accelerated in the same period
worsening the economic situation.

Table (1) compares unit labor costs in manufacturing for some European countries.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>12.6</td>
<td>17.9</td>
<td>14</td>
<td>10.4</td>
<td>4.7</td>
</tr>
<tr>
<td>7.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>11.6</td>
<td>9.2</td>
<td>6.2</td>
<td>5.1</td>
<td>5</td>
</tr>
<tr>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.K.</td>
<td>15.6</td>
<td>20.5</td>
<td>15.6</td>
<td>10.3</td>
<td>9.1</td>
</tr>
<tr>
<td>4.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>25.8</td>
<td>22.5</td>
<td>16.9</td>
<td>16.3</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Source: OCSE and ISTAT

In 1974 nominal labor costs increased much faster in Italy than in anywhere else.

In 1975 the degree of wage indexation (Scala Mobile) increased making the pass through of prices to inflation more rapid. In the same year the closure of the foreign exchange market coincided with a round of re-negotiations of the main national-wide labor contracts based on inflationary claims which, if granted, would destroy any hope of compatibility between the old exchange rate and the onerous new labor costs. One of the objectives of the monetary authorities became that
of anticipating, with a devaluation of the exchange rate, the national wage contractual agreements so to alleviate their incidence on the costs borne by the firms in the export sector. During 1976 the devaluation of the lira helped to absorb more of the economy's inflationary potential than in the past.

The policy response to the shocks was then a blend of supply side measures, inflation and exchange rate depreciation, as Giavazzi and Spaventa(1989) well describe.

Without the depreciation of the lira, in fact, the high inflation rate, the strong contractual power of the unions and the weak resistance to the wage push of the entrepreneurs would never be in accord with the external competitiveness and the profitability of the export sector.

Giavazzi and Spaventa(1989) remind us how a mixture of subsidies and exchange rate depreciation can be used in an indexed economy hit by a supply shock to yield the following results: a favorable effect on the supply side, by restoring profitability; a favorable effect on the demand side, by inducing a real depreciation and stimulating export and additional revenues to finance the subsidies. This has been the economic policy strategy followed by Italy.

It is often been claimed that the monetary authorities have changed their policy recipe after joining the EMS in 1979, as inflation was accelerating.

The idea that joining the EMS must have helped Italy in
its disinflationary effort rests on the assumptions that exchange rate targets are more credible than monetary targets. We have seen in a previous paper that it is not possible to detect an EMS effect on inflation expectations and wages after 1979. It is possible to see a change in the behavior of inflation expectations and wages in the manufacturing sector only after 1987 when the Italian monetary authorities decided to avoid any devaluation of the currency.

Table 2\(^1\) reports the annual rates of change in the unit labor costs and the annual rate of change in the franc-mark and the lira-mark exchange rate.

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\(^1\)see Giovannini (1990).
Table II Adjusted relative wages and the terms of trade, France and Italy relative to Germany, 1979-1990

<table>
<thead>
<tr>
<th>Year</th>
<th>France and Germany</th>
<th>Italy and Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative unit labor cost</td>
<td>Exchange rate</td>
</tr>
<tr>
<td>1980</td>
<td>6.9</td>
<td>0.7</td>
</tr>
<tr>
<td>1981</td>
<td>8.0</td>
<td>10.6</td>
</tr>
<tr>
<td>1982</td>
<td>8.3</td>
<td>11.0</td>
</tr>
<tr>
<td>1983</td>
<td>8.3</td>
<td>8.3</td>
</tr>
<tr>
<td>1984</td>
<td>5.2</td>
<td>-0.6</td>
</tr>
<tr>
<td>1985</td>
<td>2.8</td>
<td>0.8</td>
</tr>
<tr>
<td>1986</td>
<td>-0.4</td>
<td>8.3</td>
</tr>
<tr>
<td>1987</td>
<td>-0.1</td>
<td>1.5</td>
</tr>
<tr>
<td>1988</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>1989</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>1990</td>
<td>1.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Source: European economy

After 1987 the tendency of the franc and the lira to depreciate against the mark subsided. The change in attitude of the Banque de France and of the Banca d'Italia has been evident in 1989 when they both resisted pressures from the Bundesbank to devaluate.

In the previous period large depreciations of the franc and the lira are accompanied by large differences in relative unit labor costs with Germany. After 1987 the exchange rates are fairly stable.

Fig. (1) shows the real effective exchange rates of the lira versus the other EEC partners. It is clear that the fluctuations of the real exchange rate has been limited in an
informal target zone.
It is also easy to see the change in regime after 1987. The stabilization of the exchange rate has occurred at time where the inflation rate did not fall to the German level.
We will try to capture these effects in the model developed in the next sections.

III. A SURVEY OF RESULTS FROM THE TARGET ZONE LITERATURE

a. The first generation of target zone models

The seminal work on the theory of target zone is by Krugman (1989). He develops a simple model of exchange rate behavior in which, under the assumptions that the velocity of money follows a Brownian motion process, he shows that it is possible to obtain an explicit solution for the exchange rate as a function of the fundamentals. His conclusions are straightforward: a target zone has a stabilizing effect on the exchange rate within the band. The existence of a band constraints possible future path of the exchange rate; exchange markets, knowing this, should behave differently than they would without the target zone. The commitment of the monetary authorities to intervene to defend the band exerts a stabilizing influence even before any interventions take place. This effect is stronger the more credible is the commitment of the authorities to the defence of the band.
The basic components of the target zone model can be characterized as follows:

- the exchange rate satisfy an asset pricing relation:

\[ e_t = f_t + \alpha \left[ E_t \left( \frac{\text{de}}{dt} \right) \right] \]  \hspace{1cm} (a.1)

where \( E_t(.) \) denotes the expectation conditional on the information available at time \( t \) and \( (f_t) \) denotes the fundamentals determinant of the exchange rate. \( f_t \) includes both variables that are under the control of the monetary authorities and variables that follow autonomous dynamics.

- the monetary authorities want to keep the exchange rate from penetrating the lower and the upper bounds \( e^- \) and \( e^- \). Therefore they place lower and upper limits, \( f^- \) and \( f^- \) to fundamentals. If the saddle path solution for the exchange rate is monotonically increasing in \( f_t \), the exchange rate will be confined between the lower and the upper values \( e^- \) and \( e^- \).

- in the absence of intervention the fundamentals \( f_t \) follows a continuous Brownian motion process

\[ df_t = \epsilon \, dt + \sigma \, dz \]  \hspace{1cm} (a.2)

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where $\epsilon$ is a constant drift term and $z_t$ is a standard Brownian motion, i.e. $E(dz_t) = 0$ and $E(dz_t, dz_s) = \sigma_{s,t}$, where $\sigma_{s,t}=1$ if $s=t$ and 0 otherwise.

- the rational expectations assumption implies a unique equilibrium exchange-rate path that satisfy (a.1). It is assumed that the saddlepath solution for the exchange rate can be written as a twice continuous differentiable function of the fundamentals,

\[ e(t) = g[f(t)] \]  

Combining equations (a.1) to (a.3) and applying Ito's lemma we derive a general stationary solution

\[ e_t = f_t + \alpha\epsilon + A_1 e^{\beta_1 f_t} + A_2 e^{\beta_2 f_t} \]  

where $\beta_1 > 0$ and $\beta_2 < 0$ are the roots of the quadratic equation in

\[ \frac{\beta^2 \sigma^2}{2} + \beta \alpha \epsilon - 1 = 0 \]  

and $A_1$ and $A_2$ are constants of integration whose values are derived by the rule of intervention at the boundary adopted by
the monetary authorities. Krugman postulates infinitesimal interventions that alter the fundamental - $f$ - when the process reaches $f$ and $f^-$. The intervention at the margin is sufficient to prevent $f$ from perforate the exogenously imposed boundaries. The appropriate boundary conditions requires that the saddlepath of the exchange rate be tangent to the limits of the implied exchange rate band. The so called "smooth pasting" conditions ensures that the exchange rate is never expected to jump in response to an intervention.

Flood and Garber (1989) generalize the Krugman model and consider the possibility of discrete intervention.

The implications of the target zone solutions is a U-shaped distribution for the exchange rate in the presence of infinitesimal and discrete interventions, an S-shaped relationship between the exchange rate and the fundamentals, as well as a negative correlation between the instantaneous interest rate differential and the exchange rate as shown in fig.(2).

The predictions of the first generation of target zone models have been inconsistent with the evidence from the EMS system. The exchange rates are more often observed near the central parity than at the boundaries and for some countries it is possible to detect a positive correlation between the interest rate differential and the exchange rate.

b. The second generation of models
The second generation of target zone models have developed more realistic assumptions of the behavior of the exchange rate both at the boundaries as well as within the band.

Svensson (1991) models devaluations as occurring with some given constant probability, regardless of where in the band the exchange rate lies. Devaluations occur according to a Poisson process with constant parameters, and it is modelled as a shift of the same magnitude \( q \) in the lower and in the upper bands for the fundamentals as well as in the money supply.

The analysis concentrate mostly on the behavior of interest rate differentials for arbitrary terms. For a given term, the interest rate differential is decreasing in the fundamental and in the exchange rate. In the longer run, the relation between interest rates differentials and exchange rate is rather linear. The presence of a constant devaluation/realignment risk determines a constant upward shift, equal to the expected rate of devaluation, of all interest rate differentials.

This finding are confirmed by the data on Swedish interest rate and exchange rate but do not conform to the experience of other European countries where interest rate differentials are increasing in the exchange rate.

Bertola and Caballero(1990) introduce stochastic realignments at the boundaries of the target zone. When the
target zone is imperfectly credible policy makers can decide to either defend the parity or realign. If the probability of realignment is higher than 1/2 the relationship between the exchange rate and its fundamentals has an inverted S-shape. Moreover expected depreciation diverges rather than reverts to central parity making the relation between interest rate differential and the exchange rate positive.

An important result they obtain is that the long run distribution of the exchange rate put more weight in the center rather than at the boundaries and thus is more consistent with empirical data.

In Bertola and Caballero (1991) instead repeated realignments affect the likelihood and/or the size of the realignments and a stylized model is developed in which the level of reserves affects the position and the shape of the relationship between expected depreciation and the exchange rate.

Particularly interesting is the analysis by Bertola and Svensson (1991). In this model the exchange rate and the interest rate differentials are influenced by the current rate of expected devaluation and by the stochastic process it follows over time. They obtain the important result that if the variability over time of the devaluation rate is large relative to that of the fundamentals, then the relationship between the exchange rate and the interest rate differential becomes noisy. Incorporating stochastic devaluation risk
result in a rather rich data generation structure that could partially overcome the poor empirical performance of the previous target zone models. Unfortunately they do not offer a specific model of the determinants of the devaluations.

In the next section we depart from the existing literature and we develop a specific model of the determinants of the devaluations risk. It is a simple characterization of an exchange regime which is consistent with the main stylized facts of the EMS and other currency bands, i.e. the concentration of the exchange rate around its central parity and the coexistence of marginal and intramarginal interventions and devaluations. We assume sticky prices\(^2\) so that the exchange rate can diverge from the PPP relation, the latter being a crucial assumption of the flex-price target zone models.

### IV. Model Set-Up

While the flexible-price monetary model, which underlines much of the literature on target zone, implies a Purchasing Power Parity condition, the stochastic version of the

\(^2\) see Miller and Weller (1991) and more recently Sutherland (1991). By introducing the assumptions of sticky prices their results do not change the main important qualitative results of the traditional target zone model. By contrast, the crucial implication of price inertia in the sticky price model is that changes in the nominal exchange rate and in the nominal interest rate lead to change in the same direction in the real exchange rate and in the real interest rate.
Dornbusch model analyzed by Miller and Weller (1991) assumes inertia in the price level and that output is demand determined.

\[(m-p)=\phi y-\lambda i \quad (1)\]
\[y=-\gamma[i-E(dp)]+\epsilon(s-p+p*)\quad (2)\]
\[E[ds(t)]=(1-i*)dt \quad (3)\]
\[dp=\theta(y-\bar{y})dt+\sigma dz \quad (4)\]

- \(m\) - domestic money stock (in logs)
- \(p\) - price index of domestic goods products (in logs)
- \(p^*\) - price index of imported foreign products
- \(y\) - level of domestic final products
- \(s\) - nominal exchange rate
- \(i\) - instantaneous domestic nominal interest rate
- \(i^*\) - instantaneous foreign interest rate

Eq. (1) describes the equilibrium condition for the domestic money market.

Eq. (2) is an IS curve that capture the dependence of the demand for goods on the real exchange rate and on the real interest rate. The level of foreign prices is set equal to 0 by assumption.

Eq. (3) is the usual uncovered interest parity condition in which the expected depreciation of the nominal exchange rate is equal to the interest rate differential.

Eq. (4) is a Philipps curve relation. Prices adjust less than instantaneously to the divergence between the level of output \(y\), which is demand determined, and the level of full
employment.
By adding also a white noise disturbance we intend to introduce the possibility of a supply side shock to the process of wage/price adjustment. This formulation of the price dynamics implies that output is not always in full employment and that the exchange rate will not necessarily follow a PPP relation as in the case of a model with flexible prices.

Let's define with \( m-p = 1 \) the real supply of money and with \( s-p+p^* = s-p = q \) the real exchange rate.

In order to describe the equilibrium path for the exchange rate, it is useful to work entirely with real variables.

\[
\frac{dl}{E(dq)} = \frac{1}{q} + B \bar{y} - C \sigma dz
\]  

\[
A = \frac{-\theta y}{\delta} - \frac{-\theta \epsilon \lambda}{\delta}, \quad B = \frac{\theta (\lambda + \phi \gamma)}{\delta}, \quad C = \frac{\lambda + \gamma \phi}{\delta}
\]

The fundamental is the level of real balances and the arbitrage equation imposes the requirement that the expected depreciation of the real exchange rate be equal to the real interest rate differential.

By setting \( \sigma = 0 \) we obtain the dynamics of the
deterministic system. As shown in Appendix A the stable arm is always positively sloped.

When \( \sigma > 0 \) there are many functional relationships between \( q \) and \( l \) which satisfy equation (5) and a mapping between the real exchange rate and the fundamental of the form \( q = g(l) \) is sought.

Since the system describes the dynamics of an economy where the variables are not regulated, we have to specify the policy rule followed by the monetary authorities before studying the differential equation characterizing the solution.

a. The intervention rule

In the present model the authorities announce a target zone for the nominal exchange rate and follow an informal and not announced target for the real exchange rate. The market views the probability that the monetary authorities will intervene to recover the lost competitiveness as increasing in the deviation of the real exchange rate from the target level. In the case of no intervention the nominal supply of money is constant and real balances declines as prices increase.

When the monetary authorities intervene to recover the lost competitiveness they increase the supply of money by a quantity \( \alpha(l_t - l_0) \) where \( l_0 \) is the initial level of real
balances. We will let $\alpha = 1$ for simplicity. The jump in the fundamental is sufficient to restore the purchasing parity relation and recover the cumulated lost profitability in the export sector.

In each moment the authorities can decide to intervene. We call $\pi$ the probability of intervention which is a function of the distance between $l_t$ and $l_-$. The latter is supposed to be that level of real balances corresponding to the upper bound of the official nominal exchange rate target zone. At $l_-$ the perceived probability of intervention is equal to 1 so that the probability of a jump is a function of the distance $(l_- - l_t)$.

The effect of this type of intervention on the nominal and the real exchange rate can be better understood by looking at Fig.(4).

Fig.3 analyses the real exchange rate as a function of the fundamental $p$ in order to disentangle the effect of the increase in money supply from the effect of the change in prices. Along the AA curve $m$ is kept fixed.

Suppose that at the level $q_1 = s_1 - p_1$ the monetary authorities intervene and restore PPP. The curve AA then shifts up. For the same price level now we have a higher supply of money and $g(l_t)$ jumps to $g(l_0)$, where $g(l_0) = 0$ by

---

3 Alternatively a learning process on $\alpha$ could have been modelled. It will be the object of a further study.
hypothesis.

At the bottom of Fig.(3) we see the same effect on the nominal exchange rate. When the money supply is increased the nominal exchange rate jumps and the equilibrium point is now at point A, i.e. at the intersection of a new curve with the 45 degree line, along which PPP is valid.

b. An informal target zone

Real balances \( l_t \), evolve according to

\[
dl = \left[ -\theta \gamma \frac{1 + \theta \epsilon \lambda}{\delta} q \right] - \frac{(\lambda + \gamma \phi)}{\delta} dz - (1 - l_0) dQ \tag{7}
\]

where \( dQ \) is a Poisson process that defines the probability of a devaluation occurring during a time interval of length \( h \) as \( \pi h + o(h) \) and \( 1 - \pi h + o(h) \) is the probability of no devaluation. As shown in Appendix B. we choose the following function \( \pi \):

\[
\pi(l_t, h) = \begin{cases} 
0 & \text{if } l_0 \leq l_t, \ l_t < T \\
1 - \left( \frac{T}{l_t} \right) & \text{if } l_0 \geq l_t \geq T \\
1 & \text{if } l_t = T
\end{cases} \tag{8}
\]

We combine the two fundamentals variables \( m \) and \( p \) into a
single composite fundamental, and a mapping between the real exchange rate and the fundamental of the form $q = g(l)$ is sought.

Using the Ito's lemma we can write:

$$dq = [g'(l) \, dl + g''(l) \, dl^2] - [g(l) - g(l_0)] \, dQ \quad (9)$$

which is an application of the generalized Ito's formula for the case of mixed Poisson and Brownian process.

Plugging eq.(5) in (9) we obtain

$$E(dq) = g'(l)[a_{11}l + a_{12}g(l)]dt + g''(l)\frac{c^2 \sigma^2}{2} \, dt + \pi[g(l_0) - g(l_t)] \quad (10)$$

where $a_{ij}$ : elements of the A matrix. This equation is nonlinear and has no closed-form solutions. We solve it by a power series solution.

In order to identify the solutions to (10) appropriate boundary conditions must be imposed.

Let's consider the case in which $l = 1$- and the probability of a jump becomes equal to one. In the presence of discrete foreseen (here certain) interventions we need to impose continuity of the exchange rate. This is a requirement
familiar from the speculative attack literature. If there is a discontinuity in the exchange rate in response to an anticipated intervention, there would be a foreseeable profit at an infinite rate. Speculators would act to remove this opportunity.

Consider Fig.3.

Suppose that it exist a level of nominal exchange rate, let's call $s$, that if ever reached cannot be crossed. For that level it exist a correspondent level $l$ of the fundamental, i.e. $l = m - p$, such that the probability of an intervention is equal to one. In this case the monetary authorities intervene with a lump-sum adjustment of the money supply of size $M$. In the case shown in Fig.3, at point A, the monetary authorities intervene by decreasing the money supply and eliminate any foreseeable arbitrage profits. This is achieved by making the interventions precisely at the moment that prices reach the level where the old S curve (AA) intersect the new S curve (BB) at the point A.

A symmetric case happens when the exchange rate touches the lower bound of the band.

At the boundaries then:

$$s(p_3, m_0) = s(p_3, m_1) , \ s(p_0, m_0) = s(p_0, m_1) \tag{11}$$

where $s(m, p)$ is the nominal exchange rate.

Let $g(l_0) = 0$ and rewrite eq.(10) as
\[ 1 \ a_{21} + a_{22} \ g(l) = g'(l) [a_{11} \ l + a_{12} g(l)] \ dt + g''/2(l) \frac{c^{2}g^{2}}{2} \ dt - (12) \]

\[ \pi \ g(l) \]

We can obtain the solution of eq. (12) in terms of the nominal exchange rate by substituting

\[ g(l) = g(m, p) = [s(m, p) - p] \]

The next step is to derive a power series expansion for the function \( s(m, p) \) of the form

\[ s(m, p) = c_{0} + c_{1}(p - \overline{p}) + c_{2}(p - \overline{p})^{2} + \ldots + c_{n}(p - \overline{p})^{n} \ldots (13) \]

where the coefficients \( c_{i} \) are functions of the money supply. The solution is centered around \( p \), which could be any point provided is not a singular point.

Substituting the power series in eq. (12) we can solve for the coefficients \( c_{i} \), using the boundary conditions. The solution to eq. (12) is shown in Appendix C.

Fig. (5) shows the S curves that arise in the case of a discrete intervention at the boundaries. This is similar to the case analyzed by Sutherland (1991)\(^4\). They are obtained by

\(^4\) Sutherland analyses the case in which the stable saddlepath, of the system in \( s(m, p) \) and \( p \) is negatively sloped. This is the case in which the exchange rate overshoots.
increasing the money supply by 0.4 when the strong edge is
defended and by decreasing the money supply by 0.4 when the
weak edge is defended.

Fig.(6) instead consider the case in which the monetary
authorities has an informal target zone on the real exchange
rate within the band.

The curve shows an S-shaped relation. This is due to the
kind of intervention at the boundaries that we have assumed.
If we suppose that the authorities follow a different
strategy, i.e. it exist a positive probability of a
devaluation/revaluation also at the boundaries of the nominal
exchange rate we could have obtained an inverted S-shaped
curve like the one that Bertola and Caballero (1991) found.

c. The asymptotic distribution

The ergodic distribution of the fundamental satisfies the
Kolmogorov transition equation that takes the form (see
Appendix D)

\[ h'(l)dl - h''(l) \, dl^2 - \pi \, h(l) = 0 \]  \hspace{1cm} (14)

i.e.
\[ h'(l)[a_{11} 1 + a_{12} g(l)] \, dt - h''(l) \frac{a^2 c^2}{2} \, dt - \pi \, h(l) = 0 \]  

(15)

where we can substitute the function \( g(l) \) obtained in the previous paragraph.

To solve equation (14) we can find a power series solution of the function \( h(l) \)

\[
h(l) = h(m,p) = b_0 + b_1(p - \overline{p}) + b_2(p - \overline{p})^2 + \ldots + b_n (p - \overline{p})^n + \ldots \]

where the coefficients \( b_i \) are a function of the money supply. Eq.(16) is a second order parabolic differential equation, and for solutions we need initial and boundary condition at the end of the interval inside which \( l \) is constrained. We will impose condition both with respect to \(-m\) as well as with respect to the variable \(-p\).

Consider again Fig.(3).

For a given money supply, the probability density of being at one of the point of discrete intervention is equal to zero since the money supply immediately jumps to a new level:
\[ h(p_3, m_0) = h(p_0, m_0) = 0 \]  

We define the point B and C as "entry" points, while A and D as exit points.

The boundary conditions at the "entry" points require that the probability density "flowing" from the exit point A is equal to the flow entering at the corresponding entry point. This condition implies that

\[ h_p(p_3, m_0) = h_p(p_3, m_1) - h_p(p_3, m_1) \]  
\[ h_p(p_0, m_0) = h_p(p_0, m_{-1}) + h_p(p_0, m_{-1}) \]  

(17)

The final boundary condition is the requirement that each segment of the PDF be continuous at the entry points

\[ h(p_2, m_0) = h(p_2, m_0), h(p_1, m_0) = h(p_1, m_0) \]  

(18)

where the sign superscripts again indicate left-hand and right end limits.

The above conditions can be used to generate the joint money, prices PDF for negative and positive increments of the money supply. The resulting PDF then needs to be normalized so that its integral over \( m \) and \( p \) is unity.
Having derived the joint money, prices PDF it is possible to derive the long run density of the exchange rate within the band by a change in variables

\[ h(s,m) = \frac{h[g^{-1}(s,m), m]}{s_p[g^{-1}(m,p), m]} \]  \hspace{1cm} \text{(19)}

Integrating \( h \), over all values assumed by the variable \( m \), yields the unconditional distribution of the exchange rate. Fig. (7) shows the distribution function for the nominal exchange rate. It is interesting to note the asymmetry of the curve. When \( l_t > l_0 = 0 \), i.e. when \( s(m,p) < 0 \), there is no intervention of the monetary authorities within the band. In this interval the distribution function concentrate more weights at the boundary. When \( l_0 > l_t > l_* \), i.e. when \( s(m,p) > 0 \), the authorities intervene to restore competitiveness and devaluate the currency. In this interval the distribution function has more weight in the center than at the boundary of the band.

d. Interest rate differential

Equation (4)

\[ (i - i^*) = E(ds(t)) \]  \hspace{1cm} \text{(4)}

is the uncovered interest parity condition for an instantaneous bond.
Let \( i^*(\Gamma,t) \) denote the foreign nominal interest rate on a bond purchased at \( \Gamma \) with maturity at \( \Gamma+t \) and \( i(\Gamma,t,f) \) the domestic nominal interest rate on a bond purchased at \( \Gamma \) when the fundamental is at \( f(\Gamma)=f \).

Eq(4) can be written for finite maturity interest rate as:

\[
i(\Gamma,t,f)-i(\Gamma,t) = \mathbb{E} \left[ \frac{s(f(t+\Gamma)/f(\Gamma)=f)}{t} \right] - s \tag{20}
\]

where \( f=m,p \).

It is clear from expression (20) that:

\[
\beta = \lim_{t \to 0} \left[ i(\Gamma,t,f) - i^*(\Gamma,t) \right] = \frac{\mathbb{E}[ds(f(t))]}{d\Gamma} \tag{21}
\]

for zero term, and

\[
\beta = \lim_{t \to \infty} \left[ i(\Gamma,t,f) - i^*(\Gamma,t) \right] = 0. \tag{22}
\]

for very long term.

If we substitute (4) in eq.(5) we obtain the interest rate differential as a function of the fundamentals and of the exchange rate:

\[
i - i^* = [a_{12}s(m,p) + E(dp) + p(a_{11} + a_{22})] \tag{23}
\]

expression which, for a given money supply and absence of any intervention, is decreasing in the nominal exchange rate \( s(m,p) \).
This result is similar to the one obtained with a flexible price model. But now eq.(21) is also a function of the money supply. Eq.(23) is increasing in \( m \): a reduction in the money supply to defend the nominal exchange rate decrease the instantaneous interest rate differential. In contrast with the flex-price model there is no simple relation between the position of the interest rate within the band and the interest rate differential. But in the absence of a devaluation risk the result strengthen the prediction of the standard target zone models, i.e. increasing the negative correlation between the interest rate differential and the fundamentals.

Only when the authorities intervene to restore competitiveness and devaluate the nominal exchange rate it is possible to detect a positive correlation between interest rate differential and fundamentals, since the intervention requires an increase in the money supply.

d. Finite maturity interest rate differential

Let's consider eq.(20) and define with \( h(\Gamma,t) \) the expected exchange rate at maturity. In the presence of a devaluation risk we can express the finite maturity interest rate as\(^5\):

\(^5\) see Svensson (1991)
\[
\frac{h_l(l, \Gamma, t) - s_l(l, \Gamma)}{t} + E \int_0^t e^{(1 - \frac{T}{t})} \frac{s_l(l, \Gamma, h)}{dt} dh > 0
\]  

(24)

The first two terms on the right hand side denotes the interest rate differential resulting solely from the exchange rate movement absent any intervention. As \(_t_\) increases this term tends to zero as shown in equation (22).

The expected shift of the nominal exchange rate in the case of an intervention is captured by the term

\[
E \int_0^t e^{(1 - \frac{T}{t})} \frac{s_l(l, \Gamma, h)}{dt} dh > 0
\]

(25)

We can define the parameter function

\[
\Omega_\tau(t) = \int_0^t \pi(I_t, h) dh_t
\]

(26)

which will be non decreasing in \(t\). The expected conditional size of a devaluation at time \(t+\Gamma\), \(s(l, \Gamma, t)\) depend on the maturity. therefore the expected devaluation size during \((\Gamma, t+\Gamma)\), \(g_t^{\tau}\), fulfills.

\[
g_t^{\tau} = h(I_t, \Gamma, t) \Omega_\tau(t)
\]

(27)

Since for a Poisson process, one or several realignments
can occur during \((\Gamma, t+\Delta)\) we modify\(^6\) the process\(^7\) by assuming that there exists a finite \(t^- > 0\), such that the possibility of more than one realignment during \((\Gamma, t+\Gamma)\) can be disregarded. We also assume that the expected jump of the nominal interest rate follows a Poisson process between realignments and it is reset to zero after the intervention.

In order to derive the probability of a realignment during \((\Gamma, \Gamma+t)\), \(p\Gamma t\), we introduce \(q_r(t) = 1 - p_r t\), the probability of no realignment during \((\Gamma, \Gamma+t)\).

We then have

\[
q_r(t+\Delta t) = \text{Prob}[\text{no-realignment-during} [\Gamma, \Gamma+t+\Delta t]] = \frac{\text{Prob}[\text{no-realignment-during} - [\Gamma, \Gamma+t]]}{\text{Prob}[\text{no-realignment-during} - [t, t+\Delta t]]} = q_r(t) \left[1 - \pi_r(t) \Delta t + o(\Delta t)\right]
\]

We can rewrite this expression to get

\[
[q_r(t+\Delta t) - q_r(t)]/\Delta t = [-\pi_r(t) + o(\Delta t)/\Delta t] q_r(t)
\]

for \(\Delta t \rightarrow 0\), this yields

---

\(^6\) see Lindberg, Svensson, Soederlind (1991)

\(^7\) This process is called "self-exciting" since the occurrence of a first realignment affects the occurrence of a second, at least for some time. i.e. Conditional upon a realignment not occurring during \((\Gamma, \Gamma+t)\) the probability of a realignment occurring in the small interval \([\Gamma+t, \Gamma+t+\Delta t]\) is \(\pi_r(t) \Delta t + o(\Delta t)\). Conditional upon a realignment occurring during the small interval \([\Gamma+t, \Gamma+t+\Delta t]\) is zero.
\[ \partial q_r(t)/\partial t = -\pi_r(t) q_r(t) \]

which has the solution

\[ q_r(t) = \exp[-\Omega_r(t)] \]

Hence

\[ p_r(t) = 1 - \exp[\Omega_r(t)] \]

The expected devaluation during \((\Gamma, t + \Gamma)\) then fulfills

\[ g_r = h(1, \Gamma, t) \cdot p_r = h(1, \Gamma, t) (1 - \exp[-\Omega_r(t)]) \]

As Fig. (8) shows, for different values of the fundamentals, this terms can determine an upward sloping differential yield curve for some maturities or a hump shaped one for more long maturities. This result is due to the hypothesis that the probability of intervention is increasing in the exchange rate deviation from the target level.

VI. **CONCLUSIONS**

The model presented in this paper has provided a simple characterization of an exchange rate regime which is consistent with the main stylized facts of the EMS and other currency bands, namely the concentration of the exchange rate
around its central parity and the coexistence of marginal and intramarginal interventions and devaluations.

In particular we have been able to explain the experience of some countries in the EMS where the authorities have devaluated their currencies when the nominal exchange rate was still within the band. The existent literature has explained this fact introducing a constant probability of a devaluation independently on the position of the exchange inside the band (Svensson(1990)) or allowing for stochastic fluctuations in the size and/or the likelihood of a devaluation (Bertola and Svensson(1991)). We instead claim that the decision of devaluating the exchange rate has been, for some countries, the outcome of a precise economic strategy followed by the domestic monetary authorities.

We do offer a specific model of the determinant of the devaluation risk.

Interestingly the model generates realistic pattern for the term structure of interest rate differential.
APPENDIX A.

Consider system (5) in the text where the variables are here defined as deviations from equilibrium:

\[
dl = \frac{-\theta \gamma}{\delta} \frac{-\theta \epsilon \lambda}{\delta} \frac{1}{q}
E(dq) = \frac{-1}{\delta} \frac{\epsilon (\phi - \lambda \theta)}{\delta} \frac{q}{q} \quad (A.1)
\]

Let's call \( A \) the matrix of coefficients on the right-hand side endogenous variables in equation (A.1). The determinant of the matrix \( A \)

\[
det.A = \frac{-\theta \gamma \epsilon (\phi - \lambda \theta)}{\delta} - \theta \epsilon \lambda \quad (A.2)
\]

is negative, indicating roots of opposite sign. The characteristic equation is:

\[
\beta^2 - \beta \left( -\theta \gamma + \epsilon (\phi - \lambda \theta) \right) + \left( -\theta \gamma \epsilon (\phi - \lambda \theta) - \theta \epsilon \lambda \right) = 0 \quad (A.3)
\]

From (A.3) we can derive the two roots \( \beta_1 > 0 \) and \( \beta_2 < 0 \). The gradient for the lines of stationary for \( l \) and \( q \) follow
immediately from $A.1$ setting $\sigma = 0$

\[
\frac{dq}{dl} \frac{d\sigma}{dt} = \frac{1}{\epsilon(\phi - \lambda \theta)}
\]
\[
\frac{dq}{dl} \frac{dl}{d\sigma} = -\frac{\theta \gamma}{\theta \epsilon \lambda}
\]  \hspace{1cm} (A.4)

The slope of the eigenvectors are obtained as the roots of a quadratic equation in the parameters of $A$. Let an eigenvector, normalized on its first element, be written as $[1 \; z]'$. The condition to be satisfied is:

\[
\lambda \; \frac{1}{z} = \beta \; \frac{1}{z} \hspace{1cm} (A.5)
\]

where $\beta$ is a root of the characteristic equation of $A$.

By solving (A.5) we get:

\[
p(z) = -1 + (\epsilon(\phi - \lambda \theta) + \theta \gamma) \; z + \theta \epsilon \lambda z^2 = 0 \hspace{1cm} (A.6)
\]

$p(z)$ in the quadratic expression whose zeros give the required slopes (see Fig.9)

\[
z_s = \frac{-1}{\lambda_s - \epsilon(\phi - \lambda \theta)} > 0 \hspace{1cm} (A.7)
\]
\[
z_u = \frac{-(\lambda_u + \theta \gamma)}{\theta \epsilon \lambda} < 0
\]
The Poisson process is a continuous time process which allows discrete (i.e. discontinuous) changes in variables. The simplest independent Poisson process defines the probability of an event occurring during a time interval of length \(-h\) as follows:

\[
\text{Prob( the event does not occur in the time interval } (t, t+h) ) = \lim_{h \to 0} \left( 1 - \pi h + o(h) \right)
\]

\[
\text{Prob( the event occurs once in the time interval } (t, t+h) ) = \pi h + o(h)
\]

\[
\text{Prob( the event occurs more than once in the interval } (t, t+h) ) = o(h)
\]

where \(o(h)\) is the asymptotic order symbol defined by

\[
\phi(h) \text{ is } o(h) \text{ if } \lim_{h \to 0} \frac{\phi(h)}{h} = 0
\]

and \(\pi\) is a function of the state variable \(l_t\). In particular we have chosen

\[
\pi =\begin{cases} 
0 & \text{if } l_0 \leq l_t, l_t < I \\
\exp \left( 1 - \frac{t}{l_t} \right) & \text{if } l_0 > l_t > I \\
1 & \text{if } l_t = I
\end{cases}
\] (B.1)
(B.1) tells us that the probability that the event "jump" in the real balances, $l_t$, and in the real exchange rate, $q_t = g(l_t)$, occurs in the time interval $(t, t+h)$ increases in the distance between $l_t$ and the target level $l_0$.

When $l_t > l_0$ the authorities will never intervene and the probability of jumping to $l_0$ is then equal to 0. Therefore, for $l_t \geq l_0$ real balances follows a Brownian motion process.

When $l_0 > l_t > 1$ the fundamental follow a stochastic process driven by a superimposition of a continuous sample path diffusion process and a Poisson directed process. The Poisson directed process component is used to capture those rare events when the state variables have non local changes and the real exchange rate "jumps".

Fig.(10) illustrates the behavior of the real balances.
Eq. (12) is non linear and has no closed-form solution. It is possible to solve for a power expansion of the function \( g(l) \) [see Sutherland(1991)].

Let's re-write eq. (12)

\[
a_{21} l + a_{22} g(l) = g'(l) \left[ a_{11} l + a_{12} g(l) \right] dt + g''(l) \frac{c^2 a^2}{2} \Delta t - \pi g(l) \tag{C.1}
\]

where

\[
q_t = (s(m,p) - p) \tag{C.2}
\]

With \(-s\) we define the nominal exchange rate which is a function of the fundamentals \( m_t \) and \( p_t \).

Substituting (C.2) in (C.3) we obtain the following equation for \( s(m,p) \)

\[
s(m,p) \left[ a_{22} + a_{12} + \pi \right] = s_p(m,p) \left[ a_{11} m_t - a_{11} (p_t - \overline{p}) - a_{11} \overline{p} + a_{12} s(m,p) - a_{12} (p - \overline{p}) - a_{12} \overline{p} \right] + s_{pp}(m,p) \frac{c^2 a^2}{2} \tag{C.3}
\]

call \( k = a_{11} m_t - a_{11} p - a_{12} p \)

The next step is to derive a power series expansion for the function \( s(m,p) \) of the form:

The power series method can be used to yield numerical
s(m,p) = c_0 c_1(p-\overline{p}) + c_2(p-\overline{p})^2 + \ldots + c_n(p-\overline{p})^n \quad (C.4)

solutions to any desired degree of numerical accuracy. Consider the first n=5 terms. Substituting the power series in (C.3) we can solve for the coefficients c_i:

\[
\begin{align*}
[c_0 + c_1(p-\overline{p}) + c_2(p-\overline{p})^2 + c_3(p-\overline{p})^3 + c_4(p-\overline{p})^4 + c_5(p-\overline{p})^5] & [a_{12} + a_{22} + a_{12} + \frac{\sigma}{2}] = \\
[c_1 + 2c_2 (p-\overline{p}) + 3c_3 (p-\overline{p})^2 + 3c_4 (p-\overline{p})^3 + 4c_5 (p-\overline{p})^4] & [a_{11} (p-\overline{p}) - a_{12} (p-\overline{p}) + a_{12} \frac{\sigma}{2} + a_{22}] \\
+ 4c_3 (p-\overline{p})^2 + 5c_4 (p-\overline{p})^3 + 6c_5 (p-\overline{p})^4] & \frac{s_{pp}(m,p)}{\sigma^2}
\end{align*}
\]

from which we derive:

\[
\begin{align*}
c^2 &= \frac{c_0a_{22} + c_0a_{12} + c_1 \pi - c_1k - c_1a_{12}c_0}{\sigma^2} \\
c^3 &= \frac{c_1a_{22} + 2c_1a_{12} + c_1a_1 + c_1 \pi + c_1^2a_{12} - 2c_2k - 2c_2c_0a_{12}}{3\sigma^2} \\
c^4 &= \frac{c_2a_{22} + c_2a_{12} + c_2 \pi - c_1c_2a_{12} + 2c_2a_{11} + 2c_2a_{12} - 2c_2c_1a_{12} - 3k - 3c_3a_{12}c_0}{6\sigma^2} \\
c^5 &= \frac{c_3a_{22} + c_3a_{12} + c_3 \pi - c_1a_1 - c_2a_{12} + 3c_2a_{11} + 3c_3a_{12} - 3c_3c_1a_{12} - 4c_4k - 4c_4a_{12}c_0}{10\sigma^2}
\end{align*}
\]

For given values of c_0 and c_1, it is possible to derive the values of all the coefficients. The values of c_0 and c_1 are obtained from the boundary conditions.
APPENDIX D

Define the process \( l_t = (l_t - 10) \) the deviation of the fundamental process from its initial target point.

It follows the process,

\[
dl_t = (a_{11} l_t + a_{12} g(l_t)) \ dt - \sigma dz - (l_t - l_0) \ dQ_t \quad (D.1)
\]

where \( dQ_t \) is a Poisson process. Let \( l_0 = 0 \) and rewrite eq. (1) as:

\[
dl_t = \theta dt - \sigma dz - (l_t - l_0) \ dQ_t \quad (L.2)
\]

where \( \theta \) is a function of \( l \).

A discrete analogue of equation (D.1) is:

\[
\begin{align*}
l_t + dl_t & \quad \text{w.p.} \quad 1/2(1 + \theta dt/dl_t) \\
l_{t+1} = l_t - dl_t & \quad \text{w.p.} \quad 1/2(1 - \theta dt/dl_t) \\
- (l_t - l_0) & \quad \text{w.p.} \quad \lambda
\end{align*}
\quad (D.3)
\]

As the time and state space probability approaches zero expression (D.3) approaches (D.1) provided the rate of convergence is such that \((dl)^2 = \sigma^2 dt\).

To derive the ergodic distribution we make use of its invariance property: at every point in time the steady state probability function should satisfy the equation:

Rearranging, dividing by \( dl^2 \) and taking the limit we have

\[
\Phi'(l) \ \theta = \Phi''(l) \ \sigma^2 / 2 - \lambda \ \Phi(l - l_0) \quad (D.5)
\]

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APPENDIX E.

To solve eq. (15) we can find a power series solution of the function $h(l_t)$:

$$h(l_t) = h(m, p) = b_0 + b_1 (p - \overline{p}) + \ldots + b_n (p - \overline{p}) \quad (E.1)$$

where $d_i$ are functions of the money supply.

Eq. (E.1) and (C.4) can be substituted in eq. (15) and we obtain:

\[
\begin{align*}
   b_2 &= \frac{[b_1 k - b_0 \pi]}{\delta} \\
   b_3 &= \frac{[-b_1 a_{11} + b_1 a_{12} + 2b_2 a_{12} c_0 - b_1 \pi - a_{12}]}{\delta} \\
   b_4 &= \frac{[b_1 a_{12} c_2 - 2b_2 a_{11} - 2b_2 a_{11} + 3b_3 k + 3b_3 a_{12} c_0 - b_2 \pi]}{\delta} \\
   b_5 &= \frac{[b_1 a_{12} c_3 + 2b_2 c_2 a_{12} - 3b_3 a_{11} - 3b_3 a_{12} + 3b_3 a_{12} + 3b_3 c_1 a_{12} + 4b_4 k + 4b_4 c_0 a_{12} - b_3 \pi]}{\delta}
\end{align*}
\]

the coefficients $b_i$, $i=2, 3, \ldots, 5$ are a function of the coefficients $b_0$ and $b_1$ whose values are obtained from boundary conditions.
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Figure 1 Real effective exchange rate
Figure 2 The Flex-Price Model
Figure 3 Discrete Intervention
Figure 4 Effect on the real and the nominal exchange rate of an informal target zone.
Figure 5
Figure 6
Figure 7
Figure 9 The saddle path solution
Figure 10. The path of the real balances
CHAPTER THREE

DEVALUATION EXPECTATIONS:
THE LIRA 1979-1992

I. INTRODUCTION

A well known feature of rational expectations models is that policy regime changes can alter the stochastic behavior of economic variables. Several recent studies suggest that policy regime shifts, in particular monetary policy regime changes, have been associated with variations in the behavior of nominal interest rates, of the term structure and of real interest rates.

This paper produce additional evidence.

Specifically we test whether the change in the exchange rate management policy that the Italian monetary authorities should have undertaken after joining the EMS has affected the behavior of interest rates differentials at different maturities.

In a previous paper we have analyzed whether the decision of joining the EMS has affected the anti-inflationary reputation of the policy-makers, i.e. if the probability that the public assigns to the policy-makers pursuing low-inflationary policies has increased in Italy after 1979.

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1 see for example Mankiw and Miron (1986), Mankiw, Miron and Weil (1987), Blanchard (1984), Hamilton (1988).
In that context, we have focused our attention on expected price and wage behavior. To search for the most likely point in time in which a shift of regime occurred a non linear filter was used which allowed us not only to identify a regime change but also to assign probabilities that the process changed to an alternative regime.

The results obtained demonstrated that the mechanism of inflation expectations changed only after 1987, when the monetary authorities decided to resist any temptation to devaluate the lira. The estimates of a wage equation in the manufacturing, but not in the public sector, supported this result.

We now want to analyze if this episode has affected the interest rate differential at different maturities and in particular if devaluation expectations have changed in the same period.

In this paper, devaluation expectations are estimated with several methods, with increasing sophistication and precision. We have referred to the literature on the target zone and, as suggested by Bertola and Svensson (1990), we have estimated expected rates of devaluations by subtracting estimates of expected rates of exchange rate depreciation within the band from the interest rate differentials.

Using only interest rates differentials as an estimate of devaluation expectations can be misleading because interest rates are also affected by expected exchange rate movements
inside the band.

The expected rate of depreciation within the band has been estimated following two different methodologies. The first, developed by Svensson (1990) and applied to the experience of the Swedish krona and the French Franc, does not explicitly take into consideration the presence of the band restriction on the exchange rate. In this case information about the exchange rate bands are considered only to exclude unreasonable estimates, i.e. estimate that predict expected within the band future exchange rate as outside the band.

The second methodology, recently proposed by Z. Chen and A. Giovannini, uses a projection equation methodology of estimating expectations modified for the presence of target zones. Since rational agents should include the announced band as part of their information set, it is important for econometricians to explicitly take this information into account.

The two methods generate different results.

On the basis of the second methodology, considered by us to be more correct, following the procedure of Rose and Svensson (1991) and Lindberg, Svensson and Soderlind (1991) we have derived the expected exchange rate realignment.

Since formal test of the stability of the coefficients

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2 see Abel and Miskin (1983).
indicate that the parameters have changed over time, we have investigated the possibility of an endogenous regime shift in the series of expected devaluation.

We have then examined how devaluation expectations can be explained by selected macrovariables.

Our results, indicate that real exchange rate appreciation and wage inflation have a significant positive effect on devaluation expectations during the Regime I but they lose their explanatory power after 1988, during Regime II. This result confirms our belief that the devaluation of the lira has been a tool to recover the lost competitiveness.

The plan of the paper is the following. Section II presents the result of the simple test of target zone credibility developed by Svensson (1990). Section III and Section IV explain the method used to estimate expected devaluation. In Section V, Section VI and Section VII we perform a test to detect possible non-linearities not considered in our empirical specification of the equation explaining expected devaluation. Section VIII presents more precise estimates of devaluation expectation. Section IX and Section X are devoted to the analysis of a regime shift in the series of expected devaluation and to identify a possible set of macroeconomic variables that can explain devaluation expectations.

Section XI concludes.
II. THE "SIMPLEST" TEST

We will begin our analysis of the expected devaluation of the lira with the "simplest test" of target zone credibility proposed by Svensson (1990).

Svensson test originates from a very simple idea.

An exchange rate target zone, with an explicit band for the exchange rate, implies bounds on the amount of depreciation and appreciation of the exchange rate, since the latter cannot move further than to the edges of the band. Given foreign interest rates, the bands on the exchange rates imply bands on domestic currency rates of return to foreign investment. Therefore, if the domestic interest rate is outside the rate of return band, it means that investors must perceive a risk of a change in regime (i.e. a devaluation), before maturity.

If, instead, the interest rates are within the rate of return band it does not necessarily follow that the target zone is credible. Let $S_t$, $i^r_t$, and $i^{r,*}_t$ denote the spot exchange rate in period $t$, the domestic interest rate for maturity $r$ and the foreign interest rate in period $t$ for a $r$-period foreign asset respectively. Assuming uncovered interest
parity we can define the annualized domestic rate of interest as:

$$R_t^r = (1 + i_t^r) \left( \frac{S_t \cdot \sigma_r}{S_t} \right)^{12/r} - 1$$

(1)

where $r$ is measured in month. Since $S_t$ is confined in the interval $\bar{S} \leq S_t \leq \overline{S_t}$ also the rate of return on domestic assets will be restricted in a band $R^r \leq R^r_t \leq R^r_{t-1}$, where

$$R^r_t = (1 + i_t^r) \left[ \frac{S_t \cdot \sigma_r}{S_t} \right]^{12/r} - 1$$

(2)

and

$$R^r_t = (1 + i_t^r) \left[ \frac{S_t \cdot \sigma_r}{S_t} \right]^{12/r} - 1$$

(3)

If the exchange rate band is credible, i.e. people expect the monetary authorities to intervene in order to confine the spot exchange rate within the announced limits, the domestic interest rate should also be confined within the bounds. Clearly, if the target zone is not credible, the interest rate will cross the above limits.

This test has been applied to the one year eurolira and euromark in the period January 1981-April 1990 by Giovannini (1990). He finds that the lira interest rate was consistently
above the upper bound, confirming the evidence of systematic biases of realized returns. If risk premium were second order, this means that the perceived probability of a realignment was high.

We have decided instead to apply this test to the eurolira with maturity of T=1,3, and 6 months. The reason is that the market for the one year eurolira was particularly thin and the divergence can be due to a liquidity premium on the euromark. Fig.(1), Fig.(2), Fig.(2) shows the credibility bands and the eurolira for one, three and six months. In all three cases it is easy to see that the eurolira was outside the upper bound, even though the width of the band has been reduced to 2.25% at the beginning of 1990. The perceived probability of a realignment was high for maturity three and six month.

It is only after 1989 that the one month interest rate lies inside the band. Even if this result is based on a simple test and even if the interest rate being inside the band does not necessarily means that the exchange rate target zone has become credible after that year it is true that this finding seems to consolidate the results obtained in the first chapter where we have analyzed the behavior of wage inflation in the manufacturing sector and of inflation expectations. The exchange rate policy pursued by the Italian monetary authorities had gained credibility only in the short run.

Interestingly 1989 is after the decision of the monetary
authorities to stop devaluing the lira. These considerations need a more cautious analyses that we will develop in the next sections. In fact, if we look carefully to Fig. (1), (2) and (3) we see that the maximum bound for the expected rate of depreciation within the band is wider for shorter maturities. This means that this simple test is inconclusive for shorter maturities.

III. THE EXPECTED RATE OF REALIGNMENT

Let \( s_t = \log S_t \) be the logarithm of the spot exchange rate and \( \bar{s} = \log S_{t^-} \), \( s^- = \log S_{t^+} \) the logarithm of the upper and the lower limit of the exchange rate band respectively, where \( s_t \leq s_t \leq s_t \) in absence of any realignment. Following Svensson, we want to distinguish the expected depreciation of the exchange rate within the band from the expected realignment of the exchange rate, the latter defined as the jump in the central parity. We could have estimated devaluation expectations from interest rate differential.

This estimate is potentially misleading because interest rate differentials are also affected by expected exchange rate movements inside the band. The objective of our estimates is to test if devaluation expectations of the lira have changed since 1979 and if the expected devaluation is correlated with
the level or the rate of appreciations of the real exchange rate.

We then define $c_t$, the logarithm of the central parity, as:

$$ c_t = \frac{(s_t + S_t)}{2} \quad (4) $$

Given (4) the exchange rate within the band can be defined in terms of deviation of the spot exchange rate from the central parity, i.e.:

$$ x_t = s_t - c_t \quad (5) $$

Since $x_t = \frac{(s_t - S_t)}{2}$ is the maximum excursion of the exchange rate within the band, $x_t$ is confined in the interval $[-x_t, x_t]$. Using (5) the average expected realignment of the central parity can be expressed as

$$ E_t \Delta \frac{C_t \cdot \Gamma}{\Gamma} = E_t \Delta \frac{S_t \cdot \Gamma}{\Gamma} - E_t \Delta \frac{x_t \cdot \Gamma}{\Gamma} \quad (6) $$

where $\Gamma$ is the time interval over which we compute the expectation. If we accept uncovered interest parity as a plausible approximation of the relation between the interest rate differential ($\delta$) and the expected rate of depreciation to maturity, eq.(6) can be re-written as:
This relation tells us that to get an estimate of the expected exchange rate realignment we need to subtract the expected exchange rate depreciation of the exchange rate within the band from the interest rate differential.

IV. EXPECTED RATE OF DEPRECIATION

The estimate of the expected rate of depreciation within the band has to take into account that the lira exchange rate usually had jumped at realignment. As pointed out by Svensson, it is complicated to estimate the expected rate of depreciation within the band inclusive of possible jumps inside the band at realignments since there may be relatively few realignments and the sample distribution of realignments may not be representative. We then need to define the expected rate of depreciation conditional upon no realignment:

\[ E_t [x_t, r] = E_t[x_t, r/\text{no realignment}](1 - p_t^r) + p_t^r E_t[x_t, r/\text{realignment}] \]  

where \( p_t \) is the probability of realignment from date \( t \) to date
$t+ \Gamma$.

Plugging (8) into (7) we can write:

$$E_t \Delta c_{t+\Gamma} = p_t^{\Gamma} \frac{E_t[x_{t+\Gamma}/\text{realignment}]-E_t[x_{t+\Gamma}/\text{norealignment}]}{\Gamma}$$

$$\delta_t^\Gamma = \frac{E_t^{\Gamma}[x_{t+\Gamma}/\text{norealignment}]}{\Gamma}$$

Eq. (9) tells us that the expected rate of devaluation is equal to the difference between the interest rate and the expected depreciation within the band conditional upon no realignment.

In order to estimate the expected rate devaluation, we first estimate the expected future exchange rate. We adopt a linear specification, i.e.

$$x_{t+\Gamma} = \beta_0 + \beta_1 x_t + \epsilon_t \cdot \Gamma$$

with $E_t \epsilon_t = 0$ and $E_t x_t \epsilon_t \cdot \Gamma = 0$ and $\Gamma = 1, 3, 6$.

A linear specification is usually considered adequate in the literature. Square and cube terms of the exchange rate or of the fundamentals are often included to pick up non linear dependence which may exist, but their coefficients are usually not significant. Since we do not consider this procedure a
good test of the presence of possible non-linearities, we have implemented a test robust to heteroskedasticity and autocorrelation.

V. THE TEST FOR NON LINEARITIES IN THE LITERATURE.

An extensive analysis of non-linearities in the exchange rate behavior is given by Flood, Rose and Mathieson (F-R-M) (1990). They use daily data for EMS countries and test the traditional Krugman model of an exchange rate target zone. In the Krugman model, the relation between the exchange rate and the fundamentals is a second order differential equation that has a general solution of the type:

\[ e_t = g(f_t) = f_t + \alpha \varepsilon + A_1 \exp(\lambda_1 f_t) + A_2 \exp(\lambda_2 f_t) \tag{11} \]

where \( f_t \): fundamental \n\[
\lambda_1 > 0 \quad, \quad \lambda_2 \leq 0
\]

The integration constants \( A_1 \) and \( A_2 \) determine where the exchange rate intersects the edges of the band.

From eq. (11) it is evident that a test of the non linearity assumption is a test of the null hypothesis \( H_0: A_1 = A_2 = 0 \).
Since the fundamentals cannot be observed on a daily basis, F-R-M use the uncovered interest parity condition and, assuming no risk premium component, they get an estimate for $E_t[de/dt]$. More precisely, for all $j$, $E_{t-j}[de/dt]$ is approximated by the differential between interest rates, $(i_{t-j} - i^*_{t-j})$.

Integrating equations (12) and (13):

$$e_t = f_t + \alpha E_t(de/dt) \quad (12)$$

$$d_{t+1} = \mu + \epsilon dt + \sigma dz_t \quad (13)$$

where $\epsilon$: constant drift term

$Z_t$: standard brownian motion

they get an estimate for $\alpha, \epsilon$ and $\sigma$, and they can solve for the roots $\lambda_1$ and $\lambda_2$.

Finally, they estimate $A_1$ and $A_2$ in eq(11) and test $H_0$: $A_1 = A_2 = 0$. $H_0$ is often rejected, but the signs are opposite to those consistent with the smooth pasting conditions. Further they find that the out of sample forecasting ability of the nonlinear model is not superior to that of the linear model.

Meese and Rogoff (1990), (1991) use as fundamentals the stock of money and the index of industrial production. Let the asterisk denote the foreign country, let $m_t$ denote the money stock and $y_t$ the industrial production.
They compare a log linear model:

\[ \Delta e_t - \Delta (m_t - m^{*t}) = \alpha \Delta (y_t - y^{*t}) + \epsilon_t \]  \hspace{1cm} (14)

where \( \Delta \) denotes the difference operator, all variables in logs, with a non parametric model of the type:

\[ \Delta e_t = \Delta (m_t - m^{*t}) + f[\Delta (y_t - y^{*t})] + \epsilon_t \]  \hspace{1cm} (15)

Model (15) has been estimated by using a non parametric technique called Locally Weighted Regression (LWR) by Cleveland and Devlin (1988). The relative performance of the linear and non-parametric model has been evaluated by comparing the residuals of the two models via an F-type test. A problem connected with Meese and Rogoff test is that, due to the use of the LWR technique, the F test they use does not converge to an \( \chi^2 \) distribution as the sample gets large. The results do not strongly indicate the presence of significant non linearities.

Though the problem connected with testing for target zones are numerous and are essentially related with the assumptions made in deriving this model\(^3\), there is a further problem that can be easily overcome. This is related with the lack of

\(^3\) see Chapter 2
robustness of the tests implemented. More precisely, the testing strategy of using $F$ type tests is very sensitive to the presence of conditional heteroskedasticity and autocorrelation. Typically, time series models suffer from dynamic mispecification, and so the residuals and the score display high dependence. The object of the next section is to develop a test for non-linearities robust to conditional heteroskedasticity and autocorrelation.

VI. OUR TEST.

Let's call the null hypothesis "absence of neglected non-linearities". The basic idea of the test is that, under $H_0$, $E(\epsilon_t / h(X_t) = 0)$. This implies, by the law of iterated expectations, that $E(\epsilon_t h(X_t)) = 0$ where $\epsilon_t$ is the residual from a linear regression and $h(X_t)$ is a generic nonlinear function, named test function. Following White (1989) and Lee, White and Granger (1989) the test function is a neural network model, i.e.:

$$h(x_t) = \beta_0 + \sum_{j=1}^n \beta_j \phi(x_{1j})$$  \hspace{1cm} (16)

where

$$\phi(x_{1j}) = \left(1 + \exp(-x_{1j})\right)^{-1}$$  \hspace{1cm} (17)

is the logistic distribution.

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The choice of a neural network model as a test function is dictated by its extreme flexibility. In fact Hornick, Stinchcombe and White (1989) show that the net models are capable to approximate, to any degree of accuracy, any arbitrary square integrable functions and its derivatives, if we let increase $q$ (the number of hidden units) with the sample size at an appropriate rate.

Given the choice of the test function as in (17), $H_0$ can be formulated as

$$H_0 : E ( \epsilon \phi( x_t \gamma) ) = 0$$

(18)

Since $\gamma$ is unknown and it is unidentified under $H_0$, it must be picked randomly; anyway since the column of $\gamma$ are random vectors independent of $x_t$, then:

$$E(\epsilon_t \phi( x_t \gamma)/\gamma) = E(\epsilon_t \phi(x_t \gamma))$$

(19)

Since $\epsilon_t$ is unknown, the test is implemented by using

$$\frac{1}{n} \sum_{t=1}^{n} \epsilon_t \phi(x_t \gamma)$$

(20)

where under $H_0$,
\[ \frac{1}{n} \sum_{t=1}^{n} \epsilon_t \phi(x_t' \gamma) - E(\epsilon_t \phi(x_t' \gamma)) = 0 \] (21)

Given the auxiliary assumptions of correct specification, of conditional homoskedasticity, and of the martingale difference property of the score function, the score is \( \epsilon_t \phi(x_t' \gamma) \) under \( H_0 \). The test can be easily implemented by regressing the residual from the non-linear model, \( \epsilon_t \) on \( \phi(x_t' \gamma) \), and taking the \( R^2 \) from such regression. Under the null, \( nR^2 \to \chi^2_q \).

Unfortunately in presence of conditional heteroskedasticity and/or score non martingale difference, \( nR^2 \) will not converge in distribution to a chi-square\(^4\) (see White, 1989) and the \( P \)-value associated with the test will be often wrong. More precisely if such auxiliary assumptions fail, the estimated covariance matrix is inconsistent. Consequently, under \( H_0 \), \( TR^2 \) will converge to a mixture of \( \chi^2 \), with degrees of freedom less than \( q \), rather than converging to a \( \chi_q \). This means that, if we decide whether to reject or not \( H_0 \) according to the tabulated critical value of \( \chi_q \), we will take a wrong decision.

If we relax the assumptions of correct specification and conditional homoskedasticity but we retain the assumption that the score function is martingale difference, we can still use a regression based test, using a robust version proposed by

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\(^4\) see White (1989)
Wooldridge (1990). If we relax the assumptions that the score is a martingale difference but retain the assumptions of correct specification and conditional homoskedasticity under $H_0$, we can perform the test using the White Dynamic Matrix test (White(1987)).

Since we do not have any a priori to retain neither the assumptions of correct specification under the null, nor the assumptions of a martingale difference score, the test can be written in the following form:

$$M_n = n^{-1} \sum_{t=1}^{n} E_t \phi(x_t \gamma_t) W_n^{-1} \sum_{t=1}^{n} \epsilon_t \phi(x_t \gamma)'$$

(22)

Under $H_0$, $M_n \rightarrow \chi^2$. Unfortunately, the construction of $W_n$ is quite complicated; in fact it is written

where

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5 Recently Wooldridge(1990) proposed a regression based test robust to both conditional heteroskedasticity and no martingale difference score function. Wooldridge's test works in the following way. Let $\epsilon_t$ be the estimated residual from the linear model, let $\phi(x'tri)\ldots\phi(x'trq)$ be the set of test functions. We form the vector $\xi' = (\epsilon_t \phi(x'tr')\ldots\epsilon_t \phi(x'\gamma')')$. We run the following vector autoregression: $\xi_t$ on $\xi_{t-1}\ldots\xi_{t-p}$. Let $\nu_t$ be the residual from the vector autoregression above. Finally we regress 1 on $\nu_t$; we keep the $R^2$ from such regression and $TR^2 = X \ q$ as the sample size T goes to infinity. Basically the role of the initial vector autoregression, $\xi_t$ on its lagged values, is to make the score martingale difference and finally the regression of 1 on $\nu_t$ is an outer product and so it is robust to conditional heteroskedasticity.

6 The auxiliary assumptions of absence of dynamic mispecification is highly implausible.
\[ \hat{W}_n = \frac{1}{n} \sum_{t=1}^{n} (\phi(X_t;\gamma) - H_{\phi_x} M_{xx} X_t) \epsilon_t \epsilon_t \left( \phi(X_t;\gamma) - M_{xx}^{X_t} \right) + \] 
\[ \frac{1}{2n} \left( \sum_{j=1}^{n} w_j \left( \sum_{t=1}^{n} \left( \phi(X_t;\gamma) - H_{\phi_x} M_{xx} X_t \right) \epsilon_t \epsilon_t \left( \phi(X_{t-j};\gamma) - H_{\phi_{x-j}} M_{x_{t-j}} X_{t-j} \right) \epsilon_{t-j} \epsilon_{t-j} \left( \phi(X_t;\gamma) - H_{\phi_x} M_{xx} X_t \right) \right) \right) \] 
(23)

\[ M_{xx} = n^{-1} \sum_{t=1}^{n} X_t X_t \] 
(24)

\[ H_{\phi x} = n^{-1} \sum_{t=1}^{n} \phi(X_t;\gamma) X_t \] 
(25)

\[ w_j = 1 - \frac{j+1}{m} \quad m = o_p(n^{1/3}) \] 
(26)

and under the requirement of finiteness of the fourth moments, we have:

\[ \hat{W}_n - W = o_p(1) \] 
(27)

A last caution, since in all the test described above the \( \gamma \)'s are picked randomly, the test should be repeated for several draws\(^7\) and then the size should be calculated, using the modified Bonferroni criterion, in the following way:

\[ \alpha = \min_{j=1,2,..,p_j} \] 
where \( m \) is the number of replications of the

\(^7\) see Lee, White and Granger(1990)
test, and \( P_j \) is the P-value associated with the \( j \)-th draw.

**VII. DO WE DETECT NON LINEARITIES?**

We use monthly observations of the exchange rate from March 1987 to May 1992. We have estimated the linear model in the following form

\[
x_{t,3} - x_t = a_0 + (a_1 - 1) x_t + \epsilon_t
\]

(28)

where \( x_t \)

: nominal exchange rate

According to simple F-test the null hypothesis that \( (a_1 - 1) = a_0 = 0 \) can be rejected at 5%. Thus we can infer that in the short run there is a significant linear relationship between the expected rate of devaluation and the exchange rate.

The crucial point of this empirical investigation is to test for nonlinearities. The nonlinear model we are considering is of the type

\[
\Delta e_t = \sum_{j=1}^{6} b_j \phi(X_t, \gamma_j) + \nu_t
\]

(29)

The gammas have been generated from an uniform on \([-2,-2]\), the data have been rescaled over the range \([0,1]\), and the test
have been repeated for four different draws. Finally, the P-values have been calculated using a modified Bonferroni criterion. The results of the tests using the TR² (non robust form) are reported below. P-values are reported in parenthesis.

TR² test: 2.5 (0.29), 1.14 (0.57), 2.69 (0.26), 2.71 (0.257), 2.70 (0.256)

We have then performed the robust version of the test using the form

\[ n^{-1} \sum_{t=1}^{n} \epsilon_t \phi(X_t \gamma) W \sum_{t=1}^{n} \epsilon_t \phi(X_t \gamma) \]  

(30)

Here the computation of \( W_t \) is simpler than in the formula in the previous section because the true residual are observable under \( H_0 \). Thus:

\[ W = \frac{1}{n} \sum_{t=1}^{n} \epsilon_t^2 \phi(X_t \gamma) \phi(X_t \gamma) + \frac{1}{2n} \sum_{j=1}^{n} w_j \left( \sum_{t=1}^{n} \epsilon_t \epsilon_{t-j} \phi(X_t \gamma) \phi(X_{t-j}) \right) + \sum_{(m+1)} \epsilon_t \epsilon_{t-j} \phi(X_{t-j}) \phi(X_t \gamma) \]  

(31)

P values are reported in parenthesis

0.171 (0.91), 0.54 (0.764), 0.51 (0.774), 0.48 (0.787), 0.53 (0.768)
Finally, we report the results obtained using Wooldridge's regression based robust test.

Wooldridge test: 0.10 (0.951), 0.09 (0.956), 0.04 (0.98), 0.05 (0.975), 0.06 (0.97)

According to the Bonferroni criterion, we cannot reject the null of absence of nonlinearities at any significant level. Although all the tests lead to the non rej. ion of $H_0$, it should be noted that the use of the robust version of the test leads to a non rejection of $H_0$ at an higher significance level.

**VIII. EMPIRICAL RESULTS**

We now proceed to estimate eq. (20). As specified in the introduction, we have followed two different strategies in order to estimate the expected devaluation of the exchange rate within the band. We start by analyzing the first methodology.

A) Since the test performed in the previous paragraph rejected the hypothesis of a nonlinear relation between the expected depreciation and the exchange rate within the band, we have estimated the following specification:

$$x_{t,r} = \sum_i \beta_{0i} d_i + \beta_1 x_t + \epsilon_t$$  \hspace{1cm} (32)
for $\Gamma = 1, 3, 6$ months

t= monthly observation

i = 1,...9: regimes of the lira in the EMS\textsuperscript{8}

d$_i$= dummy for each regime

$X_{t,r} =$ log of bilateral lira-DM exchange rate.

The exchange rate is measured using percentage deviations from central parity.

The results of the estimates are shown in Tables (2), (3), and (4). Eq.(32) has been estimated on monthly data for the maturities 1,3, 6 months during the period March 1979 to May 1992. We have divided the sample into two subsamples, because the band was reduced from 6 to 2.25 % in 1990.

Specification (32) has been estimated using OLS with Newey-West standard errors, which allows for heteroskedastic and autocorrelated error terms.

As shown in Figures (4),(5) and(6), the estimated future expected exchange rate always lies inside the band. This implies that we do not need then to discard some of our estimates. In Tables (2),(3),(4) the slopes for Regime I are less than unity and decreasing in maturity. The slope for the six month maturity is not significantly different from zero. The $t$-value for the slope for the one month being less than unity is -3.89 so that on the basis of a Dickey-Fuller test we refuse the unit root hypothesis and confirm the hypothesis of

\textsuperscript{8} see table I
mean reversion. A similar pattern is shown in Regime II. From the estimate of the expected future exchange rate we can easily derive the expected rate of depreciation within the band as

$$ E_t[x_{t,T} - x_t] = \sum_i \beta_0 d_i + (\beta_1 -1) x_t + \epsilon_t $$ (33)

where $\beta_i$ are the estimated coefficient from regression (32). Figures (7), (8), and (9) plot the expected rate of depreciation. It is easy to see that the quantity of adjustment in interest rate differentials due to the expected exchange rate depreciation within the band is sometimes of the same magnitude as the interest rate differentials which are plotted in Fig.(10),(11), and (12).

We can now derive the expected devaluation by subtracting the expected amount of realignment from the interest rate differential. Figures (13), (14), and (15) plot the expected rates of devaluation. Figures (10), (11), and (12) plot the interest rate differentials.

The expected rate of devaluation follows a similar pattern for all three maturities. It is clear from the figures that the expected rate of devaluation has decreased since 1987.

B) We will now consider a different methodology recently developed by Z. Chen and A. Giovannini (C-G) (1990). In the estimates performed in section (A), we were not explicitly taking into
consideration the presence of the official band on the nominal exchange rate. But rational agents should include the announced band as part of the information set. Econometricians need to take this fact into consideration. To overcome this difficulty C-G transformed the expected exchange rate within the band $x_t$ into an unbounded variable, and then they employed estimation methods that do not rely on distributional assumptions. The new variable is then defined as:

$$y_t = \log\left(\frac{1 + x_t}{L - x_t}\right)$$

(34)

where $-1 \leq x_t \leq L$.

In expression (34), the numerator of the argument of the log-function measures the distance between the current exchange rate and the lower limit of the target zone. The denominator measures the distance between the exchange rate and the upper limit of the target zone. The ratio of the two terms is thus a measure of the position of the exchange rate relative to the limits of the band.

Given the transformed variable we have adopted a specification similar to eq. (32) in section (A). We have estimated:

$$y_{t+\Gamma} = \sum_{i=1}^{g} a_i d_i + y_t + u_t$$

(36)

$\Gamma = 1, 3, 6$ months.

From the projection equation, we can easily derive the
estimate of the expected future exchange rate using a simple transformation,

\[ x_t \cdot r = \frac{L \exp y_{t \cdot r} - 1}{1 + \exp y_{t \cdot r}} \] (36)

from which, applying the same procedure followed in section (A), we derive the expected depreciation within the band as well as the expected devaluation of the exchange rate.

Figures (16),(17), and (18) show the expected future exchange rate within the band. The estimated values differ from the ones obtained in the previous section: for all the maturities, we obtain a lower expected future exchange rate.

Following the procedure explained in section (A), we can now derive both the expected depreciation within the band [Fig. (19), (20), and (21)] as well as the expected rate of realignment [Fig. (22), (23), and (24)]. As found before, the adjustment on the interest rate differentials is sensible in many cases, due to the existence of an expected depreciation within the band.

As we see from Tables (5), (6), and (7), the coefficient of the current \( y \) is usually less than 1, like in the previous models. This implies that fluctuations within a given target zone are transitory, mean reversion processes. This result
tells us that the Central Bank allows temporary fluctuations within the band and defer long-run adjustments to later realignments of central parity.

Since we consider the second methodology more correct we will use the estimated expected rate of realignment to test whether a switch in regime occurred after 1987. We have then performed a Chow-test for parameter constancy. The value of the test statistic is 5.873 so that the hypothesis $H_0: \mu_1 = \mu_2, \sigma_1 = \sigma_2$ is rejected.

II. THE EM ALGORITHM

The evidence on parameter instability suggests that our estimates might not be very good. Because the parameters appear to be changing over time, estimations that assume constant parameters are inappropriate, and one should allow for endogenous changes of the parameters during the estimation.

One way this can be done is to apply the approach of Engel and Hamilton (1990). They develop a Markov switching model for the rate of depreciation of the dollar relative to other currencies. Engel and Hamilton (1990) use end of quarter spot exchange rates.

They postulate that the rate of depreciation is characterized by two regimes with different means and variances and with constant probabilities of transition
between the regimes. They use maximum likelihood estimates and find significant differences in the means and in the variances of the rate of depreciation for the two regimes.

They also examine the relation of interest rates differentials and the measures of expected depreciation\(^9\). Briefly we can summarize their approach by observing that the method implies the estimation of a first order Markov model. The parameters are drawn from two regimes governed by an unobservable state variable, \( z_t \), which can take on only two values, 1 and 2. This variable characterizes the "state" or "regime" that the process was in at date \( t \). When \( z_t=1 \), the observed \( c_t \) is presumed to have been drawn from a \( N(\mu_1, \sigma_1) \) distribution. When \( z_t=2 \), \( c_t \) is distributed \( N(\mu_2, \sigma_2) \).

The Markov transition probability model is therefore fully characterized by \( p_{11} \), the probability of staying in state 1 given state 1, and \( p_{22} \), the probability of staying in state 2 given state 2. Maximum likelihood estimation requires the specification of the log-likelihood function for the observed data.

The EM algorithm is a computationally convenient estimation method that consists of two steps. In the E-step, one forms expectations of the log-likelihood function of the observed and unobserved data. In the M-step, the function is maximized with respect to all parameters and probability.

Table (8) reports our estimates for the expected three

\(^9\) The methodology has been described in Chapter one
months devaluation and fig.(25) shows the probability of being in the second regime.

The shift of regime is evident at the end of 1988.

It is important to notice that states 1 and 2 are differentiated not only by their means but also by the variances of the conditional distributions. In particular, Regime II is characterized by a lower variance.

The interesting result is that the shift occurred after 1988, when the monetary authorities resisted any temptation to devalue the lira.

X. EXPLAINING DEVALUATION EXPECTATIONS

The ultimate goal of our paper is to try to shed some light on the cause of devaluation expectations, i.e. we want to see if the expected rate of devaluation we have estimated can be explained by a set of macro variables. The selection of explanatory variables is primarily based on theoretical considerations. It is our belief, in fact, that devaluations of the lira should be correlated with the real exchange rate, as well as with wage and price inflation.

As we have extensively explained in the previous paper we believe that the Italian monetary authorities have pursued an informal and unannounced target zone for the real exchange rate, using devaluations as a tool to recover competitiveness. The probability of devaluation can be thought
of as increasing in the deviation of the real exchange rate from its target level.

Table (9) reports the estimation results for the three month maturity. The results for the other maturities are similar. The equation has relatively large explanatory power. The significance of the explanatory variables drops when the regression is run in the second period. The real exchange rate appreciation lagged by two period and the wage increase in the previous period significantly explain devaluation expectations during the first period. This results seem to confirm our beliefs.

**XI. CONCLUSIONS**

In this paper we have applied two different methods to estimate depreciation expectations within a target zone during the period 1979-1992. Using only the interest rate differential as an estimate of devaluation expectations can be potentially misleading because interest rates are also affected by expected exchange rate movements inside the band.

The expected rate of depreciation inside the band has been estimated following two methodologies. The first, developed by Svensson (1990) does not consider explicitly the presence of the band imposed on the nominal exchange rate. The second, developed by Chen and Giovannini uses a projection equation methodology of estimating expectations modified for
the presence of target zones. On the basis of the second methods we have estimated expected exchange rate devaluations. Formal test of the stability of the coefficients indicate that the parameters have changed over time. This has induced an investigation of an endogenous regime shift model, with which we have been able to detect a change in regime after 1988.

More importantly, two important variables that can explain expected devaluation of the lira during 1979-1988 are the rate of real exchange rate appreciation and the lagged wage inflation.
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Giovannini,A. (1990), The European Monetary reform: Progress and Prospects, Brookings papers on Economic Activity, 2


Mankiw, N. and J. Miron (1987), the Adjustment of Expectations to a Change in Regime: a Study of the Founding of the Federal Reserve, The American Economic Review 77


EMS, N.B.E.R. Working Paper No. 3685


Svensson, L.E.O. (1991), The Simplest Test of Target Zone Credibility, I.M.F. Staff Papers 38


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</tr>
<tr>
<td>2</td>
<td>79:09</td>
<td>81:02</td>
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<td>5</td>
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</table>
TABLE 2

sample March 1973- December 1989: 1 month maturity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>t-value</th>
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<tbody>
<tr>
<td>x</td>
<td>0.698</td>
<td>0.79</td>
<td>8.833</td>
</tr>
<tr>
<td>d1</td>
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</tr>
<tr>
<td>d2</td>
<td>0.349</td>
<td>0.188</td>
<td>1.852</td>
</tr>
<tr>
<td>d3</td>
<td>-0.07</td>
<td>0.4</td>
<td>-0.175</td>
</tr>
<tr>
<td>d4</td>
<td>-0.091</td>
<td>0.69</td>
<td>-0.132</td>
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<td>d5</td>
<td>-0.697</td>
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<td>-1.272</td>
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<tr>
<td>d6</td>
<td>-0.430</td>
<td>0.28</td>
<td>-1.544</td>
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<tr>
<td>d7</td>
<td>-0.147</td>
<td>0.24</td>
<td>-0.602</td>
</tr>
<tr>
<td>d8</td>
<td>-0.346</td>
<td>0.176</td>
<td>-1.964</td>
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<tr>
<td>d9</td>
<td>0.472</td>
<td>0.177</td>
<td>2.668</td>
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$R^2 = 0.7207$

$\sigma = 1.1271$
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<th>t-value</th>
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<td>x</td>
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<td>2.601</td>
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<td>d2</td>
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<td>2.086</td>
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<td>-1.908</td>
<td>0.108</td>
<td>-1.759</td>
</tr>
<tr>
<td>d6</td>
<td>-0.976</td>
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<td>-1.957</td>
</tr>
<tr>
<td>d7</td>
<td>-0.502</td>
<td>0.521</td>
<td>-0.961</td>
</tr>
<tr>
<td>d8</td>
<td>-0.820</td>
<td>0.244</td>
<td>-3.356</td>
</tr>
<tr>
<td>d9</td>
<td>1.15</td>
<td>0.351</td>
<td>3.266</td>
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R² = 0.44992
σ = 1.5685
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<td>0.25</td>
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<td>d4</td>
<td>-0.917</td>
<td>0.76</td>
<td>-1.211</td>
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<td>d5</td>
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<td>d9</td>
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R² = 0.4683
σ = 1.543
### TABLE 5

#### Regime I: sample 1979-1989

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<td>-0.1585</td>
<td>0.1136</td>
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<td>0.1062</td>
<td>0.094</td>
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<tr>
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<td>0.176</td>
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<td>0.260</td>
<td>-0.156</td>
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<td>d5</td>
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<td>d9</td>
<td>0.1414</td>
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$R^2 = 0.7392$

$\sigma = 0.44708$

#### Regime II: sample 1990-1992

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<th>t-value</th>
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<td>c</td>
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<td>1.089</td>
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### TABLE 6

**Regime I: sample 1979-1989**

<table>
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<th>t-value</th>
</tr>
</thead>
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<td>d2</td>
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<td>2.479</td>
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<td>-0.062</td>
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<td>-0.465</td>
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<td>d9</td>
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<td>0.1001</td>
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$R^2 = 0.4547$

$\sigma = 0.64306$

**Regime II: 1990-1992**

<table>
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<th>t-value</th>
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<tr>
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<td>c</td>
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### TABLE 7

#### Regime I: sample 1979-1989

<table>
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<th>t-value</th>
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<td>0.070</td>
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<tr>
<td>d1</td>
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<td>0.09</td>
<td>1.36</td>
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<tr>
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<td>-3.442</td>
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$R^2 = 0.5184$

$\sigma = 0.6014$

#### Regime II: sample 1990-1992

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<th>t-value</th>
</tr>
</thead>
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<td>0.052</td>
<td>1.941</td>
</tr>
<tr>
<td>c</td>
<td>0.248</td>
<td>0.143</td>
<td>1.734</td>
</tr>
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<td>Estimates</td>
<td>S.E.</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>-------</td>
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</tr>
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<td>$\mu_2$</td>
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</tr>
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<td>0.063</td>
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<td>5.732</td>
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### TABLE 9

**Regime I: 1979-1989**

<table>
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<th>t-value</th>
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<td>2.699</td>
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<tr>
<td>cer2</td>
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<td>0.0865</td>
<td>2.082</td>
</tr>
<tr>
<td>d1</td>
<td>-3.478</td>
<td>2.82</td>
<td>1.233</td>
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<tr>
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<td>3.272</td>
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<td>1.220</td>
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<tr>
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<tr>
<td>d4</td>
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<td>2.84</td>
<td>4.672</td>
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<td>6.036</td>
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<td>7.6</td>
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<td>0.71</td>
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<td>d9</td>
<td>4.211</td>
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$R^2 = 0.7877$

**Regime II**
<table>
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<th>t-value</th>
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</thead>
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<td>0.5161</td>
<td>0.2139</td>
</tr>
<tr>
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<td>0.0491</td>
<td>1.690</td>
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<tr>
<td>c</td>
<td>2.14</td>
<td>0.73</td>
<td>2.9315</td>
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Figure 1 The "simple test" of target zone credibility: 1 month eurolira
Figure 2 The "simple test" of a target zone credibility: 3 month eurolira
Figure 3 The "simple test" of target zone credibility: 6 month eurolira
Figure (4) Expected future exchange rate: 1 month
Figure (5) Expected future exchange rate: 3 month
Figure (6). Expected future exchange rate : 6 month
Figure (7) Expected depreciation within the band: 1 month
Figure (8). Expected depreciation within the band: 3 month
Figure (9). Expected depreciation within the band: 6 month
Figure (10). Interest rate differential: 1 month Eurolira/Eurodm
Figure (11). Interest rate differential: 3 month Eurolira/Eurodm
Figure (12). Interest rate differential: 6 month Eurolira/Eurodm
Figure (13). expected devaluation: 1 month
Figure (14). Expected devaluation: 3 month.
Figure (15). expected devaluation: 6 month.
Figure (16). Expected future exchange rate: 1 month.  
Constrained method
Figure (17). Expected future exchange rate: 3 month. Constrained method
Figure (18). Expected future exchange rate: 6 month. Constrained method.
Figure (19). Expected depreciation within the band: 1 month
Constrained method
Figure (20) Expected depreciation within the band: 3 month.  
Constrained method
Figure (21). Expected depreciation within the band: 6 month. Constrained method.
Figure (22). Expected devaluation: 1 month.
Constrained method
Figure (23). Expected devaluation: 3 month.
Constrained method
Figure (24) Expected devaluation: 6 month. Constrained method
Figure 25. Probability $S_t=2$