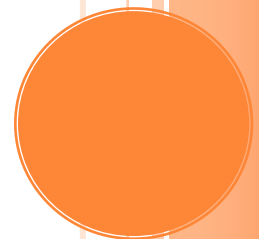


MONETARY POLICY AND CREDIBILITY

A Theoretical and Empirical Analysis

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INTRODUCTION

Policy credibility has been a key ingredient of many theoretical macro models of policymaking in the 1980s. Following the path-breaking paper by Kydland and Prescott (1979), the early literature on macroeconomic policy games has stressed the time-inconsistency of low inflation. Governments face the temptation to exploit the short-term Phillips-curve trade-off between higher inflation and lower unemployment (or more economic stimulus). Papers such as Barro and Gordon (1983a,b) predict that without the ability of policymakers to make binding policy commitments, low inflation will be unsustainable over longer periods of time owing to incentive incompatibility: optimising governments will at some point in time choose to renege on previous policy commitments and create short-term economic stimulus by surprise inflation. This is why low inflation policies are said to be time inconsistent. The public knows about this time inconsistency problem and takes it into account when forming expectations about the future course of monetary policy. As a result, market economies tend to have an inflation bias. Given this set-up, policy announcements proclaiming a non-binding commitment to future low inflation typically lack *credibility*. But what precisely is *credibility*, what are its determinants, and how can it be established? Can we measure *credibility*? These questions are at the heart of the discussion in the various chapters of this study.

Policy game models such as Barro and Gordon (1983a,b) or Backus and Driffill (1985a,b) typically assume that *credibility* can be established over time by consistent behaviour. Frequently the term *reputation* is used in this context. Both *credibility* and *reputation* are assigned to policymakers by the public. In order to avoid confusion, the term *reputation* will be used throughout this study whenever policymakers are evaluated solely on the basis their track record of policy outcomes, whilst the term *credibility* is used in a broader sense. In the present study *credibility* refers to a comparison of policy commitments or policy announcements with policy outcomes. Thus, whilst *reputation* can be established by time-consistent behaviour of policymakers, *credibility* can be established by truthful policy announcements.

How exactly may *credibility* and *reputation* be attained? What type of announcements can central banks use to establish credibility? One possibility is mentioned in Rogoff (1985a), who states that the widespread adoption of intermediate monetary quantity target announcements during the 1970s may be viewed as an institutional reform by central banks aimed at resolving their credibility problem. He demonstrates that monetary targeting under a 'conservative', that is, counterinflationary, central banker can reduce the time-consistent rate of inflation. The role of *credibility* in this process is modelled in Cukierman and Meltzer (1986b) who show that '*credible*' monetary target announcements can speed up the transition to a low-inflation equilibrium and hence reduce the welfare costs of disinflation. An alternative scenario of gaining *credibility* is outlined in Giavazzi and Spaventa (1989), who state that for a small open economy institutional reform such as entering a fixed exchange rate system may help to establish *credibility*. In this case, announcing an exchange rate target relative to a low-inflation centre country reduces the time-consistent rate of inflation. Finally, targeting nominal interest rates may be adopted by countries as a short-run operational procedure for targeting the exchange rate within the fluctuation band. On the basis of this scenario announcing an interest rate target consistent with a fixed exchange rate and given interest rates in the low-inflation country reduces the rate of inflation. All three forms of gaining *credibility* will be studied empirically below.

Whilst *credibility* and high *reputation* are usually unquestioned criteria for a good public policy, in the case of disinflation they take on special importance. *Credibility* about a pre-announced deflation policy may reduce or even eliminate the output or unemployment costs of disinflation by achieving a U-turn in expectations at the time when the policy is changed. A similar argument applies for an unannounced, 'short sharp shock' disinflation: the quicker the policymaker establishes a *counterinflation reputation*, the shorter will be the transition period during which expectations adjust, as pointed out by De Grauwe (1990). Thus, if policymakers are planning to implement disinflation policies, they will find it advantageous to establish *counterinflation reputation* and *credibility*, either on their own by purely domestic policy U-turns, or in an international context, by adhering to a system of fixed exchange rates such as the Bretton Woods system, the European currency snake system, or the European Monetary System (EMS).

This brings us to the question of whether or not the European Monetary System has helped member countries to disinflate during the 1980s. This question is at the heart of an on-going debate, and no consensus has yet been reached. Two major arguments are usually advanced in support of a positive answer. The *credibility* argument states that the EMS may have reduced the costs of disinflation, whilst the *discipline* argument states that EMS may have raised the costs of inflation. The main focus below is on the credibility aspects of the EMS, and on a quantified assessment of the presumed '*credibility bonus*' provided by EMS membership. Giavazzi and Giovannini (1987) and Giavazzi and Pagano (1988) were the first to formulate the EMS '*credibility*' hypothesis. In their opinion the EMS represents an institutional arrangement which has enabled the non-German EMS member countries to borrow *counterinflation reputation* from the Bundesbank by credibly pegging their bilateral

exchange rates relative to the German mark. This implies that the EMS has worked in an asymmetrical fashion: the Bundesbank has chooses its monetary policy independently, whilst all the remaining EMS member countries have 'tied their hands' on monetary policy and simply targeted their bilateral German mark exchange rates. Hence the EMS may be viewed as a de facto 'DM-zone'. To date, no firm empirical evidence supporting this 'credibility' hypothesis has been provided. On the contrary, the 'DM-zone' story of the EMS has recently been criticised by De Grauwe (1988), Fratianni and von Hagen (1989, 1990a,b) and Cohen and Wyplosz (1989) and Weber (1992b), amongst others, mainly on empirical grounds. Also, the 'DM zone' argument appears to be inconsistent with the empirical findings of Rogoff (1985b), Ungerer et al. (1983, 1986), Collins (1988), Artis (1987) and Weber (1990b) that disinflation inside the EMS has not been vastly different from the disinflation experience outside the system.

An explicit empirical analysis of policy *credibility* in the context of EMS membership is to be found in Weber (1991a, 1992b). Subsequent empirical studies and alternative approaches are to be found in Bolazzi (1991), Agénor and Taylor (1991) Egebo and Englander, Blackburn, Mongiardino and Soal (1992), Masson (1992), Ayuso, Jurado and Restoy (1993) and Revenga (1993), amongst others. In Weber (1991a, 1992b) it is shown that credible level pegging of exchange rates relative to the German mark was not a feature of the EMS from the beginning; it emerged in a later phase and at various points in time as the result of deliberate policy switches in the various EMS economies. Consequently, no unique pattern of *credibility gains* has been found across EMS countries. In fact, Weber (1992b) shows that only the small EMS countries appear to have gained anti-inflation *reputation* by credibly pegging to the German mark, whilst no such gains are to be found for the two large EMS countries, France and Italy.

Obstfeld (1991) makes the critical comment that Weber (1991a) evaluates the credibility of policy target range announcements by focusing on the mid-points of these ranges and completely ignoring all distributional aspects. Indeed, the probability density distribution of policy outcomes within the announced target ranges need not be uniform, and this may seriously bias the derived credibility estimates. For example, in Krugman's (1991) model the intrinsic dynamics of exchange rates within a *fully credible* currency band or target zone give rise to a bimodal distribution of exchange rates, with more mass concentrated near the zone's edges. However, in the Bertola and Caballero (1990, 1991) model of *imperfectly credible* target zones an unimodal exchange rate distributions is to be found for low degrees of target zone *credibility*. The concept of exchange rate *credibility* thus also play a key role in this recent target zone literature. Target zone *credibility* thereby typically refers to whether or not it is believed that a pre-announced exchange rate band of a given width will be defended by central bank intervention at the edges of the band, rather allowing a realignment to occur. Thus, high target zone *credibility* is closely associated with a low realignment probability. The key aspect of models of imperfectly credible target zones is that low target zone *credibility* can have adverse effects: announcing a non-credible band can fuel speculative attacks on currencies in expectation of future realignments. As a result, a run on central bank reserves may take place. The important point about target

zone models is that the intrinsic dynamics of exchange rates within bands give rise to alternative ways of measuring exchange rate *credibility*, as has been outlined in a series of papers by Svensson (1989, 1991a, b, c, d).

The present study aims at systematically reviewing and comparing the various concepts and empirical implications of *credibility* and *reputation* in both the policy game and the target zone literature. Based on this analysis, an attempt will be made to produce empirical estimates of the various measures of policy *credibility* and counterinflation *reputation* for EMS and a control group of non-EMS countries. In this analysis the *credibility* of the exchange rate commitment of central banks within the exchange rate mechanism (ERM) of the EMS plays a key role, and it will be shown that the recent collapse of the ERM after the heavy speculative attacks on the British Pound and the Italian Lira in September 1992, and on the Spanish Peseta, Belgian Franc, Danish Krona and French Franc in August 1993 come as little surprise when taking into account the evidence from the various *credibility measures*. It is a fact that until recently most countries have failed to establish credible exchange rate parities *vis-a-vis* the German Mark, and also in some cases substantial *credibility gains* have materialised, the empirical evidence nonetheless suggests that only the Dutch guilder exchange rate *vis-a-vis* the German mark has achieved almost perfect credibility. Thus, it is no coincidence that only this single exchange rate link survived the August 1993 ERM crisis.

The remainder of the study is organised as follows: chapter 2 reviews the theoretical concepts of *reputation*, *policy credibility* and *target zone credibility*. Chapter 3 discusses potential econometric approaches to implementing the competing concepts of reputation and credibility empirically. The stylised facts implied by the various models are thereby summarised in a number of testable propositions, and the econometric tools for implementing these tests are discussed. Chapter 4 presents the estimates derived from these tests. The prime focus of the empirical analysis thereby is on those countries which participated in the exchange rate mechanism of the EMS, but corresponding results for a control group of non-EMS countries is also presented. Chapter 5 concludes the study with a summary of the main results and a discussion of policy implications and policy recommendations.

THEORETICAL CONCEPTS OF POLICY CREDIBILITY

This chapter discusses the theoretical concept of reputation and credibility in both the policy game literature of the 1980's and the more recent target zone literature of the early 1990's. Despite of the fact that reputation and the perceived credibility of policies play a key role in determining policy outcomes in the both of the above strands of the macroeconomic literature, these concepts are frequently used in a rather elusive and vague fashion. Only few operational and empirically meaningful concepts of credibility and reputation are to be found in the literature.

Section 2.1 discusses some of those models of monetary policy games which imply very specific and explicitly stated concepts of credibility and reputation. By building on a stylised formal presentation of the basic policy game model of Barro and Gordon (1983a,b), the counterinflation reputation measure of Backus and Driffill (1985a, b) is derived. The concept of policy credibility is given content by referring to the Cukierman and Meltzer (1986b) model for money growth target announcements. Two measures of the credibility of policy announcements are formally derived. In addition, two modifications of the Cukierman and Meltzer (1986b) model for both interest rate target and exchange rate target announcements are presented. As in the Cukierman and Meltzer (1986b) model, the focus of the analysis is on the midpoint of the target announcements, even if targets are typically announced as ranges rather than point estimates.

Section 2.2 reviews the more recent target zone literature, where the concept of credibility applies to the announcement of the band rather than just its mid-point. By extending Krugman's (1991) basic model of a fully credible target zone model, various models of imperfectly credible target zones are discussed (Krugman, 1991 and Bertola and Caballero, 1990, 1991). In principle these models differ from the basic Krugman (1991) model only with respect to the policy rule which the central bank follows once exchange rates reach the boundaries of the band. It is shown that the concept of target zone credibility is closely related to a measure of realignment

probabilities. Also, following Svensson (1989, 1991a,b,c,d) and Bartolini and Bodnar (1991) the implications of fully and imperfectly credible exchange rate target zones for interest rate differentials are explored. In addition, second generation target zone models with imperfect credibility and two state variables are presented. It becomes obvious that in these models target zone credibility is inversely related to perceived realignment risks.

Section 2.2.3 concludes the discussion of the theoretical concepts of credibility and reputation by drawing some comparison between both groups of models. On the basis of this analysis an attempt will be made in the chapter 3 of this study to derive corresponding empirical measures of credibility and reputation, and to quantify them in chapter 4 on the basis of real world data.

2.1. REPUTATION AND CREDIBILITY IN POLICY GAME MODELS

2.1.1. The Basic Monetary Policy Game Model

The basic model of monetary policy games, as discussed in Cukierman (1986), is described in Box 1. It is assumed that the monetary authority and the public are engaged in a policy game which determines the equilibrium level of output y_t and inflation π . Equation (1.1) states that inflation is a monetary phenomenon. According to equation (1.2) output is determined by a Lucas-type supply function, which states that monetary policy is unable systematically to manipulate the level of output.¹ The central banker's objective function W_t , which may possibly be identical to the social welfare function, assumes that he dislikes inflation π_t and likes economic stimulus, defined in equation (1.3) as a level of output y_t above its natural level y^n . The public's move in the game is to form expectations which in equation (1.6) are defined to be the least-squares error type. Expectations are further assumed to be formed rationally on the basis of all available information in equation (1.7).²

As a result of this policy game, the optimal rate of inflation or monetary expansion under discretionary policymaking and rational expectations is some positive constant $b\phi$, which in equation (1.4) characterizes the inflationary bias of the Nash solution. The temptation of policymakers to aim at the unsustainable first-best solution (with $m_t = b\phi$ and $E(m_t|\Omega_{t-1}) = 0$) drives the economy away from the second-best incentive incompatible solution (with $m_t = E(m_t|\Omega_{t-1}) = 0$) to the inferior but stable third-best Nash solution (with $m_t = E(m_t|\Omega_{t-1}) = b\phi$). Note that inflation rates lower than $b\phi$, say zero, are in this static version of the basic monetary policy game model only achievable if the monetary authority can issue a credible commitment to zero inflation. Lucas and Stockey (1983) point out that this may be achieved via a constitutional amendment. For example, writing low inflation as the sole policy objective into the central bank's statutes would serve this purpose. Recently Persson and Tabellini (1993) have put forward a model in which state contingent contracts are used to make it incentive compatible for policymakers to tie their hands on inflation. This eliminates the inflation bias of market economies under discretionary policymaking, and could be implemented by making the appointment of central

BOX 1		
A Stylised Static Model of Monetary Policy Games		
Barro and Gordon (1983a, b)		
$\pi_t = m_t$	money growth causes inflation	(1.1)
$y_t = y^n + \phi(\pi_t - \pi_t^e)$	output equation	(1.2)
$W_t = -\frac{\pi^2}{2} + b(y_t - y^n)$	policymakers' objectives	(1.3)
$W_t = -\frac{m^2}{2} + b(y_t - y^n)$	policymakers' objectives	(1.4)
$m_t = b\phi$	optimal policy under discretion	(1.5)
$U_t = -(\pi_t - \pi_t^e)^2$	public's objectives	(1.6)
$\pi_t^e = E(\pi_t \Omega_{t-1}) = b\phi$	rational expectations	(1.7)

bankers conditional on contracts which force them to resign once inflation exceeds a low critical value.

In this basic one-shot policy game credibility and reputation play no role. However, if the policy game is played repeatedly, credibility and reputation may be introduced in a variety of ways.

2.1.2. The Concept of Reputation in Policy Game Models

Barro and Gordon (1983a,b) show that in infinitely repeated full information policy games the second best solution (with $m_t = E(m_t | \Omega_{t-1}) = 0$) may be sustained by reputational forces which operate through credible threats and pre-specified punishment strategies on the side of the public.³ These essentially arbitrary trigger mechanisms, however, imply no empirically testable hypotheses with respect to the concept of reputation. Empirically meaningful concepts of credibility and reputation are only derived in policy games with imperfect information, as will be discussed below.

2.1.2.1. Reputation in the Backus and Driffill Model

A prominent finite horizon monetary policy game with incomplete information is set out in the sequential equilibrium model of Backus and Driffill (1985a,b), described in equations (2.1) to (2.7). The important feature of this informational game is that the public faces two potential types of policymaker, with preferences described in equations (2.3a) and (2.3b). Throughout the game the public is uncertain as to which type of policymaker is in office. This is only revealed at the end of the game in a

known terminal period τ . This uncertainty, in connection with strategic behaviour (disguise) on the part of the policymaker, prevents the public from inferring the true state of the central bankers' preferences from the observable inflation or money growth process. This is formalised in equations (2.5a) and (2.5b) by noting that the observation of zero money growth may be due to the move of a 'hard-nosed' policymaker who always plays zero inflation ($m_t=0$) with probability one, but may also represent the move of a 'wet' policymaker who pretend to be 'hard-nosed' with a time-varying probability δ_t . Consequently the public's rational expectations of money growth in equation (2.7) is given by the expectation of the discretionary outcome ($b\phi$) multiplied by the joint probability that the policymaker is in fact 'wet' ($1-\psi$) and will not masquerade as 'hard-nosed' ($1-\delta$).⁴ Counterinflation reputation in the sense of Backus and Driffill (1985a,b) is thereby a state variable, conceived as the subjective probability ψ that the central banker is a non-inflationary or 'conservative' type.

BOX 2
A Stylised Model of Reputation in Monetary Policy Games:
Backus and Driffill (1985a, b)

$$\pi_t = m_t \quad (2.1)$$

$$y_t = y^n + \phi(\pi_t - \pi_t^e) \quad (2.2)$$

$$W_t^w = \sum_{t=0}^{\tau} \beta^t \left[-\frac{m_t^2}{2} + b\phi(m_t - m_t^e) \right] \quad (2.3a) \quad W_t^w = \sum_{t=0}^{\tau} \beta^t \left[-\frac{\pi_t^2}{2} \right] \quad (2.3b)$$

$$W_t^w = \sum_{t=0}^{\tau} \beta^t \left[-\frac{m_t^2}{2} + b\phi(m_t - m_t^e) \right] \quad (2.4a) \quad W_t^w = \sum_{t=0}^{\tau} \beta^t \left[-\frac{m_t^2}{2} \right] \quad (2.4b)$$

$$\pi_t = m_t = b\phi \quad (2.5a) \quad \pi_t = m_t = 0 \quad (2.5b)$$

$$U_t = -(\pi_t - \pi_t^e)^2 \quad (2.6)$$

$$\pi_t^e = E(\pi_t | \Omega_{t-1}) = (1 - \psi_t)(1 - \delta_t) b\phi \quad (2.7)$$

$$\psi_t = \frac{\psi_{t-1}}{\psi_{t-1} + (1 - \psi_{t-1})\delta_{t-1}}, \delta_\tau = 0 \quad (2.8)$$

Besides giving content to the notion of reputation, Backus and Driffill (1985a,b) also specify how reputation evolves over time: their counterinflation reputation measure ψ_t is updated continuously via Bayesian probability learning, as is indicated in equation (2.8). It can be shown that in order to maximise the output effects from future surprise money growth ($m_{t+\tau}=b\phi$), it pays for the inflationary 'wet' policymaker to invest into reputation building at the start of the game by strategically playing zero inflation ($m_{t+j}=0$ for $j<\tau$) for some time.⁵ This reduces the probability

($1-\delta$) and hence expected future inflation, which in turn allows for higher surprise inflation and more economic stimulus in the future. Reputation increases as long as zero inflation is observed, but is completely destroyed by the occurrence of positive inflation $m_t = b\phi$, which fully reveals the inflationary government. In view of real world inflation experience this would, however, imply that all countries have lacked counterinflation reputation, since zero inflation rates have been the exception rather than the rule in advanced economies during the post-war period. Thus, an empirically more meaningful concept of reputation has to be derived. In chapter 3 an attempt is made to do precisely this by making qualitatively different assumptions about the time series properties of the policymakers' trade-off parameter b and hence about observable inflation rates $m_t = b\phi$, which for simplicity were assumed to be constant here.

2.1.2.2. Reputation in the Cukierman and Meltzer Model

A second class of monetary policy games with incomplete information derives from the model of Cukierman and Meltzer (1986a), which is outlined in equations (3.1) to (3.7). As above inflation is a monetary phenomenon and policymakers like economic stimulus and dislike inflation. However, rather than facing two types of policymakers as in the Backus and Driffill (1985a,b) model, the public now faces a single policymaker whose preferences shift over time according to the time series process specified in equation (3.3.). The important feature of the Cukierman and Meltzer (1986a) model thereby is that these gradually and persistently changing policy objectives b_t in connection with incomplete monetary control in equation (3.5) prevent the public from inferring the true state of the central banker's preferences from the actual observable money growth process. However, central bank watching gradually reveals information about the unobservable state of the policymaker's preferences since it provides evidence on the degree of monetary noise contributed by the shifting policy objectives. To capture this formally, the public's optimal money growth expectations in equation (3.7.) are based on an elaborate weighting scheme, where the discounting of past information reflects the degree to which permanent shifts in policy preferences influence money growth and inflation dynamics.

Counterinflation reputation in the sense of Cukierman and Meltzer (1986a) is conceived as the speed λ with which the public recognises that a change in the policymaker's objectives has actually occurred, as is outlined formally in equation (3.7). Inflationary policymakers here do not mind having a low counterinflation reputation as this slows down the speed with which the public learns about their changing policy objectives when they shift to stimulating the economy through surprise inflation. Consequently, inflationary policymakers will tend to use a noisy monetary policy instrument in order to mask their true policy intentions even if perfect monetary control is feasible.

BOX 3
Reputation in a Stylised Model of Monetary Policy Games:
Cuckierman and Meltzer (1986a)

$$\pi_t = m_t \quad (3.1)$$

$$y_t = y^n + \phi(\pi_t - \pi_t^e) \quad (3.2)$$

$$W_t = \sum_{i=0}^{\infty} \beta^i \left[-\frac{\tilde{r}}{2} \cdot \dots (y_t - y^n) \right], \quad (3.3)$$

$$\text{with } \begin{cases} b_t = b + \gamma_t & b > 0, \\ \gamma_t = \rho\gamma_{t-1} + v_t & 0 \leq \rho \leq 1, \end{cases} \quad v_t \sim N(0, \sigma_v^2)$$

$$W_t^w = \sum_{i=0}^{\infty} \beta^i \left[-\frac{\tilde{r}}{2} \cdot \dots (m_t - m_t^e) \right] \quad (3.4)$$

$$m_t = \tilde{m}_t + \mu_1 \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \quad (3.5)$$

$$U_t = -(m_t - m_t^e)^2 \quad (3.6)$$

$$\begin{aligned} m_t^e &= E(m_t | \Omega_t) = (1 - \rho)b\phi\mu_0 + (\rho - \lambda)m_{t-1} + \lambda E(m_{t-1} | \Omega_{t-2}) \\ &= \sum_{j=0}^{\infty} \lambda^j [(1 - \rho)b\phi\mu_0 + (\rho - \lambda)m_{t-j-1}] \end{aligned} \quad (3.7)$$

$$\text{with } \lambda = \frac{1}{2} \left(\frac{1+r}{\rho} + \rho \right) - \sqrt{\frac{1}{4} \left(\frac{1+r}{\rho} + \rho \right)^2 - 1}, \quad r = \frac{\sigma_v^2}{\sigma_\zeta^2}$$

Key to symbols: π inflation, π^e expected inflation, m actual money growth, \tilde{m} planned growth, m^e expected money growth, y output, y^n natural output, $E(x|\Omega_t)$ rational expectations of x conditional on the information set Ω_t , W policymakers' objective function, U public's objective function, $b, \phi, \lambda, r, \rho, \mu_0, \mu_1$, parameters, v_t, ζ_t i.i.d. error terms with zero means and variances σ_v^2 and σ_ζ^2 .

2.1.3. The Concept of Credibility in Policy Game Models

Rogoff (1985a) states that the widespread adoption of intermediate monetary quantity target announcements during the seventies may be viewed as an institutional reform by central banks aimed at resolving their credibility problem. He demonstrates that monetary targeting under a 'conservative', that is, counterinflationary, central banker can reduce the time-consistent rate of inflation. The role of credibility in this process is modelled in Cukierman and Meltzer (1986b) who show that 'credible' monetary target announcements can speed up the transition to a low-inflation equilibrium and hence reduce the welfare costs of disinflation.

2.1.3.1. Establishing Credibility by Monetary Target Announcements

The Cukierman and Meltzer's (1986b) analysis of the credibility of monetary target announcements is presented in equations (4.1) to (4.7) of Box 4. This model has the same basic structure as Cukierman and Meltzer (1986a), but now the central bank is assumed in equation (4.5a) to issue a noisy monetary announcement signal in addition to the information derived by the public from watching the actual money growth process, specified in equation (4.5b). The public treats the announcement as contemporary information which, if credible, is used in forming expectations, as outlined in equation (4.7).⁶ Two measures of credibility are proposed by Cukierman and Meltzer (1986b):

Average credibility ($AC = -|m_t^a - E(m_t | \Omega_t)|$) is conceived as the extent to which the public's rational expectations deviate from the current money growth announcement (m_t^a). Average credibility is perfect for both perfect monetary control or fully precise monetary announcements. Furthermore, whilst large unexpected changes in announcements lead to a direct decrease in AC, large unexpected changes in actual money growth influence AC only with a time lag. If policymakers aim at maintaining a given level of average credibility under asymmetric information, a shift in the government's policy preferences is unlikely to be revealed to the public in the form of surprise announcements and is more likely to result in surprise money growth.

Marginal credibility (MC) is defined as the extent to which a unit change in the announcement m_t^a affects the public's money growth expectations $E(m_t | \Omega_t)$, as formally given by the weight (α) placed on the announcement in the public's expectations formation process in equation (4.6). This marginal credibility measure depends on the magnitude of the variance of the monetary control errors (σ_ξ^2) relative to the variance of the announcement bias ($\sigma_\xi^2 + \sigma_u^2$). If the policymaker always makes completely accurate announcements ($\sigma_\xi^2=0$), credibility is perfect (MC=1). However, extremely noisy announcements ($\lim \sigma_\xi^2 \rightarrow \infty$) convey little information and tend to be disregarded (MC=0).

From the above discussion it should be obvious that the concept of credibility must not be limited to monetary target announcements. In the two sections below the Cukierman and Meltzer (1986b) framework will be used to derive a formal concept of credibility in the context of interest rate and exchange rate targeting policies.

BOX 4
Reputation in a Stylised Model of Monetary Policy Games:
Cuckierman and Meltzer (1986b)

$$\pi_t = m_t \quad (4.1)$$

$$y_t = y^n + \phi(\pi_t - \pi_t^e) \quad (4.2)$$

$$W_t = \sum_{i=0}^{\infty} \beta^i \left[-\frac{\tilde{r}}{2} \dots (\dots - y^n) \right], \quad (4.3)$$

$$\text{with } \begin{cases} b_t = b + \gamma_t & b > 0, \\ \gamma_t = \rho \gamma_{t-1} + v_t & 0 \leq \rho \leq 1, \end{cases} \quad v_t \sim N(0, \sigma_v^2)$$

$$W_t^w = \sum_{i=0}^{\infty} \beta^i \left[-\frac{\tilde{r}}{2} \dots (\dots - m_t^e) \right] \quad (4.4)$$

$$m_t = \tilde{m}_t + \mu_1 \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \quad (4.5a)$$

$$m_t^a = \tilde{m}_t + \mu_1 u_t, \quad u_t \sim N(0, \sigma_u^2) \quad (4.5b)$$

$$\tilde{m}_t = \mu_0 b \phi + \mu_1 \gamma_t \quad (4.5c)$$

$$U_t = -(m_t - m_t^e)^2 \quad (4.6)$$

$$m_t^e = E(m_t | \Omega_t) = \alpha m_t^a + (1 - \alpha) E(m_t | \Omega_{t-1}) \quad (4.7)$$

$$\text{with } \alpha = \frac{(\rho - \lambda)(1 - \theta)}{\lambda + (\rho - \lambda)(1 - \theta)}, \quad \lambda = \frac{1}{2} \left(\frac{1+r}{\rho} + \rho \right) - \sqrt{\frac{1}{4} \left(\frac{1+r}{\rho} + \rho \right)^2 - 1},$$

$$r = \frac{\sigma_v^2}{\sigma_\zeta^2} \left(\frac{\sigma_u^2 + \sigma_\zeta^2}{\sigma_u^2} \right), \quad \theta = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\zeta^2}$$

Key to symbols: π inflation, π^e expected inflation, m actual money growth, \tilde{m} planned growth, m^a announced money growth, m^e expected money growth, y output, y^n natural output, $E(x|\Omega_t)$ rational expectations of x conditional on the information set Ω_t , W policymakers' objective function, U public's objective function, $b, \phi, \lambda, r, \rho, \mu_0, \mu_1$ parameters, v_t, u_t, ζ_t , i.i.d. error terms with zero means and variances σ_v^2 , σ_u^2 and σ_ζ^2 .

2.1.3.2. *Establishing Credibility by Interest Rate Target Announcements*

Interest rate target announcements may provide an alternative to establishing credibility by money growth target announcements. In this case the credibility of the official interest rate (e.g. discount rate) announcements may be used as an important indicator of the central bank's commitment to interest rate targeting policies. The modified Cukierman and Meltzer (1986b) model presented in equations (5.1) to (5.7) of Box 5 aims at formally capturing this. Policymakers are assumed to exercise short-run inflation control through open market operations. Inflation causes deviations of the nominal interest rate (i_t) from the real interest rate (r), which in equation (5.1) is assumed to be constant in the short-run. The public is uncertain about the true planned level of interest rates (i_t), due to the gradual changes in the policymaker's preferences in equation (5.3), and the imprecise control of the monetary authority over the market determined interest rate in equation (5.5a). To reduce this uncertainty the policymaker is assumed in equation (5.5b) to issue a noisy interest rate announcement signal in addition to the information provided to the public by observing past interest rate movements. The public treats the interest rate announcement as contemporary information which, if credible, is used when forming expectations in equation (5.7). This defines the average credibility ($AC = -\left| i_t^a - E(i_t | \Omega_t) \right|$) and marginal credibility ($MC = \alpha$) of the interest rate target announcements.

2.1.3.3. *Establishing Credibility by Exchange Rate Target Announcements*

An interesting scenario for gaining credibility is outlined in Giavazzi and Spaventa (1989), who state that for a small open economy an institutional reform, such as entering a fixed exchange rate system may help to establish credibility. In this case, announcing an exchange rate target relative to a low-inflation country provides credibility.

The commitment of policymakers to targeting the exchange rate in systems of fixed but adjustable parities may thus be judged on the basis of the average or marginal credibility of the official central parity announcement, as is outlined in the modified Cukierman and Meltzer model of equations (6.1) to (6.7). The nominal exchange rate (e_t) in equation (6.1) is assumed to be determined in the long run by a purchasing power parity condition. This allows the central bank of the small open economy to implement inflation control by level-pegging its bilateral exchange rate (e_t) with the foreign country, which is assumed to have zero inflation ($\pi^* = 0$). As before, the policymaker is assumed to like economic stimulus (y_t) and to dislike inflation (π_t), here equivalent to deviations of the exchange rate (e_t) from its long-run purchasing power parity level (ϵ).⁷ This then allows the average credibility ($AC = -\left| e_t^a - E(e_t | \Omega_t) \right|$) and marginal credibility ($MC = \alpha$) of the central bank's exchange rate commitment to be measured in the same way as the credibility of money growth target announcements or interest rate target announcements was measured above.

BOX 5
Credibility in a Stylised Model for Interest Rate Targeting:
A Modified Cukierman and Meltzer (1986b) Model

$$\pi_t = i_t - r \quad (5.1)$$

$$y_t = y^n + \phi(\pi_t - \pi_t^e) \quad (5.2)$$

$$W_t = \sum_{t=0}^{\infty} \beta^t \left[-\frac{(i_t - r)^2}{2} + b(y_t - y^n) \right], \quad (5.3)$$

$$\text{with } \begin{cases} b_t = b + \gamma_t & b > 0, \\ \gamma_t = \rho\gamma_{t-1} + v_t & 0 \leq \rho \leq 1, \end{cases} \quad v_t \sim N(0, \sigma_v^2) \quad (5.4)$$

$$W_t^w = \sum_{t=0}^{\infty} \beta^t \left[-\frac{\tilde{i}_t}{2} + v\phi(i_t - i_t^e) \right]$$

$$i_t = \tilde{i}_t + \mu_1 \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \quad (5.5a)$$

$$i_t^a = \tilde{i}_t + \mu_1 u_t, \quad u_t \sim N(0, \sigma_u^2) \quad (5.5b)$$

$$\tilde{i}_t = \mu_0 b\phi + \mu_1 \gamma_t \quad (5.5c)$$

$$U_t = -(i_t - i_t^e)^2 \quad (5.6)$$

$$i_t^e = E(i_t | \Omega_t) = \alpha i_t^a + (1 - \alpha) E(i_t | \Omega_{t-1}) \quad (5.7)$$

$$\text{with } \alpha = \frac{(\rho - \lambda)(1 - \theta)}{\lambda + (\rho - \lambda)(1 - \theta)}, \quad r = \frac{\sigma_v^2}{\sigma_\zeta^2} \left(\frac{\sigma_u^2 + \sigma_\zeta^2}{\sigma_u^2} \right), \quad \theta = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\zeta^2},$$

$$\lambda = \frac{1}{2} \left(\frac{1+r}{\rho} + \rho \right) - \sqrt{\frac{1}{4} \left(\frac{1+r}{\rho} + \rho \right)^2 - 1}$$

Key to symbols: π inflation, π^e expected inflation, i actual interest rate, \tilde{i} interest rate target, i^a interest rate announcement, i^e expected interest rate, y output, y^n natural output, $E(x|\Omega_t)$ rational expectations of x conditional on the information set Ω_t , W policymakers' objective function, U public's objective function, $b, \phi, \lambda, r, \rho, \mu_0, \mu_1$ parameters, v_t, u_t, ζ_t , i.i.d. error terms with zero means and variances σ_v^2, σ_u^2 and σ_ζ^2 .

BOX 6
Credibility in a Stylised Model for Exchange Rate Targeting:
A Modified Cukierman and Meltzer (1986b) Model

$$p_t = e_t p^*, \quad p^* = 1 \quad (6.1)$$

$$y_t = y^n + \phi(p_t - p_t^e) \quad (6.2)$$

$$W_t = \sum_{i=0}^{\infty} \beta^i \left[-\frac{(e_t - \varepsilon)^2}{2} + b(y_t - y^n) \right], \quad (6.3)$$

$$\text{with } \begin{cases} b_t = b + \gamma_t & b > 0, \\ \gamma_t = \rho \gamma_{t-1} + v_t & 0 \leq \rho \leq 1, \end{cases} \quad v_t \sim N(0, \sigma_v^2)$$

$$W_t^w = \sum_{i=0}^{\infty} \beta^i \left[-\frac{(\tilde{e}_t - e_t^e)^2}{2} + b\phi(e_t - e_t^e) \right] \quad (6.4)$$

$$e_t = \tilde{e}_t + \mu_1 \zeta_t, \quad \zeta_t \sim N(0, \sigma_\zeta^2) \quad (6.5a)$$

$$e_t^a = \tilde{e}_t + \mu_1 u_t, \quad u_t \sim N(0, \sigma_u^2) \quad (6.5b)$$

$$\tilde{e}_t = \mu_0 b \phi + \mu_1 \gamma_t \quad (6.5c)$$

$$U_t = -(e_t - e_t^e)^2 \quad (6.6)$$

$$e_t^e = E(e_t | \Omega_t) = \alpha e_t^a + (1 - \alpha) E(e_t | \Omega_{t-1}) \quad (6.7)$$

$$\text{with } \alpha = \frac{(\rho - \lambda)(1 - \theta)}{\lambda + (\rho - \lambda)(1 - \theta)}, \quad \lambda = \frac{1}{2} \left(\frac{1+r}{\rho} + \rho \right) - \sqrt{\frac{1}{4} \left(\frac{1+r}{\rho} + \rho \right)^2 - 1},$$

$$r = \frac{\sigma_v^2}{\sigma_\zeta^2} \left(\frac{\sigma_u^2 + \sigma_\zeta^2}{\sigma_u^2} \right), \quad \theta = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\zeta^2}$$

Key to symbols: p domestic price level, p^* foreign price level, p^e expected domestic price level, e actual exchange rate, e^T exchange rate target, e^a exchange rate rate announcement, e^e expected exchange rate, y output, y^n natural output, $E(x|\Omega_t)$ rational expectations of x conditional on the information set Ω_t , W policymakers' objective function, U public's objective function, $b, \phi, \lambda, r, \rho, \mu_0, \mu_1$ parameters, v_t, u_t, ζ_t , i.i.d. error terms with zero means and variances σ_v^2 , σ_u^2 and σ_ζ^2 .

2.2. CREDIBILITY IN TARGET ZONE MODELS

2.2.1. The Basic Exchange Rate Target Zone Model

The basic target zone model, which originates in the work of Krugman (1991), may be characterised by equations (7.1) to (7.8) in Box 7 below. Equation (7.1) states that deviations of the exchange rate e_t from a stochastic forcing process f_t , which is referred to as fundamentals,⁸ are due to speculative bubbles $E_t(de_t/dt)$. The fundamentals f_t typically include both variables with autonomous dynamics and variables under the direct control of the monetary authority, which aims at maintaining a target zone for the fundamentals via foreign exchange intervention at pre-specified upper (f_U) and lower (f_L) bounds. As will be shown below, such intervention implies well-specified bounds (e_L , e_U) for the exchange rate. Equation (7.2) states that in the absence of intervention the fundamentals f_t follow a continuous Brownian motion (or Wiener, or Wiener-Levy) process with instantaneous mean drift μ and variance σ^2 , where dz_t is the standard Wiener process.

By postulating e_t to be a non-linear, twice continuously differentiable function $x(\cdot)$ of the state f_t and using Ito's lemma to derive an expression for the expectations in equation (7.1), the exchange rate may be derived as equation (7.3). This second order differential equation has, as shown in Froot and Obstfeld (1989a), the general stationary solution (7.4), with λ_1 and λ_2 in equations (7.5a) and (7.5b) being the roots of the characteristic equation $\alpha\sigma^2\lambda^2/2 + \alpha\mu\lambda - 1 = 0$. The constants A_1 and A_2 are thereby determined by the boundary conditions satisfied for the exchange rate e_t at the edges of the band. As will be shown below, models of perfectly and imperfectly credible target zone differ primarily in these boundary conditions.

2.2.2. Models of Perfectly Credible Target Zones

2.2.2.1. The Krugman Model

In Krugman's (1991) model of a perfectly credible target zone the so-called "smooth pasting" conditions in equation (7.6.) ensure that $x(f_L)$ and $x(f_U)$ are flat at the boundary of the fundamentals band and tangent to the boundaries of the implied exchange rate band, which is maintained by infinitesimal marginal intervention. In economic terms, "smooth pasting" implies that the exchange rate is never expected to jump in response to intervention.⁹ This results in a set of implicit equations (7.7a) and (7.7b) for A_1 and A_2 which can be solved as shown in equations (7.8a) and (7.8b).

Two types of settings for A_1 and A_2 may be found in target zone models:

- (a) In perfectly credible target zones "smooth pasting" ensures $A_1 < 0$ and $A_2 > 0$, and the non-linear relationship between the exchange rate and its fundamentals has the well-known S-shape. The slope of the exchange rate function is always less than one, which reflects Krugman's "honey moon" effect: the existence of a perfectly credible fundamentals band gives rise to speculative bubbles, which stabilise the behaviour of the exchange rates within an even narrower band.

BOX 7
A Stylised Model of a Perfectly Credible Exchange Rate Target Zone:
Krugman (1991)

$$e_t = f_t + \frac{\alpha}{dt} E_t(de_t), \quad \text{exchange rate equation} \quad (7.1)$$

$$df_t = \eta dt + \sigma dz_t, \quad \text{fundamentals dynamics} \quad (7.2)$$

$$x(f_t) = f_t + \eta x_f(f_t) + \frac{\sigma^2}{2} x_{ff}(f_t), \quad \text{2nd order differential equation} \quad (7.3)$$

$$e_t = f_t + \frac{\alpha}{dt} E_t(de_t), \quad \text{reduced form solution} \quad (7.4)$$

$$\lambda_1 = \frac{-\eta + \sqrt{\eta^2 + \frac{2\sigma^2}{\alpha}}}{\sigma^2} > 0, \quad \text{1st characteristic root} \quad (7.5a)$$

$$\lambda_2 = \frac{-\eta - \sqrt{\eta^2 + \frac{2\sigma^2}{\alpha}}}{\sigma^2} > 0, \quad \text{2nd characteristic root} \quad (7.5b)$$

$$x_f(f_L) = x_f(f_U) = 0, \quad \text{smooth pasting requirements} \quad (7.6)$$

$$1 + A_1 \lambda_1 e^{\lambda_1 f_L} + A_2 \lambda_2 e^{\lambda_2 f_L} = 0, \quad \text{1st smooth pasting condition} \quad (7.7a)$$

$$1 + A_1 \lambda_1 e^{\lambda_1 f_U} + A_2 \lambda_2 e^{\lambda_2 f_U} = 0, \quad \text{2nd smooth pasting condition} \quad (7.7b)$$

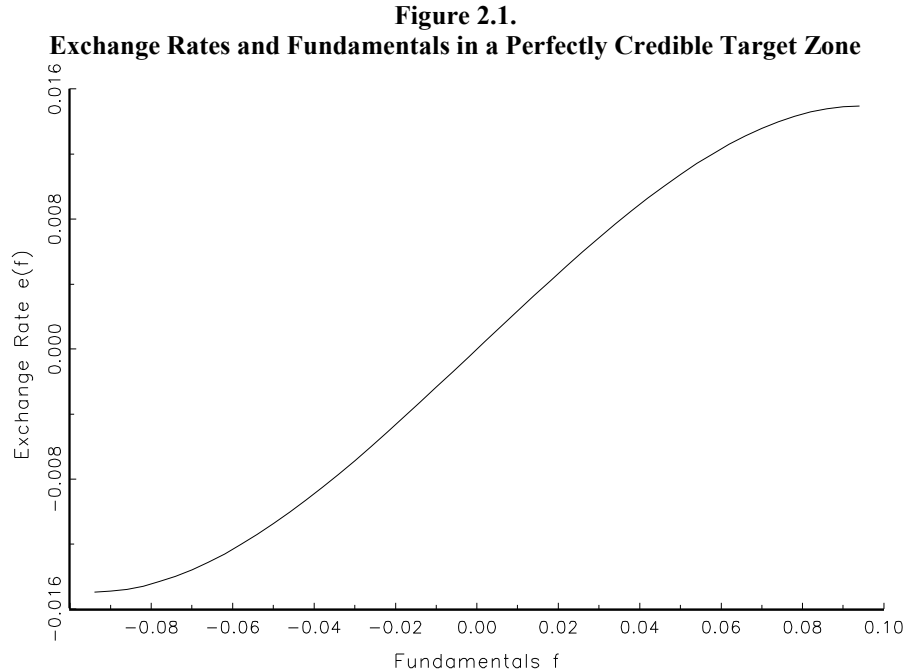
$$A_1 = \frac{e^{\lambda_2 f_U} - e^{\lambda_2 f_L}}{\lambda_1 e^{\lambda_1 f_U + \lambda_2 f_L} - \lambda_1 e^{\lambda_1 f_L + \lambda_2 f_U}}, \quad \text{1st coefficient restriction} \quad (7.8a)$$

$$A_2 = \frac{e^{\lambda_1 f_L} - e^{\lambda_1 f_U}}{\lambda_2 e^{\lambda_1 f_U + \lambda_2 f_L} - \lambda_2 e^{\lambda_1 f_L + \lambda_2 f_U}}, \quad \text{2nd coefficient restriction} \quad (7.8b)$$

Key to symbols: e_t exchange rate, f_t fundamentals, η instantaneous mean drift of f_t , σ^2 instantaneous variance of f_t , $E_t(de_t/dt)$ expected exchange rate change, $x(f)$ exchange rate function, x_f (x_{ff}) first (second) derivative of x with respect to f , z_t stochastic Wiener process, f_L and f_U (e_L and e_U) upper and lower bound of fundamentals (exchange rate), λ_1 , λ_2 , A_1 , A_2 , α parameters.

- (b) Completely ruling out speculative bubbles and ignoring the existence of a target zone ($A_1=A_2=0$) results in a linear relationship between the exchange rate e_t and its fundamentals f_t . This basically is the free float solution under which exchange rates are always driven by a random walk stochastic process. This may be derived formally from the coefficient restriction (7.8a,b) by assuming infinitely wide fundamental bands and hence letting the lower bound f_L go to minus infinity and the upper bound f_U to infinity.

The exchange rate functions under both the free-float (linear function) and the fully credible target zone (S-shaped function) are depicted in Figure 2.1, which following Svensson (1990b) uses a zero fundamental drift ($\mu=0$), $\sigma=0.1$, $\alpha=3$ and a symmetrical fundamental band of $f_U=-f_L=0.094$. This implies a symmetrical exchange rate band of $e_U=-e_L=0.015$.^{10 11} Note that the target zone exchange rate function in Figure 2.1 is bent away from the free float rate, and, in accordance with the "smooth pasting conditions (7.6) is tangent to the edges of the exchange rate band. The target zone exchange rate furthermore is less responsive to movements in fundamentals than the free float exchange rate, which implies $x_f(f_t)<1$, a phenomenon which Krugman (1991) labelled "honey moon" effect. As a result of the "honey moon" effect in a perfectly credible target zone, the exchange rate is stabilised in a band which is narrower than the band of the fundamentals.



The target zone exchange rate function in Figure 2.1 also implies a specific exchange rate distribution. The (unconditional) asymptotic probability distribution of the fundamentals is that of a regulated Brownian motion with both upper and lower bounds. Harrison (1985) shows that this probability distribution of the fundamentals is uniform for a zero fundamental drift ($\eta=0$) and is truncated exponentially for a non-zero fundamentals drift ($\eta \neq 0$), as indicated in equations (8.2a) and (8.2b) of Box 8, respectively.

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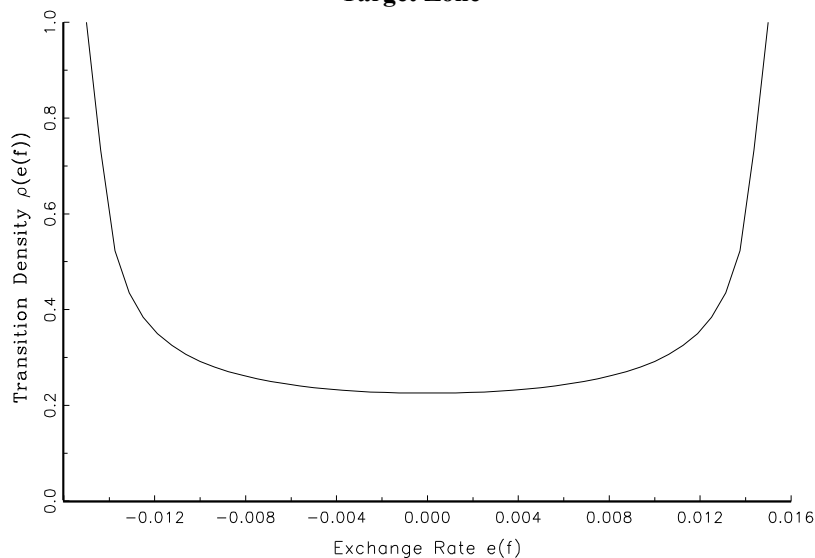
BOX 8 Testable Implications of the Perfectly Credible Target Zone Model of Krugman (1991)		
$x_f(f_t) < 1$,	'honey moon' effect	(8.1)
$\phi^f(f) = 1/(f_U - f_L)$,	$\eta = 0$,	(8.2a)
fundamentals' instantaneous density distribution for $\eta = 0$		
$\phi^f(f) = \frac{\theta e^{\theta f}}{e^{\theta f_U} - e^{\theta f_L}}$,	$\theta = 2\eta/\sigma^2$, $\eta \neq 0$	(8.2b)
fundamentals' instantaneous density distribution for $\eta \neq 0$		
$\phi^e(e) = \phi^f[x^{-1}(e)]/x_f[x^{-1}(e)]$,	exchange rate's density distribution	(8.3)
for $\eta \neq 0$ and $e_L < e < e_U$,		
$\sigma^e(e) = \sigma x_f[x^{-1}(e)]$,	exchange rate's instantaneous	(8.4)
standard deviation		

Key to symbols: e_t exchange rate, f_t fundamentals, η instantaneous mean drift of f_t , σ^2 instantaneous variance of f_t , $\sigma^e(e)$ instantaneous variance of e_t , $x(f)$ exchange rate function, x_f (x_{ff}) first (second) derivative of x with respect to f , $\phi^f(f)$ density distribution of fundamentals, $\phi^e(e)$ density distribution of exchange rate, f_L and f_U (e_L and e_U) upper and lower bound of fundamentals (exchange rate), $\lambda_1\phi$, λ_2 , A_1 , A_2 , α parameters.

The target zone exchange rate function in Figure 2.1 also implies a specific exchange rate distribution. The (unconditional) asymptotic probability distribution of the fundamentals is that of a regulated Brownian motion with both upper and lower bounds. Harrison (1985) shows that this probability distribution of the fundamentals is uniform for a zero fundamental drift ($\eta=0$) and is truncated exponentially for a non-zero fundamentals drift ($\eta \neq 0$), as indicated in equations (8.2a) and (8.2b) of Box 8, respectively.

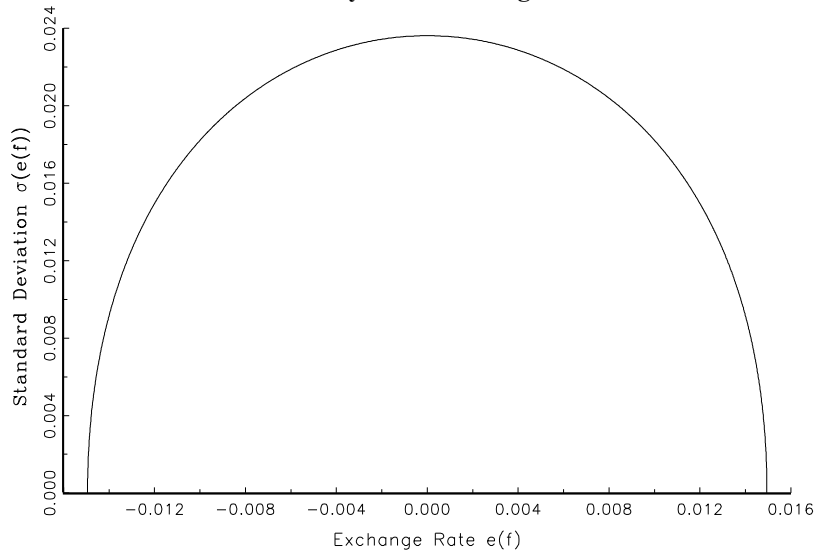
By using the "change of variable in density function lemma"¹² the exchange rate's unconditional asymptotic density function can be derived as equation (8.3), which only holds in the interior of the band ($e_L < e < e_U$). In equation (8.3) the fundamentals function $f(e)=x^{-1}(e)$ denotes the inverse of the exchange rate function $e=x(f)$. For the above example of a zero fundamentals drift ($\eta=0$) with $\sigma=0.1$, $\alpha=3$, and a fundamentals band of $f_U-f_L=0.094$ ($e_U-e_L=0.01$) the probability density distribution displayed in Figure 2.2 can be computed.¹³ This density distribution is only defined in the interior of the band,¹⁴ and is bimodal with more mass towards the edges of the band. Given the uniform distribution of the fundamentals, it is obvious that the U-shaped distribution of the exchange rate is a direct result of the S-shape of the exchange rate function: for a constant nominator in equation (8.3), the derivative x_f in the denominator is smaller close to the edges of the band, and this makes the density larger.

Figure 2.2.
Probability Density Function of the Exchange Rate in a Perfectly Credible Target Zone



Applying Ito's lemma to the exchange rate function $x(f_t)$, the instantaneous (conditional) standard deviation of the exchange rate $\sigma^e(e)$ may be obtained as equation (8.4).¹⁵ It is the product of the standard deviation of the Brownian motion fundamentals σ and the derivative $x_f[x^{-1}(e)]$ of the exchange rate function. Figure 2.3 displays the exchange rate's instantaneous standard deviation graphically. Its inverted U-shape of this function suggests that in a perfectly credible target zone the instantaneous standard deviations of the exchange rate are largest in the middle of the exchange rate band, and fall towards zero at the edges of the band, due to the "smooth pasting" conditions.

Figure 2.3.
Instantaneous Conditional Standard Deviation of the Exchange Rate
in a Perfectly Credible Target Zone



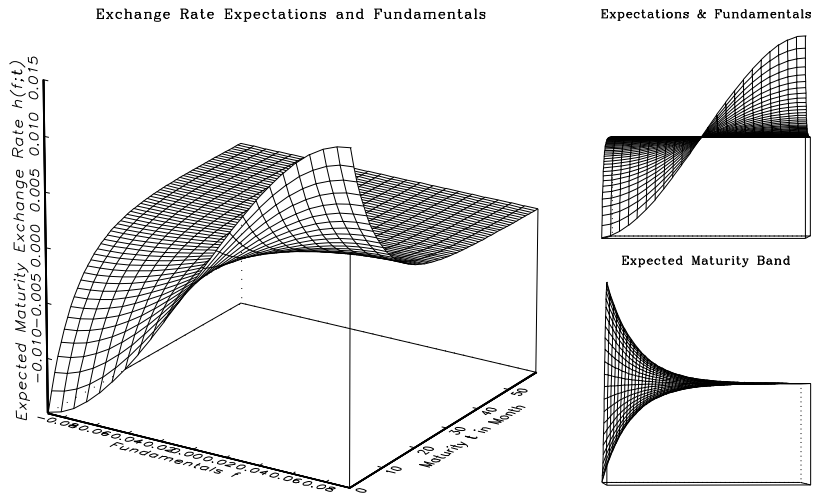
The above intrinsic dynamics of exchange rates in a fully credible target zone has been shown by Svensson (1989, 1991b) to also have important implications for expected future exchange rates and interest rate differentials, as will be discussed below.

2.2.2.2. The Term Structure of Interest Rate Differentials in Perfectly Credible Target Zones: the Svensson Model

This section discusses the effect of an exchange rate target zone on interest rate differentials, which was first derived formally in Svensson (1989, 1991b). Let $i_t^*(\tau)$ denote an exogenous foreign nominal interest rate on a pure discount bond purchased at time t with term τ , that is, maturing at time $t+\tau$, $\tau>0$. Further define $i_t(f_t, \tau)$ as the

nominal interest rate on a home currency pure discount bond, purchased at time t with the fundamental f_t equal to f , and maturing at time $t+\tau$, $\tau>0$. Svensson (1991b) shows that the interest rate differential $\delta(f;\tau)$ in a target zone may then be derived as outlined in Box 9. Equation (9.1a) describes the instantaneous interest rate differential ($\tau=0$), whilst equation (9.1b) applies for positive finite terms ($\tau>0$). Solving equation (9.1b) as a function of fundamentals requires the computing of the expected exchange rate at maturity, $h(f;\tau)\equiv E[x\{f(t)\} | f_0 =f]$, which is a complicated non-linear heteroscedastic stochastic process with variable drift and variable instantaneous standard deviation. Svensson (1991b) shows that the function $h(f;\tau)$ can be derived as the solution to the partial differential equation (9.2a) subject to the initial condition (9.2b) and the derivative boundary conditions (9.2c). Svensson (1991b) derives both an analytical Fourier-series solution, based on the methods described in Churchill and Brown (1987), and a numerical solution, based on the so-called explicit method described in Gerald and Wheatley (1989), for this parabolic partial differential equation (3.14a).¹⁶ The computations in the present study are based on the analytical Fourier series solution, which is outlined in more detail in Appendix A of this chapter¹⁷. The Fourier series solution for the parabolic differential equation is illustrated in Figure 2.4, which displays the term structure of expected maturity exchange rates as a three-dimensional non-linear function of both the fundamentals and the term.¹⁸

Figure 2.4.
Expected Maturity Exchange Rate and Fundamentals in
a Perfectly Credible Target Zone

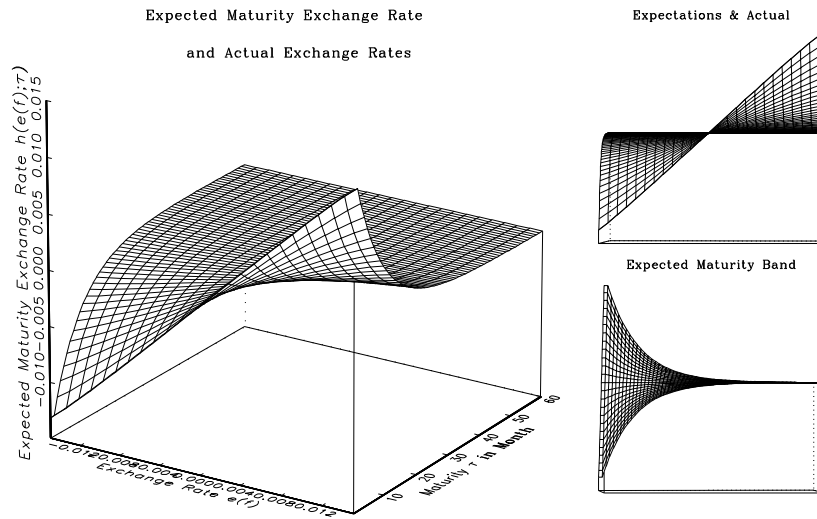


For zero term ($\tau=0$), the expected exchange rate $h(f;\tau)$, of course, coincides with the actual exchange rate e_t , and consequently the front line in the three-dimensional plane on the right-hand side of Figure 2.4 is identical to the S-shaped exchange rate function from Figure 2.1 above. For positive and short terms the

expected exchange rate $h(f;\tau)$ has a similar but flatter S-shape, as is shown most clearly in the upper two-dimensional inset on the right-hand side of Figure 2.4. The expected exchange rate $h(f;\tau)$ thereby still is increasing in the fundamentals f_t and, due to the "smooth pasting" conditions, flat at the edges of the band. For longer terms the expected exchange rate's band tends to converge to the exchange rate's unconditional mean, which is zero in the example with symmetric bands ($f_U=-f_L=0.094$, $e_U=-e_L=0.01$) and zero fundamentals drift ($\eta=0$). This can also be seen from the lower two-dimensional inset on the right-hand side of Figure 4.4, which displays the fluctuation band of the expected exchange rate $h(f;\tau)$ against the maturity τ . The width of the expected exchange rate's band is decreasing in term τ in a non-linear fashion, and tends to vanish for longer terms.

Since equation (7.4) of the target zone model expresses the exchange rate e_t as unique function of the fundamentals process f_t , the expected exchange rate $h(f;\tau)$ may also be expressed as a function $h(e(f);\tau)$ of the exchange rate e_t , which is displayed in Figure 2.5. For zero term ($\tau=0$), the expected exchange rate $h(e(f),\tau)$, of course, coincides with the 45 degree line, as drawn at the front line in the three-dimensional plane on the right-hand side of Figure 2.5.

Figure 2.5.
Expected Maturity Exchange Rate and Exchange Rates in
a Perfectly Credible Target Zone



BOX 9
Testable Implications of the Perfectly Credible Target Zone Model of
Svenssons (1989, 1991b) for the Term Structure of Interest Rate Differentials

$$\delta(f; \tau) \equiv i_t(f; \tau) - i_t^*(\tau) = \frac{e(f) - f}{\alpha}, \quad \tau=0, \quad \text{Interest rate differential for } \tau=0, \quad (9.1a)$$

$$\delta(f; \tau) = \frac{E[e\{f(\tau)\} | f_0 = f] - e(f)}{\tau}, \quad \tau > 0, \quad \text{Interest rate differential for } \tau > 0, \quad (9.1b)$$

$$h(f; \tau) = \mu h_f(f; \tau) + \frac{\sigma^2}{2} h_{ff}(f; \tau), \quad \text{Partial differential equation for the expected exchange rate at maturity} \quad (9.2a)$$

with $f_L \leq f \leq f_U, \tau \geq 0,$

$$h(f; 0) = e(f), \quad \text{Initial condition} \quad (9.2b)$$

$$h_f(f_U; \tau) = 0, \quad h_f(f_L; \tau) = 0, \quad \text{Derivative boundary condition} \quad (9.2c)$$

$$\sigma^\delta[\delta(f; \tau)] = -\sigma \delta_f(f; \tau), \quad \text{Interest rate differential's instantaneous standard deviation} \quad (9.3)$$

with $\tau > 0, \delta_{L, \tau} < \delta < \delta_{U, \tau}$

$$\phi^\delta[\delta(f; \tau)] = \phi^f[f(\delta; \tau)] / \delta_f(f; \tau), \quad \text{Interest rate differential's instantaneous probability density distribution} \quad (9.4)$$

with $\tau > 0, \delta_{L, \tau} < \delta < \delta_{U, \tau}$

$$\delta(f(e); \tau) = \frac{h(f(e); \tau) - e}{\tau}, \quad \text{Interest rate differential as a inverse function of the exchange rate} \quad (9.5)$$

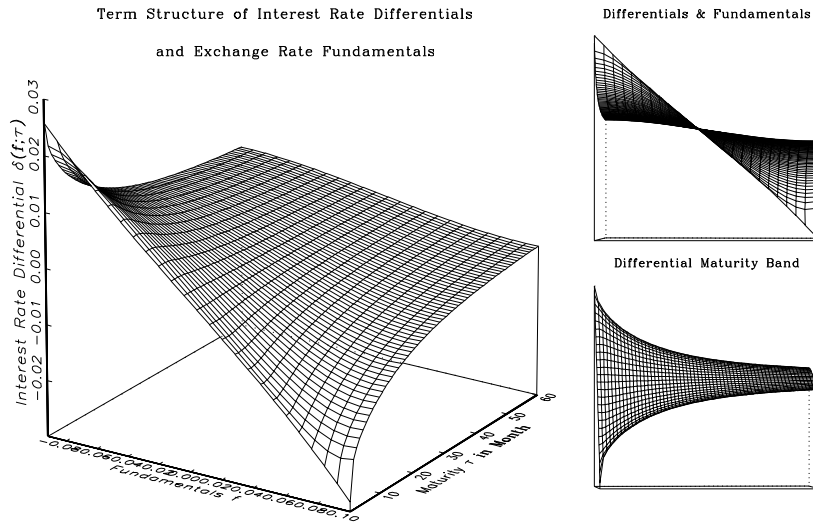
with $\tau > 0, \delta_{L, \tau} < \delta < \delta_{U, \tau}$

Key to symbols: i_t interest rate, i_t^* foreign interest rate, δ_t interest rate differential, e_t exchange rate, f_t fundamentals, $\sigma^\delta(\delta)\eta$ instantaneous conditional standard deviation of δ_t , σ^2 instantaneous variance of f_t , $\delta(f)$ interest rate differential function, δ_f (δ_{ff}) first (second) derivative of δ with respect to f , $\phi^f(f)$ density distribution of fundamentals, $\phi^\delta(\delta)$ density distribution of interest rate differential, f_L and f_U (δ_L and δ_U) upper and lower bound of fundamentals (interest rate differentials), τ maturity, α parameters.

For positive but short terms the expected exchange rate $h(f; \tau)$ has a flatter and somewhat more S-shaped slope, as is shown in the upper two-dimensional inset on the right-hand side of Figure 2.5. For longer terms the expected exchange rate $h(e(f); \tau)$ is still increasing in the exchange rate e_t , but it tends to converge to the unconditional mean of e_t , which is zero in the current example with symmetric bands and zero fundamentals drift. This can again be seen from the lower two-dimensional inset on the right-hand side of Figure 2.5, which shows that the fluctuation band of the expected exchange rate $h(e(f); \tau)$ is decreasing in term τ , and tends to vanish for longer terms.

Given the above behaviour of the expected maturity exchange rate $h(f; \tau)$, it is straightforward to calculate the term structure of interest rate differentials $\delta(f; \tau)$ for positive terms ($\tau > 0$) from equation (9.1b), which together with the instantaneous ($\tau = 0$) interest rate differential from equation (9.1a) is illustrated as a function of the fundamentals process f_t in Figure 2.6.

Figure 2.6.
Term Structure of Interest Rate Differentials and Fundamentals in a Perfectly Credible Target Zone

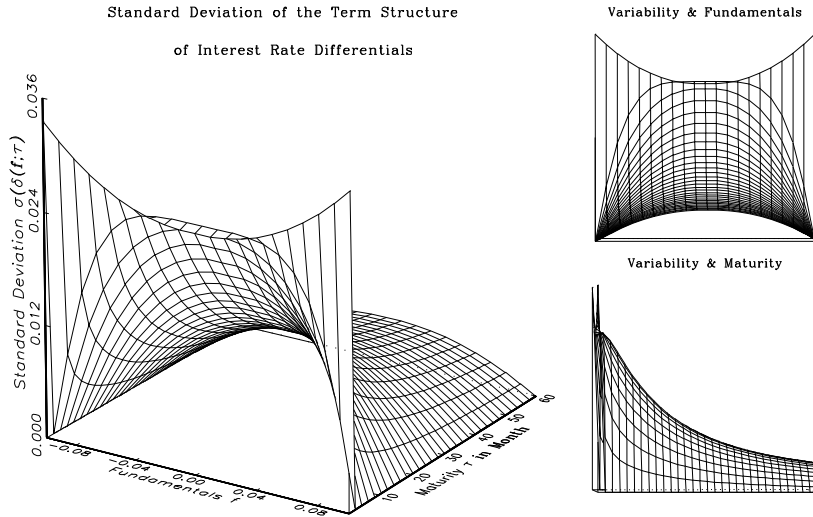


The instantaneous interest rate differential ($\delta(f; \tau)$ for $\tau = 0$), given by the front line of the three-dimensional plane on the right-hand side of Figure 2.6, does not satisfy the smooth pasting conditions. However, in the model with infinitesimal marginal intervention, the upper and lower bounds of the fundamentals process imply well-specified upper and lower bounds for the term structure of interest rate differential,¹⁹ which are decreasing functions of the fundamentals. For positive terms ($\tau > 0$) the smooth pasting conditions are fulfilled, and this is why the finite term

interest rate differential functions have a negative S-shape. The upper two-dimensional inset on the right-hand side of Figure 2.6 further shows that the interest rate differential functions become flatter and less non-linear for longer maturities. In economic terms this implies that when the fundamentals are at the lower boundary of the target zone and the domestic currency is strong, expectations of future interventions typically result in expectations of a depreciation and hence positive interest rate differentials. The lower two-dimensional inset on the right-hand side of Figure 2.6 finally shows that the interest rate differential is decreasing in the term τ , except for very long terms, where it is approximately flat. Thus, for a given width of the fundamentals band the fluctuation band of the interest rate differential is decreasing in term in a non-linear fashion, but it does not completely vanish for long maturities.

Svensson (1991b) also shows that the interest rate differentials' instantaneous standard deviation $\sigma^\delta(\delta)$ is given by the product of its derivative with respect to the fundamentals, $\delta_f(f;\tau)$, and the instantaneous standard deviation of the fundamentals (σ), as formalised in equation (9.3) of Box 9. Figure 2.7. displays the standard deviation of interest rate differentials for the above numerical example of a symmetric band with zero fundamentals drift ($\eta=0$, $\sigma=0.1$, $\alpha=3$, $f_U=-f_L=0.094$, $e_U=-e_L=0.01$) as a function of both the fundamentals f_t and the term τ .²⁰

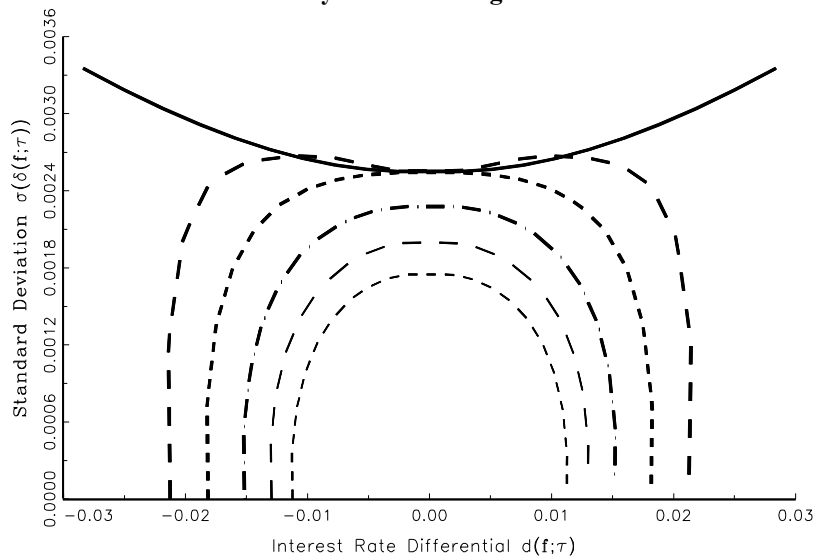
Figure 2.7.
Standard Deviation of the Term Structure of Interest Rate Differentials in a Perfectly Credible Target Zone



The interest rate differentials instantaneous standard deviation for a zero term ($\tau=0$) is a U-shaped function, as is indicated by the front line of the three-

dimensional plane on the left-hand side of Figure 2.7, whilst for positive terms this function has an inverted U-shape. Thus, in contrast to zero-term interest rate differentials, the standard deviation of positive-term interest rate differentials is largest in the middle of the band and falls to zero at the edges of the fundamentals band. This result derives from the fact that the positive-term interest rate differentials fulfil the smooth pasting conditions, whilst the zero-term interest rate differentials do not. Hence there is a discontinuity between the finite and zero term interest rate differentials at the edges of the fundamentals band, corresponding to the discontinuity of the derivative $\delta_f(f;\tau)$ at $\tau=0$. Lindberg and Söderlind (1991) further point out that for longer terms τ the same fundamentals band $f_L < f < f_U$ results in an ever narrower interest rate differential band $\delta_{L,\tau} < \delta < \delta_{U,\tau}$. This is why in Figure 2.8, the inverted U-shape of the standard deviation functions tend to be more compressed if displayed for alternative terms ($\tau=0,1,3,6,9,12$) against the interest rate differential itself. Another important result of Svensson (1991b) is that the standard deviation of interest rate differentials declines in a non-linear fashion as the terms to maturity of the underlying bonds increases.

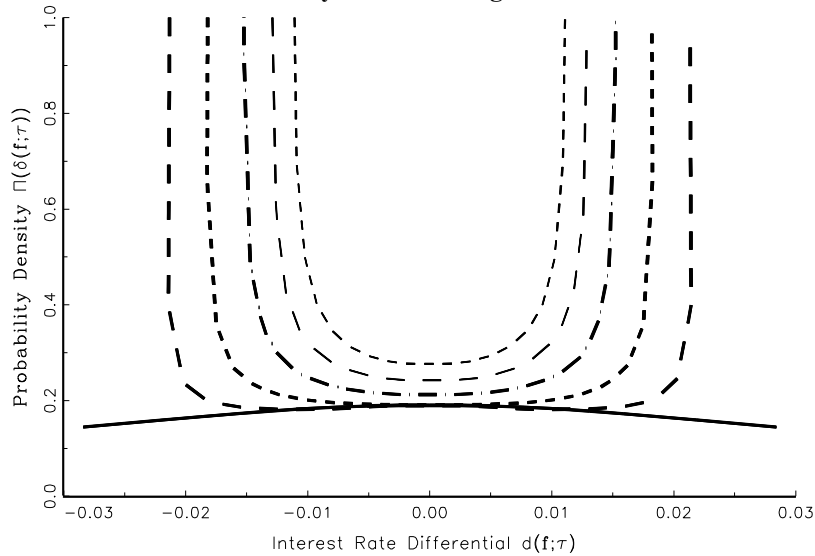
Figure 2.8
Standard Deviation of the Term Structure and Interest Rate Differentials in a Perfectly Credible Target Zone



The probability density of interest rate differentials $\phi^\delta(\delta)$ is derived in Svensson (1991b)²¹ as equation (9.4), with $f(\delta;\tau)$ denoting the inverse of $\delta(f;\tau)$. Figure 2.9, borrowed from Lindberg and Söderlind (1991), displays this probability density for alternative terms ($\tau=0,1,3,6,9,12$) against the interest rate differential itself. The probability density functions of positive term interest rate differentials are again

more compressed in interest rate differential space and tend to be U-shaped or bimodal with more mass towards the edges of the interest rate differential band $\delta_{L,\tau} < \delta < \delta_{U,\tau}$.

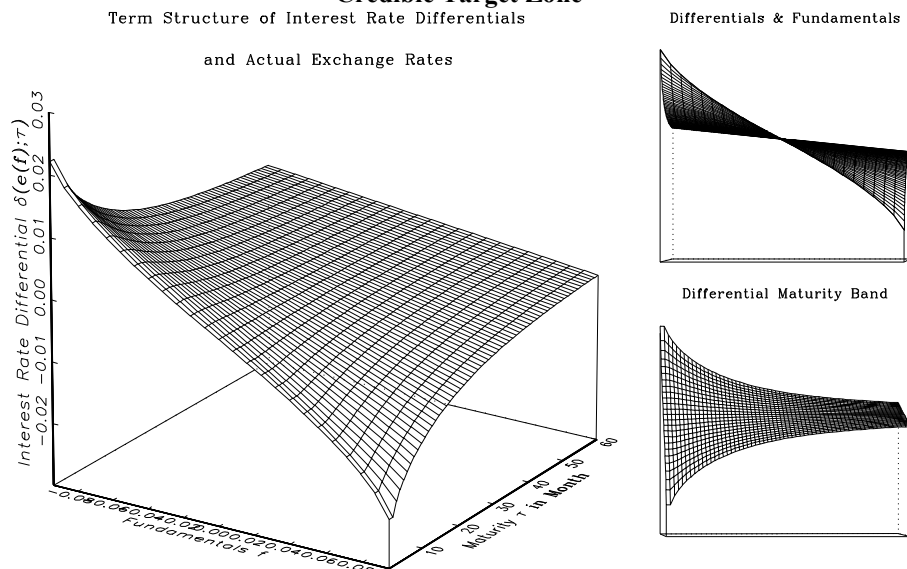
Figure 2.9.
Probability Density of the Term Structure and Interest Rate Differentials in a Perfectly Credible Target Zone



Using the non-linear S-shaped relationship between exchange rates and fundamentals from equation (7.4), Svensson (1991b) also derives a functional relationship between the term structure of interest rate differentials and the exchange rate in a fully credible target zone, as formalised by equation (9.5). The fundamentals function $f(e)=x^{-1}(e)$ thereby denotes the inverse of the exchange rate function $e=x(f)$, and may easily be computed numerically.²²

Figure 2.10 displays this relationship, which is discontinuous in τ at $\tau=0$. Both instantaneous and finite term interest rate differentials are decreasing in the exchange rate, and the non-linearity as well as the negative slope of this function are more pronounced at the short end of the maturity range (see upper inset). Furthermore, the interest rate differential's fluctuation band for a given exchange rate band is strictly decreasing in the term (see lower inset).

Figure 2.10.
Term Structure of Interest Rate Differentials and Exchange Rates in a Perfectly Credible Target Zone



2.2.3. Models of Imperfectly Credible Target Zones

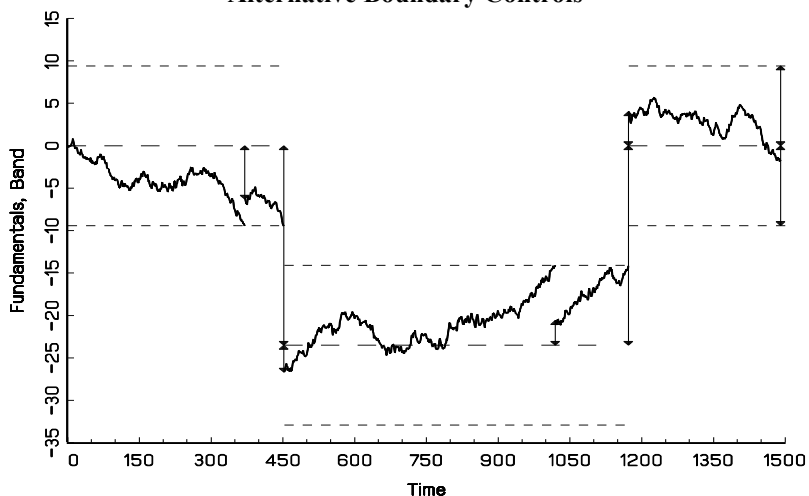
Imperfect credibility may be introduced into the standard target zone model in various ways: Krugman (1991) analyses the case of a possible collapse of an imperfectly credible target zone, which is defined as one in which the probability that the target zone will be defended (by infinitesimal marginal intervention) when the fundamentals hit the boundary of the fundamentals band is less than unity. In the absence of such stabilising intervention, Krugman (1991) assumes that the exchange rate system will revert to a free float, and this event has a non-zero probability *ex ante*. Bertola and Caballero (1991) also model an imperfectly credible target zone as one which is defended with a probability of less than unity, but they assume that a realignment, viewed as an infrequent shift from one target zone to another, will occur with non-zero probability as the fundamentals hit the edges of the band. Svensson (1991b), on the other hand, models imperfectly credible exchange rate target zones by introducing an exogenously given constant devaluation risk, and Bertola and Svensson (1991) explicitly formalise time-varying devaluation/realignment expectations as a second state variable in addition to the fundamentals.

In order to discuss formally and compare the various models of imperfectly credible target zones, the general solution derived in Bartolini and Bodnar (1991) for a number of alternative boundary control hypotheses will be employed. A neat feature of the Bartolini and Bodnar solution is that it reduces to the special model of

Krugman (1991), Bertola and Caballero (1991), Svensson (1991b) or Flood and Garber (1989) under certain parameter restrictions.

Figure 2.11 summarises the intervention policies considered in the Bartolini and Bodnar (1991) model, whereby allowance is made for different realignment risks at the upper and lower boundaries of the fundamentals band, as well as asymmetric intervention rules for repositioning fundamentals inside the old band (in case it is defended), or inside a new band (in case of a realignment). Let the current central parity of the fundamentals be denoted by c_t , the width of the symmetric fundamentals band by $2\hat{f}$, and the probabilities that the band is realigned when the fundamentals hit the upper and lower edges of the band by π and ψ , respectively. When a devaluation occurs, the new central parity becomes $(c+C)$, and the position of the fundamentals inside the new band becomes $(c+C+D)$. However, if the central bank responds to devaluation pressure by defending the central parity, fundamentals are repositioned inside the old band at $(c+D^*)$. Similarly, when a revaluation occurs, the new central parity becomes $(c-C)$, and the position of the fundamentals inside the new band becomes $(c-C-R)$, whilst in the case of a defence of the central parity the fundamentals are repositioned inside the old band at $(c-R^*)$.

Figure 2.11.
Simulation of Possible Time-Paths of Exchange Rate Fundamentals under Alternative Boundary Controls



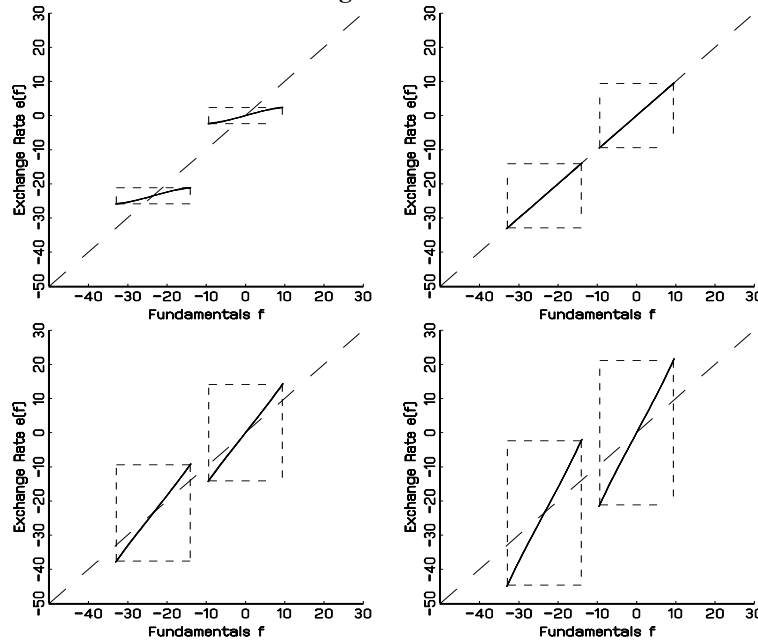
In Box 10 the Bartolini and Bodnar (1991) solution for imperfectly credible exchange rate target zones like those depicted in Figure 2.11. for alternative boundary control scenarios, is spelled out formally. As Bartolini and Bodnar (1991) stress, in a fully credible target zone with $\pi=\psi=0$ the Flood and Garber (1989) case of impulse-control adjustment is obtained. The Krugman (1991) and Svensson (1991b) case of fully credible infinitesimal marginal control may, in turn, be obtained for $\pi=\psi=0$ by

additionally letting D^* and R^* go to \bar{f} .²³ Finally, the Bertola and Caballero (1991) model of an imperfectly credible target zone follows for $\pi=\psi$, $D=D^*=R=R^*=0$ and $C=2\bar{f}$, whilst Krugman's (1991) case of the collapse of an imperfectly credible target zone to a free float derives for $\pi=\psi=1$, $D=D^*=R=R^*=0$ and $C=\bar{f}$.

Box 10	
Bartolini and Bodnar's (1991) General Solution of Models of Imperfectly Credible Target Zones under a Variety of Possible Intervention Policies	
$e_t = x(f_t, c_t),$	(10.1)
$x(c + \bar{f}, c) = \pi x(c + C + D, c + C) + (1 - \pi)x(c + D^*, c),$	(10.2a)
$x(c - \bar{f}, c) = \psi x(c - C - R, c - C) + (1 - \psi)x(c - R^*, c),$	(10.2b)
$e_t = f_t + \alpha\eta + A_1 e^{\lambda_1(f_t - c_t)} + A_2 e^{\lambda_2(f_t - c_t)},$	(10.3)
$\lambda_1 = \frac{-\eta + \sqrt{\eta^2 + \frac{2\sigma^2}{\alpha}}}{\sigma^2} > 0, \quad \lambda_2 = \frac{-\eta - \sqrt{\eta^2 + \frac{2\sigma^2}{\alpha}}}{\sigma^2} < 0,$	(10.4a)
$A_1 = \frac{\gamma_1\phi_4 - \gamma_2\phi_2}{\phi_1\phi_4 - \phi_2\phi_3}, \quad A_2 = \frac{\gamma_2\phi_1 - \gamma_1\phi_3}{\phi_1\phi_4 - \phi_2\phi_3},$	(10.4b)
$\phi_1 = \pi e^{\lambda_1 D} + (1 - \pi)e^{\lambda_1 D^*} - e^{\lambda_1 \bar{f}},$	(10.4c)
$\phi_2 = \pi e^{\lambda_2 D} + (1 - \pi)e^{\lambda_2 D^*} - e^{\lambda_2 \bar{f}},$	(10.4d)
$\phi_3 = \psi e^{-\lambda_1 R} + (1 - \psi)e^{-\lambda_1 R^*} - e^{-\lambda_1 \bar{f}},$	(10.4e)
$\phi_4 = \psi e^{-\lambda_2 R} + (1 - \psi)e^{-\lambda_2 R^*} - e^{-\lambda_2 \bar{f}},$	(10.4f)
$\gamma_1 = \bar{f} - \pi(C + D) - (1 - \pi)D^*,$	(10.4g)
$\gamma_2 = -\bar{f} - \psi(-C - R) - (1 - \psi)(-R^*).$	(10.4h)
<p><i>Key to symbols:</i> e_t exchange rate, c_t central parity, f_t fundamentals, η instantaneous mean drift of f_t, σ^2 instantaneous variance of f_t, $E_t(de_t/dt)$ expected exchange rate change, $x(f)$ exchange rate function, x_f (x_{ff}) first (second) derivative of x with respect to f, z_t stochastic Wiener process, $\bar{f} = -f_L$ and $\bar{f} = f_U$ (e_L and e_U) symmetric lower and upper bounds of fundamentals (exchange rates), λ, $\lambda_1\phi$, λ_2, $\phi_1\phi$, ϕ_2, $\phi_3\phi$, ϕ_4, $\gamma_1\phi$, γ_2, A, A_1, A_2, α parameters, π realignment probability ($0 \leq \pi \leq 1$), realignment size $2f_U$ ($c_1 = c_0 + 2f_U = f_0 + 2f_U$).</p>	

It is obvious from Box 10 that a given fundamentals process with a given band width may now result in differing exchange rate processes and bands, depending on the probability that the fundamentals band will be defended as the process hits the edges of the band. Figure 2.12. displays a number of such processes for a selection of values of the realignment probability π . To illustrate this point, I have chosen $\pi=0.1$, $\pi=0.4$, $\pi=0.6$, and $\pi=0.9$.

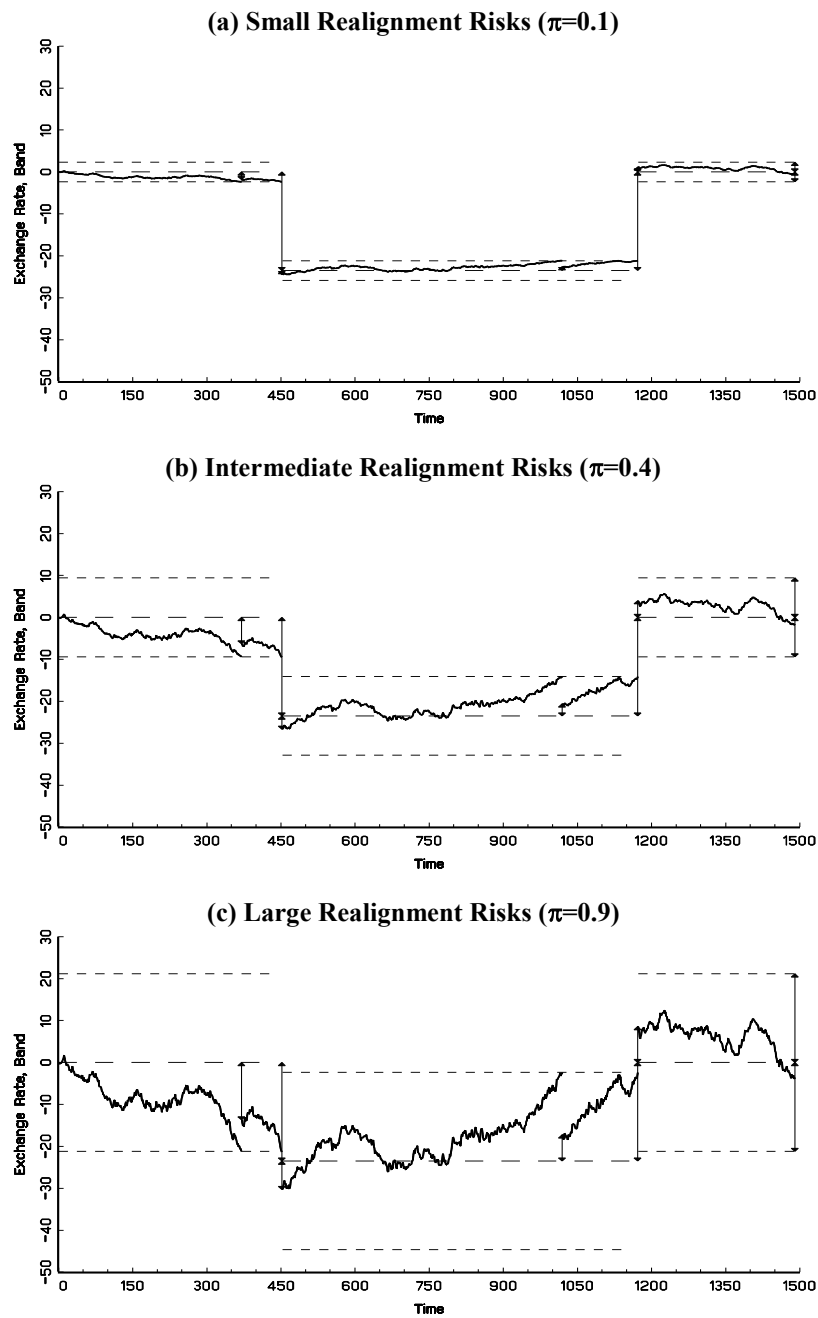
Figure 2.12.
Simulation of Exchange Rates and Fundamentals under Various Degrees of Realignment Risks



Using Figure 2.12 the time-paths of the exchange rate which correspond to the given time-path of the fundamentals from Figure 2.11 can be derived. They are displayed in Figure 2.13 for various degrees of realignment risks, as measured by the realignment probability π . In order to demonstrate the effects of a perceived increase of realignment risks on exchange rates, I have chosen to report results for $\pi=0.1$, $\pi=0.4$, and $\pi=0.9$ respectively.

In Figures 2.11 to 2.13 it is assumed that the central bank engages exclusively in intervention at the margins of the fundamentals band, although the credibility of defending the band is only partial, that is, agents believe that the target zone will be defended at the upper and lower boundary with probability $\pi=\psi$, and changed in a realignment of size $C=2.5\bar{f}$ with probability $(1-\pi)=(1-\psi)$, whereby $0 < \pi = \psi < 1$ holds.

Figure 2.13
Simulations of Exchange Rates under Various Degrees of Realignment Risks in Imperfectly Credible Target Zones



The upper panel of Figure 2.13 displays the time-path of the exchange rate in this set-up if the target zone for the fundamentals is relatively credible, and hence the probability of defending the target zone is relatively high ($\pi=0.1$). In this case the exchange rate band is much narrower than the corresponding fundamentals band, and the inherent stabilisation effect of a target zone is still present, even though the credibility of defending the target zone is only partial. In imperfectly credible target zones with a low realignment probability ($1-\pi, 1-\psi$) the exchange rate function still has the familiar S-shape, but it is everywhere steeper than the corresponding curve in a fully credible target zone (say for $\pi=\psi=0$).

The panel in the middle of Figure 2.13 displays the time-path of the exchange rate under the free float solution of the model, which typically arises for intermediate levels of credibility. Note that due to $C=2.5\bar{f}$ the free float solution (with $A_1=-A_2=0$) results in the present example for $\pi=\psi=0.4$, whilst in the Bertola and Caballero (1991) model with $C=2\bar{f}$ the free float emerges for $\pi=\psi=0.5$. In this case the exchange rate band has the same width as the fundamentals band, and there is no inherent stabilisation effect of a target zone whatsoever.

The lower panel of Figure 2.13 shows the time-path of the exchange rate if a realignment is relatively likely when the fundamentals hit the boundaries of the target zone, and hence the probability of defending the target zone is relatively low ($\pi=0.1$). The exchange rate band is much wider than the corresponding fundamentals band and the target zone for the fundamentals results in an inherent destabilising effect for exchange rates. In imperfectly credible target zones with a high realignment probability ($1-\pi, 1-\psi$) the exchange rate function then has the inverted S-shape postulated in the Bertola and Caballero (1991) model, and it is everywhere steeper than the corresponding free float curve (which due to $C=2.5\bar{f}$ results here for $\pi=\psi=0.4$).

In the target zone literature a number of special cases for the above general model of an imperfectly credible target zone from Box 10 have been discussed, where differences can be observed primarily in the specification of the behaviour of the monetary authority when the target zone is not defended. These models and their main implications shall be briefly reviewed below.

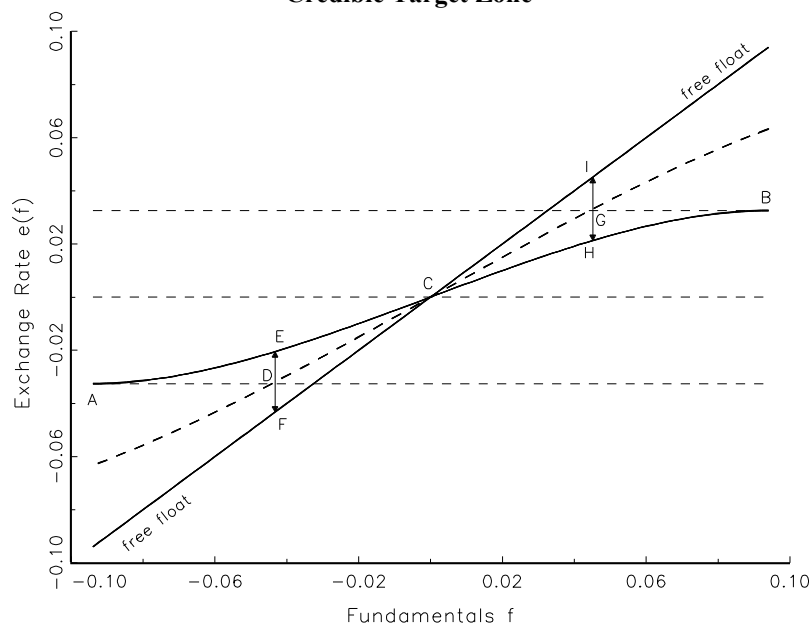
2.2.3.1. Krugman's Model of a Collapsing Target Zone

Krugman (1991) analyses the case of an imperfectly credible target zone which the monetary authority defends by infinitesimal marginal intervention at the upper and lower boundary of the fundamentals band with probability ($1-\pi, 0\leq\pi\leq 1$). In case the target zone is not defended it will collapse and revert to a free float with probability π . What are the effects of this imperfect credibility of the central bank's commitment to defending the band on the principle conclusions of the target zone model?

Using Krugman's (1991) model of an imperfectly credible target zone this may best be illustrated by referring to Figure 2.14. At point A (B) with $\bar{f}=f_L$ ($\bar{f}=f_U$) the familiar S-shaped exchange rate function of a fully credible target zone "smooth pasted" to the lower (upper) boundary e_L (e_U) of the targeted exchange rate band. At

$f=e_L$ ($f=e_U$) the free float exchange rate function intersects with this currency band. At point D (G) with $f=f_D$ ($f=f_G$) the equilibrium exchange rate function of Krugman's imperfectly credible target zone model hits the boundaries of the targeted currency band. At the point D (G) the monetary authority must intervene, either to defend or to abandon the target zone.²⁴

Figure 2.14.
Exchange Rates and Fundamentals in Krugman's Model of an Imperfectly Credible Target Zone



If the target zone is defended, the exchange rate e jumps to point E (H) on the exchange rate function $e_t = f_t + \alpha\eta + A_1e^{\lambda_1 f_t} + A_2e^{\lambda_2 f_t}$, the S-shaped fully credible case. If the target zone is abandoned, the exchange rate e jumps to point F (I) on the freely floating trajectory $e=f$. Thus, given the exogenous probability π of an exchange rate target zone collapse and given the upper (lower) boundary e_L (e_U), the upper (lower) boundary f_D (f_G) of the corresponding target zone for fundamentals must at the point of intervention satisfy the "no arbitrage" condition: the *expected* jump of the exchange rate in response to the intervention at the lower and upper boundaries of a pre-specified exchange rate band must be zero. This is indicated in equations (11.4a) and (11.4b) of Box 11. These "zero expected profit" conditions imply the boundary conditions (11.5a) and (11.5b).

BOX 11		
A Stylised Model of an Imperfectly Credible Exchange Rate Target Zone: Krugman's (1991) Regime Collapse Model		
$e_t = f_t + \frac{\alpha}{dt} E_t(de_t),$	exchange rate equation	(11.1)
$df_t = \eta dt + \sigma dz_t,$	dynamics of fundamentals	(11.2)
$x(f_t) = f_t + \eta x_f(f_t) + \frac{\sigma^2}{2} x_{ff}(f_t),$	2nd order partial diff. equation	(11.3)
$e_t = f_t + \alpha\eta + (1-\pi) [A_1 e^{\lambda_1 f_t} + A_2 e^{\lambda_2 f_t}]$	exchange rate function	(11.4)
$\lambda_{1,2} = \frac{-\eta \pm \sqrt{\eta^2 + \frac{2\sigma^2}{\alpha}}}{\sigma^2}$	characteristic roots	(11.5)
$0 = (f_D + \alpha\eta - e_L) + (1-\pi) [A_1 e^{\lambda_1 f_D} + A_2 e^{\lambda_2 f_D}]$	zero profits at upper boundary	(11.6a)
$0 = (f_G + \alpha\eta - e_U) + (1-\pi) [A_1 e^{\lambda_1 f_G} + A_2 e^{\lambda_2 f_G}]$	zero profits at lower boundary	(11.6b)
$e_L = f_D + \alpha\eta + (1-\pi) [A_1 e^{\lambda_1 f_D} + A_2 e^{\lambda_2 f_D}]$	lower boundary condition	(11.7a)
$e_U = f_G + \alpha\eta + (1-\pi) [A_1 e^{\lambda_1 f_G} + A_2 e^{\lambda_2 f_G}]$	upper boundary condition	(11.7b)
$A_1 = \frac{e^{\lambda_2 f_U} - e^{\lambda_2 f_L}}{\lambda_1 e^{\lambda_1 f_U + \lambda_2 f_L} - \lambda_1 e^{\lambda_1 f_L + \lambda_2 f_U}},$	1st coefficient restriction	(11.8a)
$A_2 = \frac{e^{\lambda_1 f_L} - e^{\lambda_1 f_U}}{\lambda_2 e^{\lambda_1 f_U + \lambda_2 f_L} - \lambda_2 e^{\lambda_1 f_L + \lambda_2 f_U}},$	2nd coefficient restriction	(11.8b)
$x_f = 1 + (1-\pi) \left[\frac{e^{\lambda_2 f_U + \lambda_1 f_L} - e^{\lambda_2 f_L + \lambda_1 f_U}}{e^{\lambda_1 f_U + \lambda_2 f_L} - e^{\lambda_1 f_L + \lambda_2 f_U}} + \frac{e^{\lambda_1 f_L + \lambda_2 f_U} - e^{\lambda_1 f_U + \lambda_2 f_L}}{e^{\lambda_1 f_U + \lambda_2 f_L} - e^{\lambda_1 f_L + \lambda_2 f_U}} \right]$	slope of exchange rate function	(11.9)
$x_f = 1 + (1-\pi) \left[\frac{e^{\lambda_1 f_L + \lambda_2 f_U} - e^{\lambda_1 f_U + \lambda_2 f_L}}{e^{\lambda_1 f_U + \lambda_2 f_L} - e^{\lambda_1 f_L + \lambda_2 f_U}} \right] = \pi$	slope at the boundary	(11.10)

Key to symbols: e_t exchange rate, f_t fundamentals, η instantaneous mean drift of f_t , σ^2 instantaneous variance of f_t , $E_t(de_t/dt)$ expected exchange rate change, $x(f)$ exchange rate function, x_f (x_{ff}) first (second) derivative of x with respect to f , z_t stochastic Wiener process, f_L and f_U (e_L and e_U) upper and lower bound of fundamentals (exchange rate), λ_1 , λ_2 , A_1 , A_2 , α parameters, π collapse probability.

The collapse probability π appears in these boundary conditions only as a multiplicative factor on the non-linear part. For simplicity, consider the case of driftless fundamentals with $\eta=0$. For $\pi=1$ the boundaries of the equilibrium exchange rate trajectory coincides with the free float trajectory and $f_D=e_L$ ($f_G=e_U$) holds for the lower (upper) bound of the implied fundamentals band. For $\pi=0$ the target zone is defended with certainty and the boundaries of the implied fundamentals band f_D (f_G) must be equal to f_L (f_U), the margins of a fully credible target zone. For $0<\pi<1$, however, the boundaries of the equilibrium trajectory lie somewhere between those of the freely floating trajectory and those of a fully credible target zone. Thereby, the higher the collapse probability, the narrower will be the range of intervention-free fundamentals movements, which is consistent with a given width of a targeted exchange rate band.

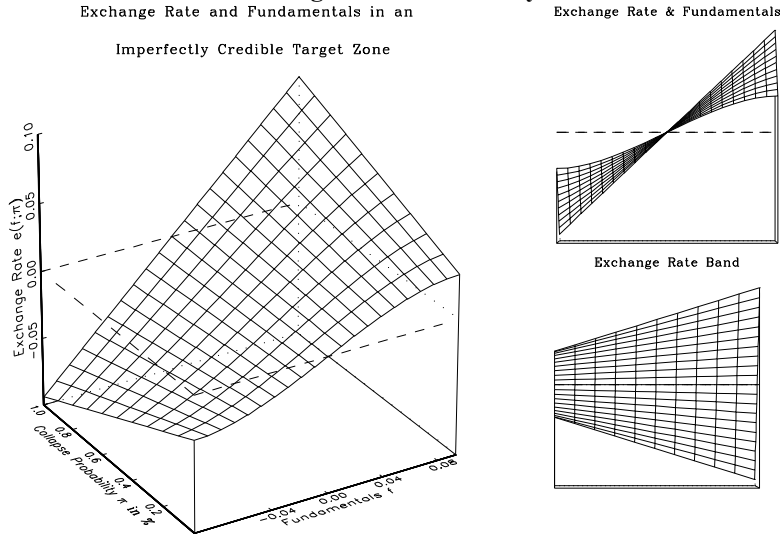
Given the width of the fundamentals band which is determined implicitly by equations (11.7a,b), it is easy to demonstrate that Krugman's solution for the equilibrium exchange rate inside the band is determined by equation (11.8a,b) in Box 11,²⁵ which using the notation from section 2.2.1. may be re-written as equation (11.4). The slope of this exchange rate is given by equation (11.9). At the lower and upper boundary of the fundamentals band, that is for $f_t=f_L$ and for $f_t=f_U$, this expression for the slope of the equilibrium exchange rate function reduces to equation (11.10).

From equation (11.10) it is obvious that in Krugman's model of a potentially collapsing imperfectly credible target zone the "smooth pasting" condition $x_f=0$ only holds if the collapse probability is zero ($\pi=0$). On the other hand, a unit slope of the exchange rate function at the boundaries of the fundamentals band (and everywhere inside the band) results for a collapse probability equal to unity ($\pi=1$). In this case the target zone is sure to collapse as soon as the fundamentals hit the boundaries of the fundamentals band, and in effect there exists a free float system with $e_t=x(f_t)=f_t$. Note that in both extreme cases above and in the general cases with $0<\pi<1$ the slope of the equilibrium exchange rate function at the boundaries of the fundamentals band simply reflects the collapse probability π .

The above effect of an increase of the collapse probability on the width of the exchange rate band implied by a given fundamentals band is displayed in Figure 2.15, again for the above example of a zero fundamentals drift and a symmetric band (with $\eta=0$, $\sigma=0.1$, $\alpha=1$ and $f_U-f_L=0.094$). For $\pi=\psi=0$ the exchange rate function fulfils the "smooth pasting" condition and Krugman's (1991) model coincides with Svensson's (1991b) model of a fully credible target zone with infinitesimal marginal intervention. For $0<\pi<1$ the slope of the exchange rate function still has the familiar S-shape, but it is now everywhere steeper than in a fully credible target zone and violates the "smooth pasting" conditions at the boundaries of the fundamentals band. Stated differently, for $0<\pi<1$ the lower the credibility of defending the target zone, the wider will be the exchange rate band implied by the same fundamentals band, and for $\pi=\psi=1$ the exchange rate function will lie on the free float locus. Thus, as long as the public attaches some non-zero probability to the event that the monetary authority will intervene in order to defend the target zone once fundamentals reach the boundaries of the band, then the qualitative conclusions about the inherent stabilisation effect of

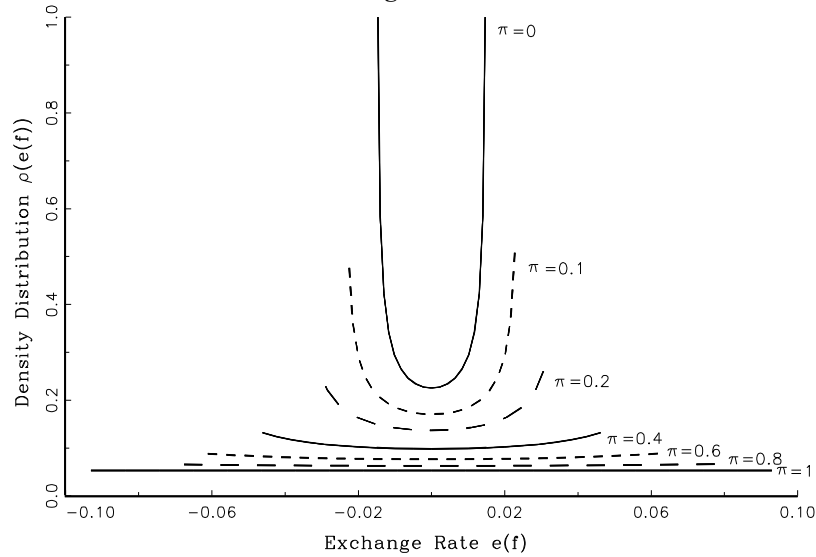
fully credible target zone models will carry over to the case of an imperfectly credible target zone, even though the quantitative stabilisation effects may be quite low.

Figure 2.15.
Exchange Rates and Fundamentals in Krugman's Model under Various Degrees of Target Zone Credibility.



Similar conclusions can be reached for the probability density distribution of exchange rates, $\varphi^e(e) = \varphi^f[x^{-1}(e)]/x_f[x^{-1}(e)]$, in Krugman's model of a potentially collapsing target zone. In fully credible target zones this density was shown to have an U-shape, with more mass concentrated at the boundaries of the exchange rate band, whilst under a free float the probability density was shown by Harrison (1985) to be uniform for a zero fundamental drift [$\varphi^f(f) = 1/(f_U - f_L)$ for $\eta = 0$], and truncated exponential for a non-zero fundamentals drift [$\varphi^f(f) = \theta e^{\theta f} / (e^{\theta f_U} - e^{\theta f_L})$ for $\eta \neq 0$ and $\theta = 2\eta/\sigma^2$]. These results imply that in imperfectly credible target zones a less credible commitment to intervention at the boundaries of the band (higher π 's) result in wider exchange rate bands for the same width of the fundamentals band, as may be seen from Figure 2.16.²⁶

Figure 2.16.
Probability Density Function of the Exchange Rate in an Imperfectly Credible Target Zone

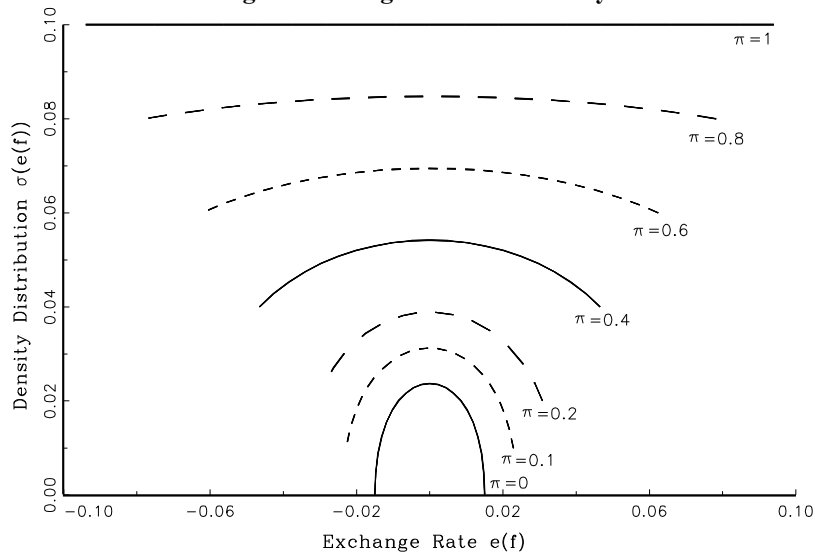


The exchange rate's density distribution, which is only defined in the interior of the band,²⁷ is U-shaped or bimodal with more mass towards the edges of the band for $0 \leq \pi < 1$ and uniform for $\pi = 1$, which is the free float solution of the Krugman (1991) model. Furthermore, the density distributions are more compressed for smaller π 's and the bimodality is more pronounced. This flattening of the U-shapes for higher collapse probabilities π is a direct result of the flattening of the S-shapes of the exchange rate function for larger π 's: for a given constant nominator in equation (8.5), the derivative x_f in the denominator is larger close to the edges of the band the higher the collapse probability π , and this makes the density smaller.

A similar result emerges in Krugman's model of an imperfectly credible target zone for the instantaneous standard deviation of the exchange rate, $\sigma^e(e) = \sigma x_f [x^{-1}(e)]$, which is the product of the standard deviation of the Brownian motion fundamentals σ and the derivative $x_f [x^{-1}(e)]$ of the exchange rate function. Figure 2.17 displays this instantaneous standard deviation of the exchange rate with zero drift in a symmetric band ($\eta = 0$, $\sigma = 0.1$, $\alpha = 0.3$ and $f_U = -f_L = 0.094$). The standard deviation of exchange rates still has an inverted U-shape for $0 \leq \pi < 1$, but for the free float solution with $\pi = 1$ it is uniform and equal to the standard deviation of the fundamentals process. Thus, a comparison of imperfectly and fully credible target zones shows with respect to the former that the instantaneous standard deviation of exchange rates is still largest in the middle of the exchange rate band, but it now falls to $\sigma\pi$ instead of zero at the edges of the band. This is due to the violation of the "smooth pasting" condition in imperfectly credible target zones, since the derivative

of the exchange rate function at the edges of the band is given by $x_f[x^{-1}(e)] = \pi$, instead of being $x_f[x^{-1}(e)] = 0$, as in the "smooth pasting" case.

Figure 2.17.
Standard Deviation of the Exchange Rate in Krugman's Model Under Various Degrees of Target Zone Credibility



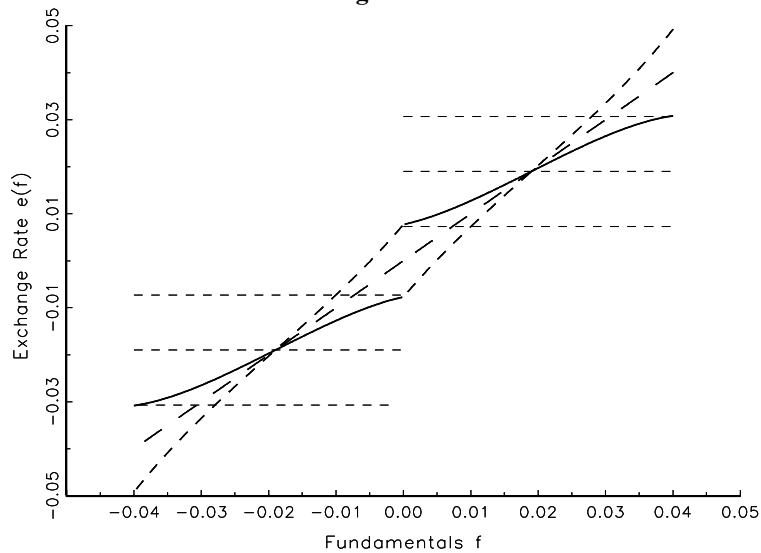
2.2.3.2. Bertola and Caballero's Models of Repeated Realignments

Bertola and Caballero (1990) analyse the case where, as in the Krugman (1991) model, the credibility of defending the band is only partial. In case the current target zone is not defended by discrete marginal intervention, the monetary authority will initiate a realignment. These realignments are viewed as infrequent, recurring stochastic regime shifts.

Bertola and Caballero (1990) assume that any form of intervention by the monetary authority only takes place at pre-specified, common knowledge points $c_t - f_U$ and $c_t + f_U$, where c_t stands for the no longer immutable current central parity and f_U for the upper boundary of the band. One form of intervention is a defence of the current target zone, where the monetary authority is assumed to bring the exchange rate back to the centre of the current band ($e_t = c_0 = f_0$).²⁸ The second form of central bank intervention in the Bertola and Caballero (1990) model is a realignment. In a realignment the central bank declares a new fluctuation band and central parity (c_1) and brings the exchange rate to the centre of the new band ($e_t = c_1 = c_0 + 2f_U = f_0 + 2f_U$). Assume that the defence of the target zone occurs with probability $1 - \pi$, whilst the probability of a realignment is π ($0 \leq \pi \leq 1$).

Figure 2.18 illustrates the effects of realignments in the Bertola and Caballero (1991) model for the case of a symmetric band ($f_U = -f_L$) and a zero fundamentals drift ($\eta = 0$). Point A in Figure 2.18 characterizes the intervention point on an exchange rate function in a relatively credible target zone with central parity c_0 and low realignment probability ($0 < \pi < 0.5$), whilst point B depicts the intervention point in a non-credible target zone with a high realignment probability π ($0.5 < \pi < 1$). It is obvious that the exchange rate bands over two continuous fundamentals zones begin to overlap for $\pi \geq 0.5$, since for a given parity ($c_t = e_C = f_C$) the exchange rate band becomes wider than the fundamentals band (due to $e_U = 2\pi f_U$). In this case the exchange rate function is everywhere steeper than it would be under a free float. The exchange rate function depicts an inverted S-shape.

Figure 2.18.
Realignments in Bertola and Caballero's Model of an Imperfectly Credible Target Zone



To understand this result, it is again important to discuss formally the boundary conditions. Equations (12.5a) and (12.5b) in Box 12 state that the exchange rate at the point of intervention must satisfy the "no arbitrage" condition, which states that the *expected* jump of the exchange rate in response to the intervention at the lower and upper boundaries of the band must be zero. For the simple but instructive case of a zero fundamentals drift ($\eta = 0$ and hence $\lambda_1 = -\lambda_2 = \sqrt{2/\alpha}/\sigma$) in a symmetrical target zone ($f_U = -f_L$) this may, after inserting the relevant exchange rate function (12.4), be modified to obtain the boundary conditions (12.7a) and (12.7b), from which the constant A ($=A_1 = -A_2$) can be solved as indicated in equation (12.8).

BOX 12		
A Stylised Model of an Imperfectly Credible Exchange Rate Target Zone: The Bertola and Caballero (1990, 1991) Model of Repeated Realignments		

$e_t = f_t + \frac{\alpha}{dt} E_t (de_t),$	exchange rate equation	(12.1)
---------------------------------------------	------------------------	--------

$df_t = \eta dt + \sigma dz_t,$	fundamentals dynamics	(12.2)
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$x(f_t) = f_t + \eta x_f(f_t) + \frac{\sigma^2}{2} x_{ff}(f_t),$	2nd order partial differential equation	(12.3)
------------------------------------------------------------------	-----------------------------------------	--------

$e_t = x(f_t, c_t) = f_t + Ae^{-\lambda(f_t - c_t)} - Ae^{\lambda(f_t - c_t)},$	exchange rate function	(12.4)
---------------------------------------------------------------------------------	------------------------	--------

$\lambda_1 = -\lambda_2 = \sqrt{2/\alpha}/\sigma$	characteristic roots	(12.5)
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$x(c_t + f_U, c_t) = \pi x(c_t + 2f_U, c_t + 2f_U) + (1 - \pi)x(c_t, c_t)$	no arbitrage at upper boundary	(12.6a)
----------------------------------------------------------------------------	--------------------------------	---------

$x(c_t - f_U, c_t) = \pi x(c_t - 2f_U, c_t - 2f_U) + (1 - \pi)x(c_t, c_t)$	no arbitrage at lower boundary	(12.6b)
----------------------------------------------------------------------------	--------------------------------	---------

$c_t + f_U + Ae^{-\lambda f_U} - Ae^{\lambda f_U} = \pi(c_t + 2f_U) + (1 - \pi)c_t$	lower boundary condition	(12.7a)
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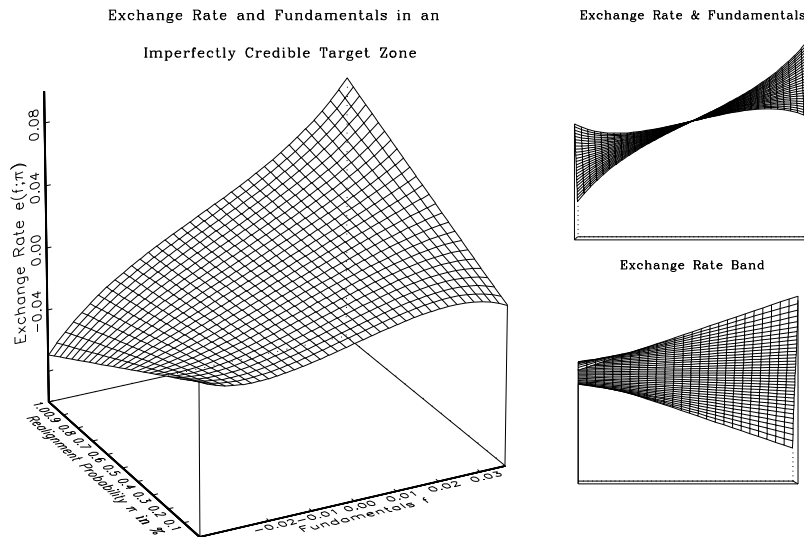
$c_t - f_U + Ae^{\lambda f_U} - Ae^{-\lambda f_U} = \pi(c_t - 2f_U) + (1 - \pi)c_t$	upper boundary condition	(12.7b)
-------------------------------------------------------------------------------------	--------------------------	---------

$A = \frac{(1 - 2\pi)f_U}{e^{\lambda f_U} - e^{-\lambda f_U}}$	coefficient restriction	(12.8)
----------------------------------------------------------------	-------------------------	--------

Key to symbols: e_t exchange rate, c_t central parity, f_t fundamentals, η instantaneous mean drift of f_t , σ^2 instantaneous variance of f_t , $E_t(de_t/dt)$ expected exchange rate change, $x(f)$ exchange rate function, x_f (x_{ff}) first (second) derivative of x with respect to f , z_t stochastic Wiener process, f_L and f_U (e_L and e_U) upper and lower bound of fundamentals (exchange rate), λ , λ_1 , λ_2 , A , A_1 , A_2 , α parameters, π realignment probability ($0 \leq \pi \leq 1$), realignment size $2f_U$ ($c_1 = c_0 + 2f_U = f_0 + 2f_U$).

Obviously, the familiar S-shape²⁹ of the exchange rate function, which requires $A > 0$, results in an imperfectly credible target zone only for $\pi < 1/2$, whilst the free float solution with $A = 0$ emerges here for $\pi = 1/2$. Finally, for $1/2 < \pi \leq 1$ the exchange rate function is everywhere steeper than it would be under a free float. In this case the exchange rate function has an inverted S-shape, implying that a non-credible target zone may have inherently destabilising effects on exchange rates. This result of the Bertola and Caballero (1991) model is visualised in Figure 2.19, which displays the exchange rate function in an imperfectly credible target zone under various degrees of realignment risk, as indicated by realignment probability π .

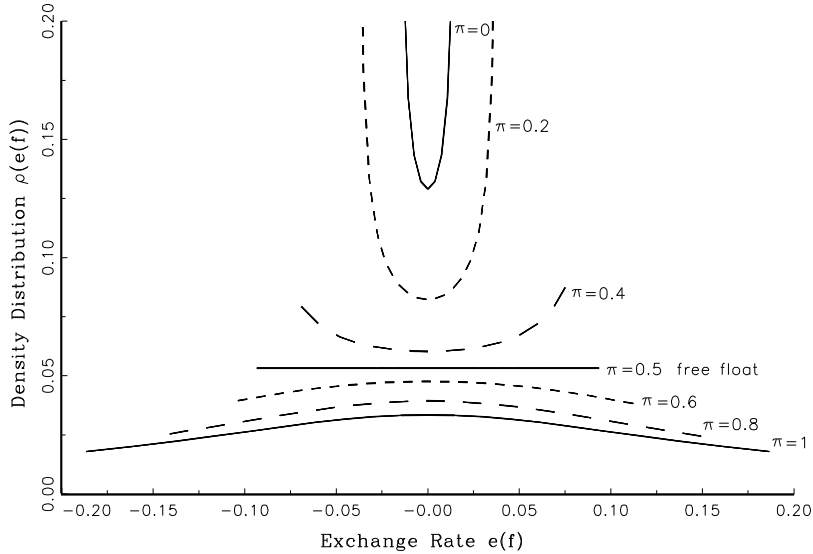
Figure 2.19.
Exchange Rates and Fundamentals under Discrete Marginal Intervention under Various Degrees of Realignment Risk



As in the case of a fully credible target zone, the slope of the exchange rate functions in an imperfectly credible target zone has important implications for the probability density distribution of exchange rates. Figure 2.21 reports the probability density distributions of exchange rates, $\varphi^e(e) = \varphi^f[x^{-1}(e)]/x_f[x^{-1}(e)]$, in the Bertola and Caballero (1991) model under various degrees of realignment risks. As before, the exchange rate's density distribution, which is only defined in the interior of the band,³⁰ has the familiar U-shape in both fully ($\pi = 0$) and relatively credible ($0 < \pi < 1/2$) target zones, and is bimodal with more mass towards the edges of the band. Furthermore, the density distributions are more compressed for smaller π 's and the bimodality is more pronounced. This flattening of the U-shapes for higher realignment probabilities π is a direct result of the flattening of the S-shapes of the exchange rate function for larger π 's: for a given constant nominator in equation (8.3)

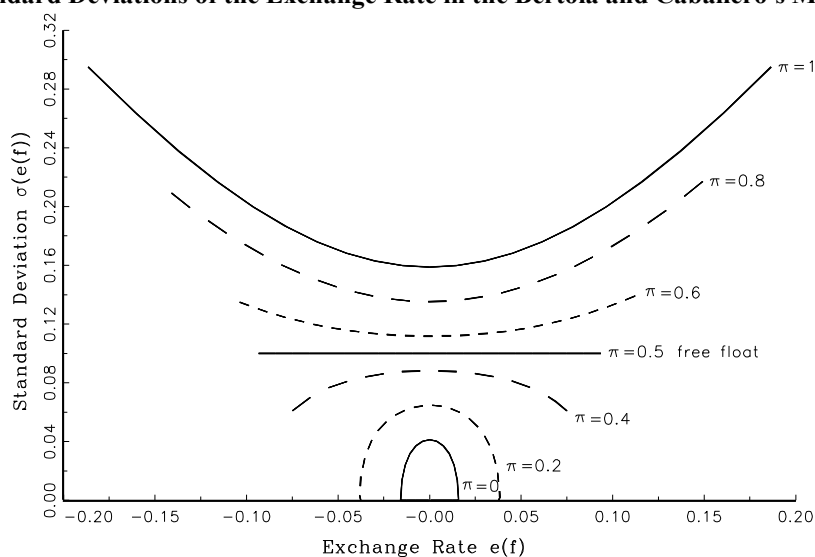
in Box 8, the derivative x_f in the denominator is larger close to the edges of the band, the higher the collapse probability π , and this makes the density smaller. For $\pi=1/2$, which is the free float solution of the Bertola and Caballero (1991) model, the probability density is, as shown by Harrison (1985), uniform for a zero fundamental drift [$\phi^f(f)=1/(f_U-f_L)$ for $\eta=0$], and truncated exponential for a non-zero fundamentals drift [$\phi^f(f)=\theta e^{\theta f}/(e^{\theta f_U}-e^{\theta f_L})$ for $\eta \neq 0$ and $\theta=2\eta/\sigma^2$]. Finally, for the case of a non-credible ($1/2 < \pi < 1$) target zones the exchange rate's density distribution has an inverted U-shape and is uni-modal with more mass towards the middle of the band, and again the density distributions are more compressed for smaller π 's.

Figure 2.20.
Probability Density Distributions of the Exchange Rate in the Bertola and Caballero Model



The various slopes of the exchange rate function in an imperfectly credible target zone also determine the exchange rate's (conditional) instantaneous standard deviation, $\sigma^e(e)=\sigma x_f[x^{-1}(e)]$, which is the product of the standard deviation of the Brownian motion fundamentals σ and the derivative $x_f[x^{-1}(e)]$ of the exchange rate function. Figure 2.21 displays the standard deviation of the exchange rate. In both fully ($\pi=0$) and relatively credible ($0 < \pi < 1/2$) target zones the standard deviation of exchange rates has an inverted U-shape. For $\pi=1/2$ the standard deviation of the exchange rate is uniform across the band and for a zero fundamental drift ($\eta=0$) equal to the standard deviation σ of the fundamentals process. Finally for non-credible ($1/2 < \pi < 1$) target zones the exchange rate's standard deviation has an U-shape, and in all cases the exchange rate's instantaneous standard deviation functions are more compressed for smaller π 's.

Figure 2.21.
Standard Deviations of the Exchange Rate in the Bertola and Caballero's Model



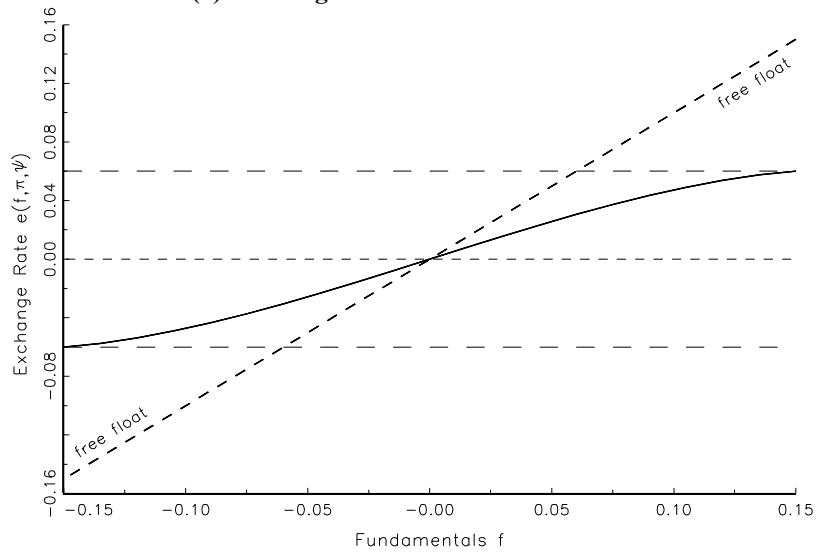
2.2.3.3. Bartolini and Bodnar's Model of Interest Rate Differentials in Imperfectly Credible Target Zones

Formally the only difference between models of perfectly credible and imperfectly credible target zones lies in the boundary conditions for the exchange rate at the point of intervention. Consequently, the determination of the interest rate differential $\delta_t(f_t, c_t, \tau) \equiv i_t(f_t, c_t, \tau) - i_t^*(\tau)$ between domestic and foreign pure discount bond maturing at time $t+\tau$ is given (for $\tau > 0$) by equations (9.1a) and (9.1b) in Box 9, which also applies for the Bartolini and Bodnar (1991) model. As before, determining (9.1b) requires computation the expected exchange rate at maturity, $h(f, c, \tau) \equiv E[x\{f(\tau), c(\tau)\} | f_0 = f]$.

Extending the work of Svensson (1991b), Bartolini and Bodnar (1991) show that in a target zone with limited credibility the function $h(f, c, \tau)$ is the solution for the partial differential equation (9.2a) with initial condition (9.2b) and boundary conditions (9.2c, d). These boundary conditions are defined by the specific intervention rules adopted by the monetary authority, as characterised by the restrictions on C, R, D, R^* and D^* for the exchange rate in Box 10.

Figure 2.22.
The Term Structure of Interest Rate Differentials, Exchange Rates and Fundamentals in a Target Zone With Relatively High Credibility ($\pi=0.2$)

(a) Exchange Rates and Fundamentals



(b) Interest Rate Differentials, Fundamentals and Term to Maturity

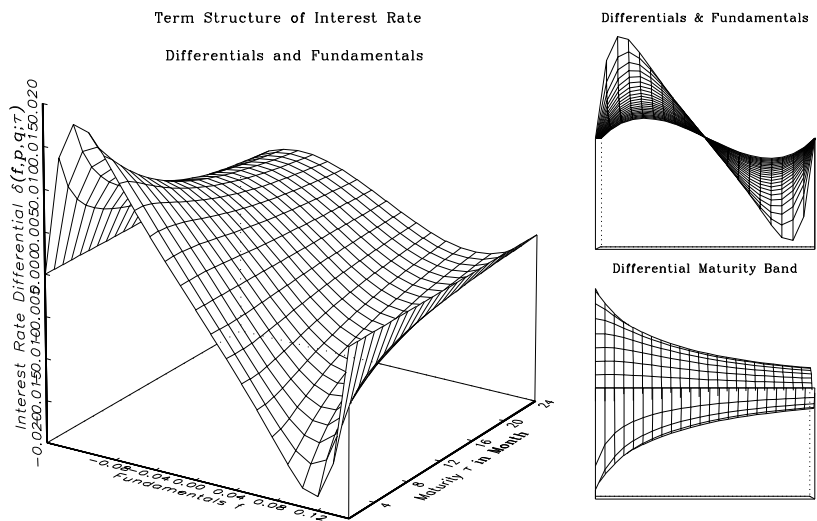
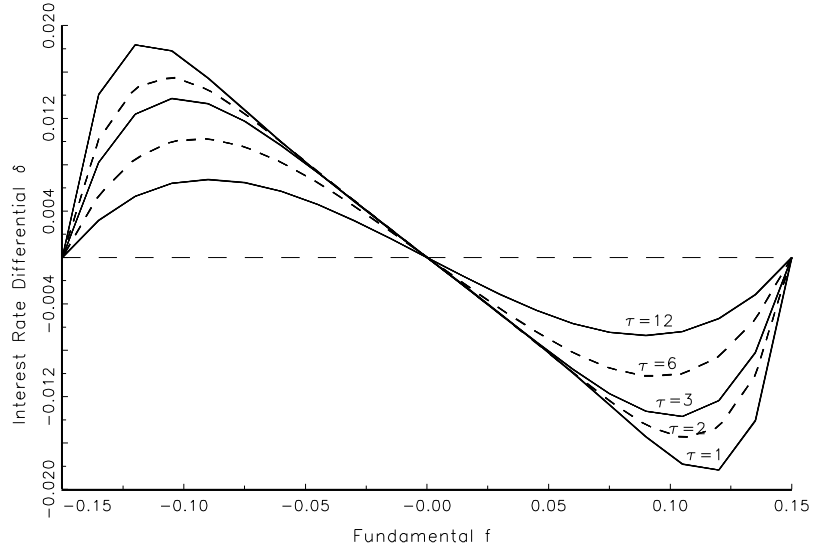
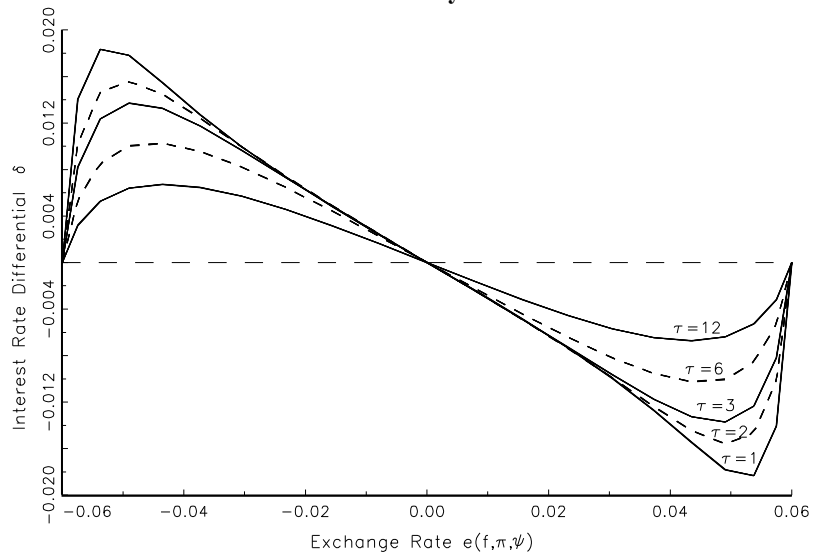


Figure 2.22. continued

(c) Interest Rate Differentials and Fundamentals for Selected Terms to Maturity



(d) Interest Rate Differentials and Exchange Rates for Selected Terms to Maturity



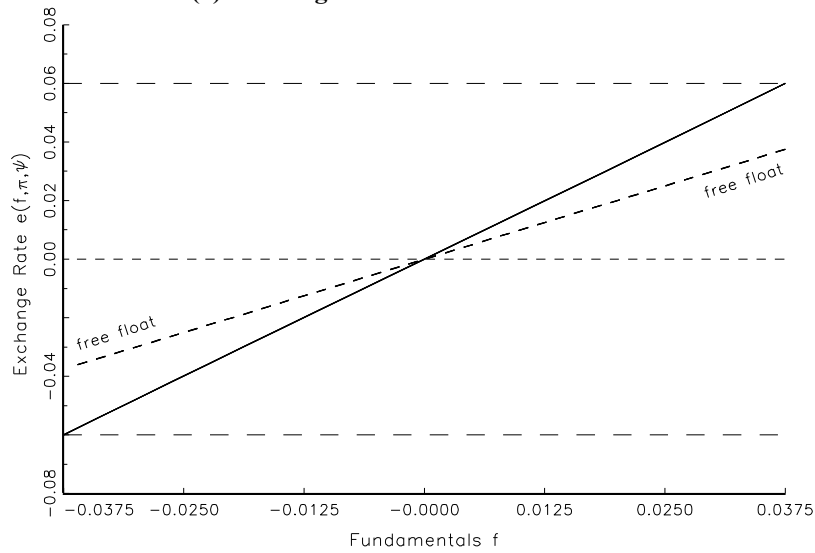
Due to the non-standard nature of the boundary conditions (9.2b) and (9.2c) a closed-form analytical solution for $h(f,c,\tau)$ has not yet been derived. However, Bartolini and Bodnar (1991) show that a numerical solution for the partial differential equation (9.2a) may be obtained by using a numerical procedure, the so-called explicit method from Gerald and Weatley (1989). This complex solution procedure is spelled out in detail in Appendix B of this chapter. Using the Bartolini and Bodnar procedure the numerical solution displayed in Figures 2.22 and 2.23 may be obtained.

Consider first the case of a *highly, but not fully credible* (say $\pi=\psi=0.3$) commitment of the monetary authority to defend the target zone whenever fundamentals hit the boundary of the fundamentals band. When the target zone is defended, the fundamentals are reset to the middle or parity of the old band ($D=R=0$), whilst in the case of a realignment of size $C=2f_U$ the fundamentals are reset to the middle or parity of the new band ($D^*=R^*=0$). Bartolini and Bodnar (1991) show that in the context of the Bertola and Caballero (1991) model such a low realignment probability, which in Figure 2.22a implies an S-shaped exchange rate function, results in functions for the term structure of interest rate differentials, as displayed in Figures 2.22b to 2.22d. *High credibility* of the target zone thus generates a pattern of interest rate differentials or forward premia which are positive at the bottom and negative at the top of the fundamentals band. As in the Svensson (1991b) model, the interest rate differential is decreasing in the fundamentals over a wide range around the middle of the band, and becomes flatter and less non-linear for longer maturities. The lower two-dimensional zoom on the right-hand side of Figure 2.22b further shows that the fluctuation band of interest rate differentials is decreasing in the term τ . However, the combination of high but imperfect target zone credibility and discrete marginal intervention results in hump-shaped interest rate differential profiles towards the edges of the band, as opposed to the monotonic pattern from the infinitesimal marginal intervention case in the Svensson (1991b) model of a fully credible target zone from Figures 2.6. By comparing Figures 2.22c and 2.22d, it also becomes clear that the above conclusions for the relationship between interest rate differentials and fundamentals carry over to the relationship between interest rate differentials and exchange rates. which will be the focus of the empirical analysis of the present study.

The second case considered by Bartolini and Bodnar (1991) is that of a target zone with *low credibility* and a high realignment probability ($\psi=\pi=0.8$), which is displayed in Figures 2.23a to 2.23d. Such a high realignment probability implies the inversely S-shaped exchange rate function in Figure 2.23a, which is steeper than the free float line. The resulting term structure of interest rate differential functions are displayed in Figures 2.23b to 2.23d. The *low credibility* of the target zone generates a pattern of interest rate differentials or forward premia which are negative at the bottom of the band and positive at the top of the band. Thus, in contrast to the Svensson (1991b) model, the interest rate differential is now increasing in the fundamentals over a relatively wide range around the middle of the band. The combination of high but imperfect target zone credibility and discrete marginal intervention again results in hump-shaped interest rate differential profiles.

Figure 2.23.
The Term Structure of Interest Rate Differentials, Exchange Rates and
Fundamentals in a Target Zone With Relatively Low Credibility ($\pi=0.8$)

(a) Exchange Rates and Fundamentals



(b) Interest Rate Differentials, Fundamentals and Term to Maturity

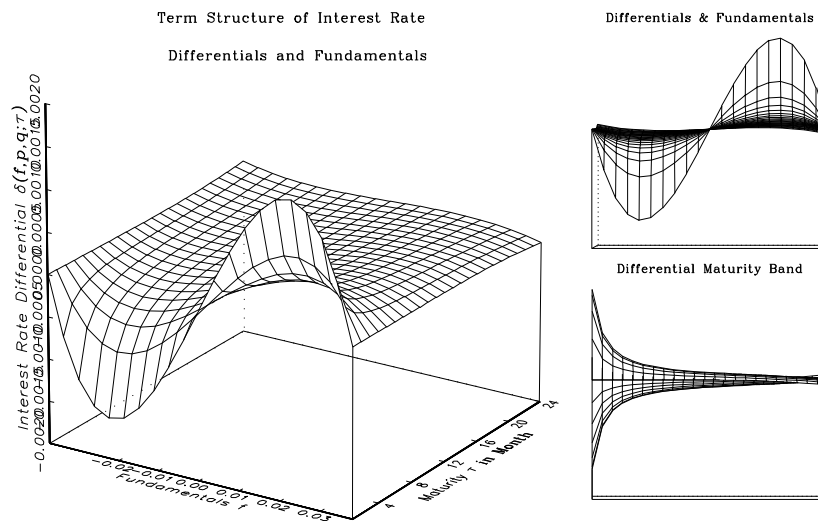
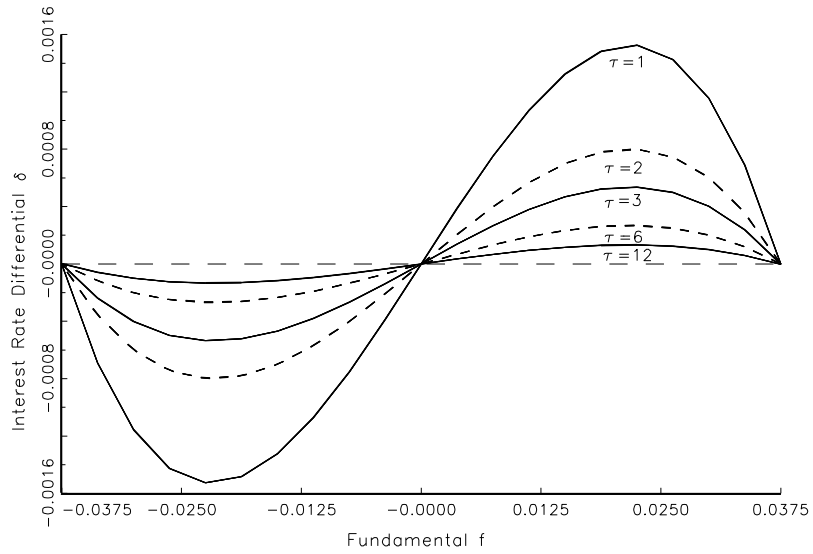
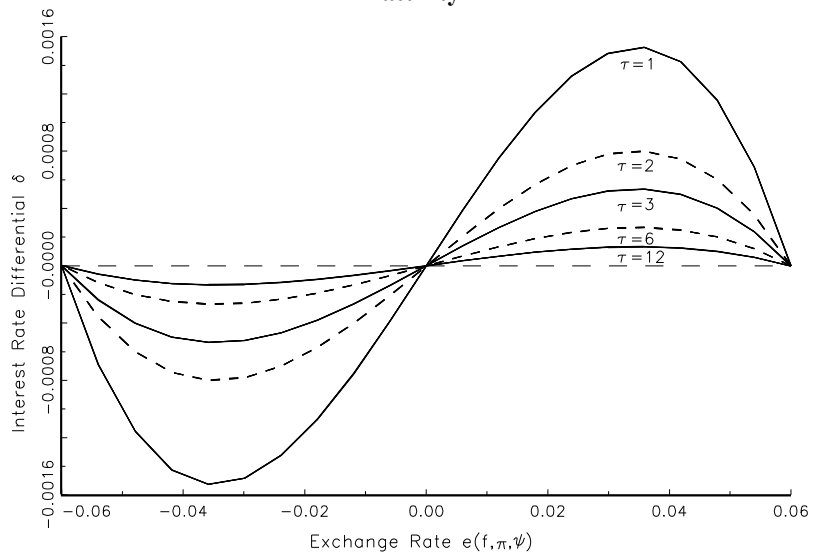


Figure 2.23. continued

(c) Interest Rate Differentials and Fundamentals for Selected Terms to Maturity**(d) Interest Rate Differentials and Exchange Rates for Selected Terms to Maturity**

As before, the term structure of interest rate differentials also becomes flatter and less non-linear for longer maturities, and the fluctuation band of interest rate differentials is decreasing in the term τ . Comparing Figure 2.23c and 2.23d it further becomes obvious that these conclusions for the relationship between interest rate differentials and fundamentals also apply to the relationship between interest rate differentials and exchange rates.

To summarise, the main implication of the Bartolini and Bodnar (1991) model is that the sign of the slope of the non-linear relationship between the term structure of interest rate differentials and exchange rates depends strongly on the degree of target zone credibility. Depending on the probability π of a realignment this slope of the term structure function may have a positive or negative slope near the middle of the band.

2.2.3.4. Imperfectly Credible Target Zones and Devaluation Expectations

The first attempt to explicitly model devaluation risks in imperfectly credible target zones as a process rather than a probability is to be found in Svensson (1989, 1991b). He views realignments as re-occurring with some given constant probability, irrespective of the exchange rate's position within the band. In particular, a realignment is modelled as a shift of magnitude g in the upper and lower bounds of the fundamentals band ($f_L' = f_L + gN$, $f_U' = f_U + gN$) and the same simultaneous shift g in the fundamentals process ($df_t = gdN + \eta dt + \sigma dz_t$). The number of realignments is given as N , and dN is equal to unity with probability $v dt$, which is drawn from a Poisson distribution. As Svensson (1989, 1991b) shows, these devaluations, which leave the relative position of the fundamentals within the band unchanged, result in the modified equation (13.2) for the interest rate differential as opposed to equation (13.1) in the original Svensson (1991b) model.

Note that even if no realignments have yet occurred (for $N=0$), equations (13.2) differs from its counterparts (13.1) in Box 13 by the inclusion of the term vg . The implication of this for the exchange rate function in Figure 2.1 and the term structure of interest rate differentials in Figure 2.10 is that constant devaluation risk shifts these functions upwards by an amount proportional to vg .

As noted in Bertola and Svensson (1991), the above constant devaluation risk is unlikely to result in empirically more successful target zone models. The authors therefore introduce stochastic devaluation risk g_t as a second source of time variation in exchange rates and interest rate differentials. This second state variable g_t is thereby assumed to follow a continuous Brownian motion process ($dg_t = \mu dt + \sigma du_t$) with instantaneous mean drift μ and variance σ , where du_t is the standard Wiener process.³¹ Solving the model in the two state variables g_t and f_t then enables Bertola and Svensson (1991) to explain much of the residual variation in interest rate differentials left unexplained by standard target zone models to the omission of the second state variable g_t .

Box 13
Empirical Implications of Target Zone Models with Respect to the Relationship between Interest Rate Differentials and Exchange Rates

Svensson (1991b)

$$\delta_t(\tau) = c(\tau) + b(\tau)e_t + \varepsilon_t(\tau) \quad (13.1)$$

- the slope coefficient $b(\tau)$ are negative and increasing in term.
- in the absence of any fundamental drift ($\mu=0$), the the intercept coefficient $c(\tau)$ should be zero for all τ if there is no devaluation risk..

Svensson (1991b)

$$\delta_t(\tau, \nu g) = c(\tau, \nu g) + b(\tau)e_t + \varepsilon_t(\tau), \quad (13.2)$$

- the intercept coefficient is negative and depends on both the term τ and the product of the probability intensity of a realignment (ν) and the expected size of the realignment (g):

Svensson and Bertola (1991)

$$\delta_t(g_t, \sigma_g^2/\sigma_f^2; \tau) = c(g_t, \tau) + b(\sigma_g^2/\sigma_f^2, \tau)e_t + \varepsilon_t(\tau), \quad (13.3)$$

- the time-varying intercept $c_t(\tau)$ may take positive and negative values
- the slope coefficient where $b(\sigma_g^2/\sigma_f^2, \tau)$ is negative and increasing in term for low degrees of variability of expected devaluations (σ_g^2 relative to σ_f^2),
- in the absence of fundamental drift ($\eta=0$) the intercept $c(g_t, \tau)$ should largely reflect devaluation risks.

Bartolini and Bodnar (1991)

$$\delta_t(g_t, \pi_t, \sigma_g^2/\sigma_f^2; \tau) = c(g_t, \pi_t, \tau) + b(\pi_t, \sigma_g^2/\sigma_f^2, \tau)e_t + \varepsilon_t(\tau) \quad (13.4)$$

- the slope coefficient $b(g_t, \pi_t, \sigma_g^2/\sigma_f^2; \tau)$ is negative and decreasing in term for low realignment probabilities π_t and low degrees of variability of expected devaluation rates σ_g^2 relative to σ_f^2), but positive and decreasing in term for high realignment probabilities π_t and high degrees of the variability of expected devaluation rates (σ_g^2) relative to the fundamentals (σ_f^2)

Key to symbols: i_t interest rate, i_t^* foreign interest rate, δ_t interest rate differential, e_t exchange rate, f_t fundamentals, $\sigma^\delta(\delta)\eta$ instantaneous conditional standard deviation of δ_t , σ^2 instantaneous variance of f_t , $\delta(f)$ interest rate differential function, δ_f (δ_{ff}) first (second) derivative of δ with respect to f , $\varphi^f(f)$ density distribution of fundamentals, $\varphi^\delta(\delta)$ density distribution of interest rate differential, f_L and f_U (δ_L and δ_U) upper and lower bound of fundamentals (interest rate differentials), τ maturity, α parameter, π realignment probability ($0 \leq \pi \leq 1$), realignment size $2f_U$ ($c_1=c_0+2f_U=f_0+2f_U$).

An interesting result of Bertola and Svensson (1991) is that the negatively sloped instantaneous interest rate differential in Figure 2.10 now fluctuates vertically as the expected rate of devaluation g_t changes over time, so that combined with the simultaneous fluctuations in the fundamentals f_t almost any pattern of exchange rate and interest rate differential observations may result. More specifically, as the variability of g_t relative to f_t increases, the correlation between the instantaneous interest rate differential and the exchange rate will be less negative, and may even become positive. This is captured by equation (13.3) in Box 13. For positive and finite terms matters are even more complicated, as one has to be more specific about what happens to the expected rate of devaluation in the future: if expected devaluation rates g_t being driven by a Brownian motion process across realignment regimes, then interest rate differentials will be non-stationary. Alternatively, to obtain stationary interest rate differentials, some type of mean reverting properties (or re-setting at a realignment) of g_t is required. On purely theoretical grounds Bertola and Svensson (1991) prefer the latter alternative. Their simulations then show that for a low variability of the expected devaluation rates g_t relative to the fundamentals f_t the negative correlation between the term structure of interest rate differentials and exchange rates is maintained, but for relatively high degrees of time-variability of expected devaluation rates g_t this negative correlation may vanish or even become positive. This result parallels that of Bartolini and Bodnar (1992) for various degrees of realignment probabilities in the Bertola and Caballero model, as formalised in equation 13.4 of Box 13.

2.3. Comparing Credibility in Policy Game and Target Zones Models

To summarise, the various models of perfectly credible and imperfectly credible exchange rate target zones have strong empirical implications for both exchange rates and interest rate differentials. These empirical implications primarily concern the probability distributions and variability of both exchange rates and interest rate differentials within certain boundaries defined by the target zone framework. Another strong empirical implication of the target zone model is that it predicts a specific correlation between exchange rates and interest rate differentials. An interesting feature of the fully and imperfectly credible target zone models thereby is that they contradict each other on almost every of the above aspects. It should therefore be easily possible to empirically discriminate between both classes of target zone models.

The empirical analysis of the target zone model is carried out in chapter 4. Before turning to this evidence, some remarks on the econometric methods and empirically testable propositions with respect to credibility in both the policy game and the target zone models are in order. The following chapter 3 of the study discusses these issues.

Endnotes to Chapter 2

¹ Note that here unexpected inflation rates π_t ($\pi_t = p_t - p_{t-1}$), instead of the unexpected level of prices p_t as in Lucas (1973), explain the deviation of output from its natural level.

² Since the public cannot observe m and there are no contemporary information signals available, $E(m_t | \Omega_t)$ is identical to $E(m_t | \Omega_{t-1})$ in this simple version of the basic game.

³ Note that these reputational equilibria unravel backwards infinitely repeated games with the full information, and the above discretionary Nash equilibrium (with $m_t = E(m_t | \Omega_{t-1}) = b\phi$) is obtained in all periods.

⁴ Note that in the solution of the models of Backus and Driffill (1985a,b) and Barro (1986) the government may, after a certain point in time, randomise between the two pure strategies. This feature of the solution, which is due to the simple structure of the model, disappears if, for example, a continuum of possible government types is postulated. See Driffill (1988) for further reverences on this point.

⁵ Barro (1986) shows that such strategic behaviour ($\delta_t > 0$) of the inflationary policymaker is less likely to occur the higher his time preference rate r . Furthermore, the same qualitative conclusion holds the shorter the government's planning horizon and the lower its initial counterinflation reputation.

⁶ Note that the coefficients and in the reduced form for the optimal money growth rate in equation (4.4c) are determined by the requirement of rational expectations in the solution of the public's signal extraction problem in equation (4.5). See Cukierman and Meltzer (1986c) for the details of the derivation of these reduced form coefficient restrictions within an optimising framework.

⁷ In fixed but adjustable exchange rate systems like the EMS a realignment typically leads to new exchange rate parities, which are the outcome of a bargaining process amongst the participants and are frequently not fully indexed to cumulated past inflation differentials. This fact justifies the formulation in equation (6.3) according to which a central bank's PPP target of the exchange rate may differ from the officially announced new central exchange rate parity.

⁸ Froot and Obstfeld (1989a) show (in footnote 2) how equation (1) may be derived from a monetary model of exchange rates such as Mussa (1976). Miller and Weller (1989, 1990a,b) present an interpretation of this equation in terms of Dornbusch's (1976) overshooting model.

⁹ If such jumps were allowed for, risk neutral investors would face an arbitrage opportunity as fundamentals approach the point of intervention at the margins of the band. Flood and Garber (1989) further show that this no-jump requirement also provides boundary conditions for more general intervention policies, such as finite intervention strictly in the interior of the band.

¹⁰ Svensson (1991a) shows that in case of a symmetrical fundamental band ($f_U = -f_L$) and a zero fundamentals drift ($\mu = 0$) the target zone model has a neat solution: the roots λ_1 and λ_2 are given by $\lambda_1 = -\lambda$ and $\lambda_2 = \lambda$, with $\lambda = \sqrt{2/\alpha}/\sigma$, and the constants A_1 and A_2 fulfil $A_1 = \bar{A}$ and $A_2 = -A$, with $A = 1/[2\lambda \cosh(\lambda f_U)]$. The target zone exchange rate function can then be written as $x(f) = f - \sinh(\lambda f)/\lambda \cosh(\lambda f_U)$.

¹¹ Lindberg and Söderlind (1991) show that in order for the monetary authority to determine a suitable symmetrical band around zero for the fundamentals ($f_U = -f_L$) which corresponds to a desired symmetrical exchange rate band ($e_U = -e_L$), the equation $s_U = f_U - \tanh(\lambda f_U)/\lambda$.

¹² See, for example, Spanos (1986).

¹³ It is obvious that for a zero drift and a symmetrical fundamentals band the derivative of in the denominator of (8.3) is given by $x_f(f(e)) = 1 - \cosh(\lambda f)/\lambda \cosh(\lambda f_U)$.

¹⁴ This is true since the exchange rate function is strictly increasing and invertible only in the interior of the band, and its derivative is zero at the edges of the band.

¹⁵ See Svensson (1989, 1991b) and Lindberg and Söderlind (1991).

¹⁶ Of course, both the direct numerical method and the analytical Fourier series method, of course, yield the same quantitative results. Svensson (1991b) uses the direct numerical method in calculating the three-dimensional graphs in which he displays his results. However, the present analysis uses the analytical Fourier series solution for deriving the same three-dimensional graphs.

¹⁷ As the published version of the paper by Svensson (1991b) does not contain the analytical Fourier series solution on which the graphs in the present paper are based, this Fourier series solution is reported here from Svensson's (1991b) Centre for Economic Policy Research (CEPR) Discussion Paper No. 495, pages 29-32.

¹⁸ The analytical Fourier series solution involves the summation of infinitely many terms, ($n=0,1,2,\dots$) and in practice this analytical solution has to be computed numerically as a summation of a truncated series. In the present analysis a truncation at $n=9$ proved to be sufficiently accurately enough to reproduce Svensson's results based on the direct numerical method.

¹⁹ In the above example with $\eta=0$, $\sigma=0.1$, $\alpha=3$ and $f_U=-f_L=0.094$ ($e_U=-e_L=0.01$) this results in a symmetrical interest rate differential band of approximately $\delta_U=-\delta_L=0.026$.

²⁰ In the case of the instantaneous interest rate differential the derivative in equation (9.4) is given by $-\delta_f(f;\tau)=\cosh(\lambda f)/\alpha \cosh(\lambda f_U)$, and the derivatives of the instantaneous differential at the edges are given by $-\delta_f(f_L;\tau)=-\delta_f(f_U;\tau)=1/\alpha>0$, which clearly violates the smooth pasting conditions.

²¹ See equation (A17) in Appendix A.4 of Svensson's (1991b) Centre for Economic Policy Research (CEPR) Discussion Paper No. 495, page 35.

²² Iterating e in equi-distant steps and at each step numerically optimising the right-hand side of equation (7.4) yields the required values of $f(e)$, which then may be used to calculate $h(f(e);\tau)$. Computing $\delta(f(e);\tau)$ from equation (9.5) is then straightforward.

²³ Formally this equivalence comes from the L'Hopital's rule: $\lim_{x \rightarrow f} m(x)/n(x) = \lim_{x \rightarrow f} m'(x)/n'(x)$.

²⁴ See also Pesenti (1990), pp. 26 on this point.

²⁵ See, for instance, Pesenti (1990).

²⁶ It is obvious that for a zero drift and a symmetrical fundamentals band the derivative of in the denominator of (8.3) is given by $x_f(f(e))=1-\cosh(\lambda f)/\lambda \cosh(\lambda f_U)$.

²⁷ This is true since the exchange rate function is strictly increasing and invertible only in the interior of the band, and its derivative is zero at the edges of the band.

²⁸ Bertola and Caballero (1990) model central bank intervention in foreign exchange markets as discrete (large and infrequent) marginal intervention, as in the Flood and Garber (1989) model, instead of infinitesimal (small and frequent) marginal intervention, as in the Krugman (1991) and Svensson (1991b) models.

²⁹ Compared to the fully credible infinitesimal marginal intervention case, these S-shaped exchange rate functions in the discrete marginal intervention case do exhibit smooth-pasting at the boundaries of the exchange rate band.

³⁰ This is true since the exchange rate function is strictly increasing and invertible only in the interior of the band, and its derivative is zero at the edges of the band.

³¹ Bertola and Svensson (1991) further allow a non-zero correlation between the increments of the stochastic processes driving the expected realignment rates g_t and the fundamentals f_t , which is disregarded here for simplicity.

EMPIRICAL MEASURES OF POLICY CREDIBILITY

3.1. SURVEY

Despite strong empirical motivation, the analysis of policy credibility and reputation from the policy game literature has not been seriously taken to the data, as Persson (1988) notes. In sharp contrast, theoretical developments in the target zone literature are primarily caused by the fact that the simple Krugman (1991) model of a perfectly credible target zone did not explain the data very well. The present section aims at briefly surveying recent developments in both strands of the credibility literature.

Following Wyplosz (1989) the existing empirical literature on credibility and reputation in the policy game context may be divided into the two broad categories of indirect and direct evidence.

The indirect approach is based on Fellner's (1979) stabilisation policy argument that a '*credible policy*' is less costly - in terms of output foregone - than a policy which the public expects to be abandoned. Consequently, '*credible policies*' imply more favourable output-inflation trade-offs. Some informal empirical evidence on this proposition is provided in Sachs and Wyplosz (1987), Giavazzi and Spaventa (1989), Dornbusch (1989) and Ball (1993) by presenting estimates of '*sacrifice ratios*', defined as the cumulated increase in unemployment rates divided by the total decrease in the rate of inflation. Along the same lines De Grauwe (1988) compares the history of output-inflation trade-offs between countries. Slightly more formal evidence on output-inflation trade-offs is presented in Perry (1983), Blanchard (1984), Christensen (1987a,b, 1988) and Kremers (1990), who examine whether suspected deflationary policy shifts were '*credible*' in the sense that actual inflation or interest rates were lower than those predicted by structural Phillips curve models estimated over the period prior to the policy shift. A similar approach is taken in Giavazzi and Giovannini (1989), who use vector autoregressive models of inflation and output growth to search for policy shifts to more credible policies in EMS member countries. Similar approaches are to be found in the more recent studies by Bolazzi (1991),

Agénor and Taylor (1991) Egebo and Englander (1992), Blackburn Mongiardino and Sola (1992), Masson (1992), Ayuso, Jurado and Restoy (1993) and Revenga (1993), amongst others. The main problem with this indirect evidence is that it is typically very vague with respect to precisely what is meant by credibility and how it may be measured.

Less illusive concepts are used in the direct approach to estimating credibility and reputation. The aim of this literature is to empirically estimate a pre-specified measures of credibility. Such credibility measures have been derived from the policy-game literature, and, more recently, the target zone literature.

The direct approach to estimating policy credibility is pursued in papers by Baxter (1985), Hardouvelis and Barnhart (1987), and Weber (1990a, 1991a, 1992b). Baxter (1985) follows McCallum (1985) in using the term 'credibility of policies' to characterise a 'believable policy'. She assumes that credibility is obtained to the extent that beliefs concerning a policy conform to the way in which the policy is actually being conducted and to official announcements about its conduct. In this context 'credibility' implies 'precommitment'. In studying the Chilean and Argentine stabilisation efforts, Baxter (1985) draws on the Sargent (1982, 1983, 1986) argument that a credible monetary reform implies a path for the fiscal deficit which is compatible with the long-run sustainability of national debt. Credibility in Baxter (1985) is defined as the probability that the estimated coefficients of a reduced form model of government debt and money growth satisfy the parameter restrictions implied by a feasible monetary reform aimed at stabilising inflation. Note that Baxter (1985) uses Bayesian regression inference to estimate credibility as a time-varying conditional posterior probability. Bayesian inference is also used in Weber (1992b) by applying Bayesian multi-process Kalman filters to estimate the prior probability that observable inflation rates follow stationary stochastic processes. This prior probability is interpreted as an empirical counterpart to the Backus and Driffill (1985a,b) measure of the counterinflation reputation of policymakers. This concept will be discussed in some depth in section 3.2. below.

A different approach to estimating credibility directly is applied in Weber (1989a, 1991a) by estimating the Cukierman and Meltzer (1983, 1986b) measures of the credibility of announcements concerning the future course of monetary policy. Credibility here is defined as the weight attached to the money growth announcement signal in the public's money growth expectations. In Weber (1991a) the empirical estimates of these Cukierman and Meltzer (1986b) credibility measures are derived by using Bayesian Kalman filtering and recursive least squares methods. A similar approach without explicit reference to the Cukierman and Meltzer model is pursued in Hardouvelis and Barnhart (1987). The concept used in Weber (1991a) will be discussed in detail in section 3.3. below.

The detailed empirical analysis of exchange rate target zone models was initiated by Svensson's (1989, 1991a,b,c) analysis of the unilateral Swedish target zone. Additional evidence about the Swedish experience is provided in Lindberg and Söderlind (1991). Svensson (1991b) estimates a linearized version of his model by regressing interest rate differentials of various maturity on the parity deviation of the exchange rate. The estimated slope coefficients exhibit the expected pattern of being

negative and smaller for longer maturities, as postulated by the simple target zone model. However, the fit between theory and data is far from perfect, and a strongly serially correlated component is left unexplained in the relationship between exchange rates and interest rate differentials, as Bertola and Svensson (1991) note. Serious doubts about the empirical validity of the standard target zone model for the Swedish data are also raised in Lindberg and Söderlind (1991), who apply parametric methods to daily data and show that their results in most cases refute the standard target zone model.

For the EMS extensive empirical evidence on the validity of the target zone model is provided in Flood, Rose and Mathieson (1990), who find no compelling evidence of the type of non-linearities implied by standard target zone models. Again the components left unexplained by non-linear models are highly serially correlated and, in many cases, so large as to raise serious doubts about the validity of target zone models, as Bertola and Svensson (1991) stress.

In order to close the obvious gap between the theory of a fully credible target zone and empirical facts, Bertola and Caballero (1990) have developed a model of an imperfectly credible target zone in which realignments are permitted to occur with a given constant probability, and confront this model with data from the EMS. They find that their model is more consistent with the EMS experience than the fully credible target zone model of Krugman (1991). Bartolini and Bodnar (1991) formalise the link between exchange rates and the term structure of interest rate differentials in such imperfectly credible target zones, and provide simulation results for the EMS. As above, their model produces more coherent results than the Krugman (1991) model.

Another way of incorporating time-varying devaluation risks into the target zone model has been adopted by Bertola and Svensson (1991), who model stochastic fluctuations in expected devaluation rates as a second state variable (in addition to fundamentals) in order to introduce noise in the empirical relationship between interest rate differentials and exchange rates. The authors use simulation experiments to show that this can account for some of the stylised empirical facts found in Flood, Rose and Mathieson (1990) for the EMS. Further evidence on the relevance of this type of model is provided in Rose and Svensson (1991, 1993) and Svensson (1991d) for EMS exchange rates and interest rate differentials relative to Germany. Rose and Svensson (1991) show that many of the features of the Bertola and Svensson (1991) model seem to be consistent with the data: adding fluctuating devaluation risk can reconcile some of the problems associated with early target zone models which have only a single forcing variable, the fundamentals process. Similar evidence based on the Bertola and Svensson (1991) model is provided in Weber (1992a). The various approaches to evaluating the relevance of the different types of target zone models is outlined in detail in section 3.4 below. In order to provide some discriminating evidence on the fully credible versus the imperfectly credible target zone models a number of theoretical propositions and their empirical implications are thereby spelled out in detail. Before turning to this analysis, some empirically meaningful concepts and implications of credibility and reputation in the policy game literature are discussed in sections 3.2 and 3.3 below.

3.2. Measuring Counterinflation Reputation

The interesting point about the Backus and Driffill (1985a,b) model is that in general the public will not know what type of policymaker is in office. Instead, this information has to be inferred from observing inflation. The problem thereby is that zero inflation realisations do not fully reveal whether the policymaker in office is in fact the anti-inflationary type: zero inflation may also be the outcome under an inflationary policymaker who for some time masquerades as the counterinflationary type. But as long as zero inflation is observed, the counterinflation reputation of the policymaker in office increases due to the Bayesian probability updating process. However, this reputation is completely destroyed if positive surprise inflation $\mu_t = b$ occurs, which fully reveals the inflationary central banker. In view of real world inflation experiences this would, however, imply that all countries have lacked counterinflation reputation since zero inflation rates have been the exception rather than the rule in post-war history. Thus, to provide an empirically meaningful concept of reputation different assumptions about the time series properties of the policymakers trade-off parameter b and hence observable inflation rates $\mu_t = b$ are required.

3.2.1. An Empirically Meaningful Concepts of Reputation

One possible approach to implementing reputation in an empirically meaningful way would be to follow Barro and Gordon (1983a,b) and to allow the preference parameter b_t and hence the inflation rate $\mu_t = b_t$ to be randomly time-varying. For example, inflation μ_t may be given by the sum of a fixed controllable component (μ) and a normally distributed random component (n_t) with zero mean and constant finite variance σ_n^2 . As before the two types of policymakers are still characterised by whether they choose to set the controllable component of inflation equal to $\mu^w = b$ or $\mu^h = 0$ respectively. Depending on the magnitudes of σ_n^2 and $\mu^w = b$, a positive inflation realisation will now no longer necessarily reveal the type of policymaker and hence may leave reputation intact for a some time.¹ During this period the public will observe inflation in order to infer whether the mean of inflation μ_t tends towards zero or towards $\mu^w = b$. In this context reputation is destroyed as soon as the mean ($\bar{\mu}$) of μ_t deviates significantly from zero, which is the case for $\bar{\mu} > 2\sigma_n^2$.

Although it is more realistic, a major problem with the above empirical concept of reputation is that it only allows for stationary stochastic variations in inflation rates. This stationarity assumption conflicts sharply with the empirical evidence that inflation rates frequently exhibit unit roots, as demonstrated Alogoskoufis (1991) and Weber (1993) by using Dickey-Fuller and Philips-Perron non-stationarity tests. Thus, in order to make empirically reasonable assumptions, the analysis below will follow Cukierman and Meltzer (1985a,b) by allowing the policymaker's preference parameter b_t and hence the resulting inflation rate $\mu_t = b_t$ to follow non-stationary time-paths.

3.2.1.1. Inflation and Reputation

Instead of being a dichotomous (0,1)-variable as in Backus and Driffill (1985a), inflation is assumed to be determined by an ARIMA time series model which, in order to be more general, is formulated below in terms of the price level rather than the inflation rate. The observable price level P_t is assumed to be the sum of a controllable component p_t , determined by the government's monetary policy actions, and a stochastic control error v_t , which is independently randomly distributed with mean zero and constant finite variance σ_v^2 . This is formalised in the linear measurement equation (14.1a) for the unobservable state p_t in Box 14. The dynamics of the policy determined component p_t of the price level are described by the set of three state transition equations (14.1b) to (14.1d) with n_t , r_t and s_t defined as independently distributed random variables with mean zero and constant finite variances σ_n^2 , σ_r^2 and σ_s^2 respectively. Thus, inflation $\mu_t = b_t$ is allowed to follow a random walk with a stochastic drift d_t , which itself may follow a random walk.

In order to derive a measure of reputation ψ_t , defined in Backus and Driffill (1985a,b) as the probability of a government being the anti-inflationary type, two alternative models of inflation behaviour under an inflationary and an anti-inflationary government have to be specified.

The *anti-inflationary policymaker* is assumed to aim at maintaining some initially low² level of inflation, regardless of the output costs. In terms of the above time series model this implies that the counterinflationary policymaker will attempt to offset any permanent exogenous shocks (r_t , s_t) to inflation μ_t . In this case the dynamic linear model reduces to equations (14.2a)-(14.2c), which derive from equations (14.1a) to (14.1d) for $d_t = d_{t-1} = 0$ and $\sigma_r^2 = \sigma_s^2 = 0$. In this special case observable inflation will be a stationary stochastic process with a constant mean ($\mu_t = \mu_{t-1} = \mu_0$) and a finite variance ($\sigma_n^2 + 2\sigma_v^2$), whilst the observable price level follows an integrated autoregressive moving-average process, or ARIMA(0,1,1) process.

The *inflationary policymaker* on the other hand is assumed to allow or to generate permanent inflation shocks and may even permanently accelerate inflation rates in order to stimulate the economy. In this case inflation behaviour is described by the more general dynamic linear model (14.1a)-(14.1d) from above. Thus, under the inflationary policymaker inflation rates are non-stationary and integrated of order one or two, in which case the observable price level follows an ARIMA(0,2,2) or ARIMA(0,3,3) process.

In specifying an *empirically meaningful concept of reputation* it now makes sense to adopt the stringent criterion that a counterinflationary government will attempt to preserve the initially low levels of inflation according to the time series model (14.2a)-(14.2c), whilst the occurrence of repeated permanent shocks to inflation levels μ_t or first differences d_t reveals the inflationary government, under which inflation rates will be non-stationary and unbounded in the long run.

Box 14
State Space Representation of Prices Under Both Inflationary and Counterinflationary Policymakers

(a) State Space Model for an Inflationary Policymaker
Equations (14.1a)-(14.1d)

$$P_t = p_t + v_t, \quad E(v_t) = 0, E(v_t v_t^T) = \sigma_v^2, E(v_t v_{t-j}^T) = 0 \forall j \neq 0, \quad (14.1a)$$

$$p_t = p_{t-1} + \mu_t + n_t, \quad E(n_t) = 0, E(n_t n_t^T) = \sigma_n^2, E(n_t n_{t-j}^T) = 0 \forall j \neq 0, \quad (14.1b)$$

$$\mu_t = \mu_{t-1} + d_t + r_t, \quad E(r_t) = 0, E(r_t r_t^T) = \sigma_r^2, E(r_t r_{t-j}^T) = 0 \forall j \neq 0, \quad (14.1c)$$

$$d_t = d_{t-1} + s_t, \quad E(s_t) = 0, E(s_t s_t^T) = \sigma_s^2, E(s_t s_{t-j}^T) = 0 \forall j \neq 0, \quad (14.1d)$$

(b) State Space Model for a Counterinflationary Policymaker
Equations (14.2a)-(14.2c)

$$P_t = p_t + v_t, \quad E(v_t) = 0, E(v_t v_t^T) = \sigma_v^2, E(v_t v_{t-j}^T) = 0 \forall j \neq 0, \quad (14.2a)$$

$$p_t = p_{t-1} + \mu_t + n_t, \quad E(n_t) = 0, E(n_t n_t^T) = \sigma_n^2, E(n_t n_{t-j}^T) = 0 \forall j \neq 0, \quad (14.2b)$$

$$\mu_t = \mu_{t-1} = \mu_0, \quad E(r_t) = 0, E(r_t r_t^T) = \sigma_r^2, E(r_t r_{t-j}^T) = 0 \forall j \neq 0, \quad (14.2c)$$

3.2.1.2. The Concept of Borrowing Counterinflation Reputation

Assume now that a government in an open economy with flexible exchange rates has been acquired a low counterinflation reputation due to inflationary behaviour in the past. According to Giavazzi and Pagano (1988) and Giavazzi and Spaventa (1989) an institutional reform such as entering a fixed exchange rate system with a low-inflation centre country may help to gain counterinflation reputation. This may be achieved by credibly pegging the level of the exchange rate *vis-a-vis* the low-inflation centre on the basis of a purchasing power parity (PPP) condition. This is formalised in equation (15.3) in Box 15, where ε_t is the logarithm of the official bilateral nominal exchange rate and P_t^* is the logarithm of the domestic price level, as described in equations (15.1a) to (15.1d). The evolution of the foreign price level is described in equations (15.2a) to (15.2c). Under relatively fixed exchange rates (say $\varepsilon_t - \varepsilon_{t-1} \cong 0$) inflation rates in the domestic country ($\mu_t = P_t - P_{t-1}$) will now closely resemble inflation rates in the low-inflation centre country ($\mu_t^* = P_t^* - P_{t-1}^*$), which follow a stationary stochastic process. In the terminology of Rogoff (1985a) this is equivalent to appointing a 'conservative' foreign central banker. Consequently, as the public is observing low and stationary domestic inflation rates, as indicated in equations (15.4a) to (15.4c) it will gradually learn that a policy switch has occurred, lower its inflation expectations and update the probability that the policymaker in office is the counterinflationary type. Thus, anti-inflation reputation is gained simply by pegging the exchange rate and

'tying the policymakers' hands on monetary policy', as postulated by Giavazzi and Pagano (1988).

Box 15
The Concept of Borrowing Counterinflation Reputation

(a) State Space Model for an Inflationary Domestic Policymaker
Equations (15.1a)-(15.1d)

$$P_t = p_t + v_t, \quad E(v_t) = 0, E(v_t v_t^T) = \sigma_v^2, E(v_t v_{t-j}^T) = 0 \forall j \neq 0, \quad (15.1a)$$

$$p_t = p_{t-1} + \mu_t + n_t, \quad E(n_t) = 0, E(n_t n_t^T) = \sigma_n^2, E(n_t n_{t-j}^T) = 0 \forall j \neq 0, \quad (15.1b)$$

$$\mu_t = \mu_{t-1} + d_t + r_t, \quad E(r_t) = 0, E(r_t r_t^T) = \sigma_r^2, E(r_t r_{t-j}^T) = 0 \forall j \neq 0, \quad (15.1c)$$

$$d_t = d_{t-1} + s_t, \quad E(s_t) = 0, E(s_t s_t^T) = \sigma_s^2, E(s_t s_{t-j}^T) = 0 \forall j \neq 0, \quad (15.1d)$$

(b) State Space Model for a Counterinflationary Foreign Policymaker
Equations (15.2a)-(15.2c)

$$P_t^* = p_t^* + v_t^*, \quad E(v_t^*) = 0, E(v_t^* v_t^{*T}) = \sigma_{v^*}^2, E(v_t^* v_{t-j}^{*T}) = 0 \forall j \neq 0, \quad (15.2a)$$

$$p_t^* = p_{t-1}^* + \mu_t^* + n_t^*, \quad E(n_t^*) = 0, E(n_t^* n_t^{*T}) = \sigma_{n^*}^2, E(n_t^* n_{t-1}^{*T}) = 0 \forall j \neq 0, \quad (15.2b)$$

$$\mu_t^* = \mu_{t-1}^* = \mu_0^*, \quad E(r_t^*) = 0, E(r_t^* r_t^{*T}) = \sigma_{r^*}^2, E(r_t^* r_{t-1}^{*T}) = 0 \forall j \neq 0, \quad (15.2c)$$

(c) Borrowing Counterinflation Reputation by Exchange Rate Pegging

$$P_t = P_t^* + \varepsilon_t, \quad \varepsilon_t = \varepsilon_{t-1} = \varepsilon_0, \quad (15.3)$$

(d) Resulting Domestic State Space Model under Exchange Rate Pegging
in the Presence of a Counterinflationary Foreign Policymaker
Equations (15.4a)-(15.4c)

$$P_t = p_t^* + \varepsilon_0 + v_t^*, \quad E(v_t^*) = 0, E(v_t^* v_t^{*T}) = \sigma_{v^*}^2, E(v_t^* v_{t-j}^{*T}) = 0 \forall j \neq 0, \quad (15.4a)$$

$$p_t^* = p_{t-1}^* + \mu_t^* + n_t^*, \quad E(n_t^*) = 0, E(n_t^* n_t^{*T}) = \sigma_{n^*}^2, E(n_t^* n_{t-1}^{*T}) = 0 \forall j \neq 0, \quad (15.4b)$$

$$\mu_t^* = \mu_{t-1}^* = \mu_0^*, \quad E(r_t^*) = 0, E(r_t^* r_t^{*T}) = \sigma_{r^*}^2, E(r_t^* r_{t-1}^{*T}) = 0 \forall j \neq 0, \quad (15.4c)$$

3.2.2. Estimating Counterinflation Reputation

To obtain an estimate of counterinflation reputation a Bayesian learning algorithm, a variant of the so-called Bayesian multi-process Kalman filter of Harrison and Stevens (1971, 1976), is employed. For a more formal description of this method and for references to other applications in economics the discussion in Weber (1988) should be consulted.

In order to use this algorithm to derive a measure of counterinflation reputation the above model is transformed into its general state-space form with

measurement equation (16.1a) and state transition equation (16.1b), whereby the vector and matrix conventions in (16.2) apply.

The multi-process framework now requires that the alternative process models are specified as sub-models of the above general state-space model. In the present context this is done by simply introducing certain zero restrictions for the variance-covariance matrices of the residuals. For example, the reference model for inflation under a *counter-inflationary policymaker* assumes $q_2=q_3=0$ and thus only allows for a combination of purely transitory price level shocks (model M_t^1 with $q_1=q_2=q_3=0$) and/or purely transitory inflation shocks (model M_t^2 with $h=q_2=q_3=0$). On the other hand, inflation under an *inflationary policymaker* may be generated by higher order shocks ($q_1, q_2 > 0$), which may be purely permanent inflation shocks (model M_t^3 with $h=q_1=q_3=0$) and/or purely permanent shocks to the drift in inflation rates (model M_t^4 with $h=q_1=q_2=0$).³

Box 16

**State Space Representation of an Hybrid Model of Prices Under Both
Inflationary and Counterinflationary Policymakers**

(a) State Space Representation of Equations (14.1a)-(14.1d)

$$y_t = z_t a_t + S_t v_t, \quad E(v_t) = 0, E(v_t v_t^T) = \sigma^2 H, E(v_t v_{t-j}^T) = 0 \forall j \neq 0, \quad (16.1a)$$

$$a_t = T a_{t-1} + R u_t, \quad E(u_t) = 0, E(u_t u_t^T) = \sigma^2 Q, E(u_t u_{t-j}^T) = 0 \forall j \neq 0, \quad (16.1b)$$

(b) Matrix and Vector Conventions

$$y_t = P_t, \quad a_t^T = [p_t \quad \mu_t \quad d_t], \quad z_t = [1 \quad 0 \quad 0], \quad v_t = v_t, \quad u_t^T = [n_t \quad r_t \quad s_t], \quad (16.2)$$

$$S_t = 1, \quad H = h, \quad T = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}, \quad R = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}, \quad Q = \begin{bmatrix} q_1 & 0 & 0 \\ 0 & q_2 & 0 \\ 0 & 0 & q_3 \end{bmatrix}.$$

Given these four alternative specifications of the variance-covariance matrices Q^i and H^i ($i=1,2,3,4$), estimates of the unobservable state vectors a_t^i and their variance-covariance matrices $\sigma^2 \Phi_t^i$ may now be extracted from the observable process P_t by using the Kalman filter. In doing so, the possibility of stochastic process switching is explicitly taken into account.

Assume that the observable price level process switches from model M_{t-1}^i ($i=1,2,3,4$) in period $t-1$ to model M_t^j ($j \neq i$) in period t . Let the model which captures this process switching be denoted by $M_{t,t-1}^j$. The Kalman filter's prediction equations (17.1a)-(17.1b) and the update equations (17.1c) to (17.1g) in Box 17 may then be used to forecast price level movements under four types of pure stochastic processes

and twelve types of stochastic process switching, given a suitable initialisation of the state vector (a_{t_0}) and its variance-covariance matrix ($\sigma^2\Phi_{t_0}$). The empirical relevance of stochastic process switching may thereby be evaluated in probabilistic terms.

In order to calculate an overall estimate of the state vectors a_t^i and their variance-covariance matrices $\sigma^2\Phi_t^i$, the probability weighted averages of the individual state and variance estimates in equations (17.8a) and (17.8b) are calculated, where $\pi_t^i = \sum_j \pi_t^{ij}$ holds. Note that the inclusion of the term $(a_t^{ij} - a_t^i)(a_t^{ij} - a_t^i)^T$ in addition to the individual estimates Φ_t^{ij} in equation (17.8b) is justified by the fact that a large dispersion of the point estimates around their average should reduce confidence in the precision of the average point estimate.

The probability distribution of the alternative process models is calculated and recursively updated in the Bayesian part of the multi-process Kalman filter by using Bayes' law. To illustrate this process, assume that each model M_t^i at each point in time has a prior probability $E_{t-2}\pi_{t-1}^i$, as well as a posterior probability π_t^i , and that the probability of process switching $M_{t,t-1}^{ij}$ is denoted by π_t^{ij} . According to Bayes' theorem, the conditional posterior probability π_t^{ij} of each model may then be calculated as formalised in equation (17.2), which corresponds to equation (17.3) in the notation of the Kalman filter. Equation (17.3) states that the transformation of old prior ($E_{t-2}\pi_{t-1}^i$) and posterior (ψ_{t-1}^i) probabilities into new prior probabilities ($E_{t-1}\pi_t^i$) for the subsequent period represents the Bayesian learning mechanism. This probability learning is largely determined by the relative likelihood of the individual models, as measured by the likelihood function (17.4) of each model. Driffill (1988) states that the multi-process Kalman filter set-up closely parallels the Bayesian probability learning of the Backus and Driffill (1985a) model. It is thus viewed here as its empirical counterpart and allows a measure of counterinflation reputation to be formalised.

Proposition 1

Counterinflation reputation ψ_t is defined as the sum of the two probabilities $E_{t-1}\pi_t^1$ and $E_{t-1}\pi_t^2$ of the transitory and permanent price level shock models. This implies that under a counterinflationary policymaker inflation rates are stationary at their initially low levels.

Estimates of counterinflation reputation based on this measure are provided in Weber (1992b) for both EMS and a number of non-EMS countries. It is found that in most cases the reputation measure accords well commonly held beliefs about the counterinflation orientation of various countries. The empirical evidence provided in section 4.1 below extends the analysis of Weber (1992b) by including the more recent period of EMS crisis around September 1992 and August 1993.

Box 17
The Multi Process Kalman Filter Algorithm for Extracting a Measure of Counterinflation Reputation from Observable Price Data

(a) Multi Process Kalman Filter's Prediction and Update Equations

$$\mathbf{a}_{t,t-1}^{ij} = \mathbf{T} \mathbf{a}_{t-1,t-1}^{ij}, \quad (17.1a)$$

$$\Phi_{t,t-1}^{ij} = \mathbf{T} \Phi_{t-1,t-1}^{ij} \mathbf{T}^T + \mathbf{R} \mathbf{Q}^j \mathbf{R}^T, \quad (17.1b)$$

$$\mathbf{a}_{t,t}^{ij} = \mathbf{a}_{t,t-1}^{ij} + \mathbf{K}_t^{ij} \boldsymbol{\varepsilon}_t^{ij}, \quad (17.1c)$$

$$\Phi_{t,t}^{ij} = (\mathbf{I} - \mathbf{K}_t^{ij} \mathbf{z}_t) \Phi_{t,t-1}^{ij} (\mathbf{I} - \mathbf{K}_t^{ij} \mathbf{z}_t)^T + \mathbf{K}_t^{ij} \mathbf{H}^j \mathbf{K}_t^{ijT}, \quad (17.1d)$$

$$\boldsymbol{\varepsilon}_t^{ij} = \mathbf{y}_t - \mathbf{z}_t \mathbf{a}_{t,t-1}^{ij}, \quad (17.1e)$$

$$\mathbf{K}_t^{ij} = \Phi_{t,t-1}^{ij} \mathbf{z}_t^T (\mathbf{F}_t^{ij})^{-1}, \quad (17.1f)$$

$$\mathbf{F}_t^{ij} = \mathbf{z}_t \Phi_{t,t-1}^{ij} \mathbf{z}_t^T + \mathbf{S} \mathbf{H}^j \mathbf{S}^T, \quad (17.1g)$$

(b) Multi Process Kalman Filter's Bayesian Probability Learning

$$\begin{aligned} \pi_t^{ij} = & \text{PROB} \left\{ y_t \mid M_t^j, M_{t-1}^i, (y_{t-1}, y_{t-2}, y_{t-3}, \dots) \right\} \\ & * \text{PROB} \left\{ M_t^j \mid M_{t-1}^i, (y_{t-1}, y_{t-2}, y_{t-3}, \dots) \right\} \\ & * \text{PROB} \left\{ M_{t-1}^i \mid (y_{t-1}, y_{t-2}, y_{t-3}, \dots) \right\} / \text{PROB} \left\{ y_t \mid (y_{t-1}, y_{t-2}, y_{t-3}, \dots) \right\}, \end{aligned} \quad (17.2)$$

$$\pi_t^{ij} = k_t \mathbf{L}_t^{ij} \mathbf{E}_{t-1} \pi_{t-1}^j, \quad (17.3)$$

$$\mathbf{L}_t^{ij} = \left[2\pi \sigma^2 \mathbf{F}_t^{ij} \right]^{-1/2} \exp \left[-(\boldsymbol{\varepsilon}_t^{ij})^2 / 2\sigma^2 \mathbf{F}_t^{ij} \right], \quad (17.4)$$

$$\mathbf{E}_{t-1} \pi_t^j = \frac{\theta \mathbf{E}_{t-2} \pi_{t-1}^j + \boldsymbol{\psi}_{t-1}^j}{\sum_j (\theta \mathbf{E}_{t-2} \pi_{t-1}^j + \boldsymbol{\psi}_{t-1}^j)}, \quad (17.5)$$

$$\pi_{t-1}^i = \sum_j \pi_{t-1}^{ij} \quad (17.6)$$

$$\boldsymbol{\psi}_{t-1}^j = \sum_i \pi_{t-1}^{ij} \quad (17.7)$$

(c) Multi Process Kalman Filter's Condensation Conventions

$$\mathbf{a}_t^j = \sum_i \pi_t^{ij} \mathbf{a}_t^{ij} / \pi_t^j, \quad (17.8a)$$

$$\Phi_t^j = \sum_i \pi_t^{ij} \left\{ \Phi_t^{ij} + \left[(\mathbf{a}_t^{ij} - \mathbf{a}_t^j)(\mathbf{a}_t^{ij} - \mathbf{a}_t^j)^T \right] \right\} / \pi_t^j, \quad (17.8b)$$

3.3. Measuring the Credibility of Policy Announcements

A detailed discussion of the concept of policy credibility is found in Weber (1990a, 1991a). The derivation of an empirical counterpart to the credibility measures from the Cukierman and Meltzer (1986b) model from section 2.1 is briefly outlined below.

In order to obtain an estimate of the marginal and average credibility measures (MC and AC hereafter), it is necessary to model the public's expectations formation process. In the present study a two-step approach is adopted: first the optimal time series expectations of the unobservable planned policy targets conditional on past information are calculated. The MC credibility measure is then derived by incorporating the policy target announcements into the above time series expectations by using least-squares regression methods.

In implementing the money growth, interest rate and exchange rate expectations conditional on past information, a time series model for these policy variables is required. The theoretical model of Cukierman and Meltzer (1986b) in section 2 implies the time series models (18.1a) and (18.1b) for the actual observable policy outcomes (m_t) and (18.2a) and (18.2b) for the money growth announcements (m_t^a) respectively. For the purpose of an empirical evaluation a slightly modified version of these dynamic linear models has been employed by using the signal extraction method outlined in the section 3.1 above in the context of price level predictions.⁴

The time series projections obtained by the multi-process Kalman filter are then used as input for the rational expectations equation (18.4). These rational expectations were derived as the fitted values of a least-squares regression of the actual observable policy outcome ($x_t = \{m_t, i_t, \varepsilon_t\}$) on the policy announcements ($x_t^a = \{m_t^a, i_t^a, \varepsilon_t^a\}$) and on the expected policy outcome conditional on past information ($Ex_t|\Omega_{t-1}$), which itself may in principle be calculated by iterating θ , the relative weigh of the two univariate time series expectations from equation (18.3), between zero and one and selecting that value of θ which minimises the overall sum of squared residuals of the regression equation. Since all three types of announcements are low frequency signals, that is, they change infrequently, the information content of past announcements is typically found to be very low and θ is close to one in many cases.⁵ Consequently, for the results discussed in the present study the restriction $\theta=1$ was imposed and the influence of the announcement on expectations was estimated directly from equation (18.5), which states that the change in expectations due to new information is proportional to the unexpected bias ($x_t^a - Ex_t|\Omega_{t-1}$) revealed by the current announcement signal relative to projections of policy outcomes based on past information only. This allows the marginal credibility measure for money growth target, exchange rate target and interest rate target announcements to be formalised.

Box 18
Measuring the Credibility of Money Growth Target, Exchange Rate Target and Interest Rate Target Announcements
(a) Time Series Model for Observable Policy Outcome $x_t = \{m_t, i_t, \varepsilon_t\}$

$$x_t = x_t^p + \xi_t, \quad \xi_t = \mu_1 \zeta_t, E(\xi_t) = 0, E(\xi_t \xi_t^T) = \sigma_\xi^2, E(\xi_t \xi_{t-j}^T) = 0 \forall j \neq 0, \quad (18.1a)$$

$$x_t^p = \rho x_{t-1}^p + \gamma_t, \quad \gamma_t = v_t / \mu_1, E(\gamma_t) = 0, E(\gamma_t \gamma_t^T) = \sigma_\gamma^2, E(\gamma_t \gamma_{t-j}^T) = 0 \forall j \neq 0, \quad (18.1b)$$

(b) Time Series Model for Policy Announcements $x_t^a = \{m_t^a, i_t^a, \varepsilon_t^a\}$

$$x_t^a = x_t^p + \omega_t, \quad \omega_t = \mu_1 u_t, E(\omega_t) = 0, E(\omega_t \omega_t^T) = \sigma_\omega^2, E(\omega_t \omega_{t-j}^T) = 0 \forall j \neq 0, \quad (18.2a)$$

$$x_t^p = \rho x_{t-1}^p + \gamma_t, \quad \gamma_t = v_t / \mu_1, E(\gamma_t) = 0, E(\gamma_t \gamma_t^T) = \sigma_\gamma^2, E(\gamma_t \gamma_{t-j}^T) = 0 \forall j \neq 0, \quad (18.2b)$$

(c) Optimal Prediction of Planned Policy under Past Information

$$E(x_t^p | \Omega_{t-1}) = \theta E(x_t | x_{t-1}, x_{t-2}, \dots) + (1 - \theta) E(x_t^a | x_{t-1}^a, x_{t-1}^a, \dots), \quad (18.3)$$

(d) Optimal Prediction of Planned Policy under Current Information

$$E(x_t^p | \Omega_t) = \alpha x_t^a + (1 - \alpha) E(x_t^p | \Omega_{t-1}), \quad (18.4)$$

(e) Influence of Announcement on Expectations under Current Information

$$E(x_t^p - E(x_t^p | \Omega_{t-1}) | \Omega_t) = \alpha (x_t^a - E(x_t^p | \Omega_{t-1})), \quad (18.5)$$

(f) Marginal Credibility Measure

$$MC = \alpha, \quad (18.6)$$

(g) Average Credibility Measure

$$AC = - \left| x_t^a - E(x_t^p | \Omega_t) \right|. \quad (18.7)$$

Proposition 2.1.

The marginal credibility of policy announcements is measured for money growth target, exchange rate target and interest rate target announcements alike. The marginal credibility (MC) measure is given by the slope coefficient of a regression of policy projection errors ($x_t - Ex_t | \Omega_{t-1}$) on the policy announcement bias ($x_t^a - Ex_t | \Omega_{t-1}$). The more informative the announcement bias, the higher is marginal credibility.

Given a quantified measure of the above projections, the measure of average credibility for money growth target, exchange rate target and interest rate target announcements may also be formulated.

Proposition 2.2.

The average credibility of policy announcements is measured for money growth target, exchange rate target and interest rate target announcements alike. The average credibility (AC) measure is given by the negative value of the absolute policy announcement bias $-(x_t^a - Ex_t | \Omega_{t-1})$. The smaller the announcement bias, the higher is average credibility.

Both the AC and the MC measures will be used in the empirical analysis for assessing the credibility of the monetary policy stance of EMS countries. However, due to its intuitive appeal, the MC credibility measure will be at the centre of the discussion. Before turning to the empirical section, a brief discussion of the approach to assessing target zone credibility is in order.

3.4. Measuring Target Zone Credibility

3.4.1. Indirect Evidence About Target Zone Credibility

In the previous chapter it was shown that standard models of fully credible target zones imply a deterministic, non-linear (S-shaped) relationship between the exchange rate and its fundamentals, as derived in Krugman (1991). This may be summarised as Proposition 3.1:

Proposition 3.1

In models of fully credible target zones the exchange rate is a non-linear, S-shaped function of the fundamentals and the slope of this function is always less than unity.

The problem with this Proposition is that in all target zone models the term "fundamentals" refers to a rather illusive and vague concept, which has no obvious empirical counterpart. Thus, unless some completely ad hoc measure of fundamentals is specified, it is impossible to test this proposition about the specific type of non-linearities of the exchange rate function. However, some evidence on the relevance of non-linearities may be obtained by focusing on the intrinsic dynamics of exchange rates within the band.

Svensson (1991a, b) shows that owing to the above non-linear intrinsic dynamics of exchange rates within the band the probability density distribution and instantaneous standard deviation of exchange rates within the band also have very distinctive characteristics, which are summarised in Propositions 3.2 and 3.3

Proposition 3.2

In models of fully credible target zones the exchange rate's probability density distribution inside the band has a U-shape, with more mass concentrated towards the edges of the band.

Proposition 3.3

In models of fully credible target zones the exchange rate's conditional standard deviation inside band has an inverted U-shape.

Evidence about this type of non-linearity may then be interpreted as indirect evidence on target zone credibility. Svensson (1989,1991b) further shows that a fully credible target zone also implies an inverse non-linear relationship between exchange rate deviations from parity and the term structure of interest rate differentials, which results in Propositions 3.4 and 3.5.

Proposition 3.4

In models of fully credible target zones the term structure of interest rate differentials is a negatively sloped non-linear (inversely S-shaped) function of the fundamentals. The slope of the interest rate differential function tends to be flatter and less non-linear for longer maturities.

Proposition 3.5

In models of fully credible target zones the term structure of interest rate differentials is a negatively sloped non-linear (inversely S-shaped) function of the exchange rate. The slope of the interest rate differential function tends to be flatter and less non-linear for longer maturities.

As before, unless some measure of fundamentals is constructed, Proposition 3.4 is impossible to test. However, since both interest rate differentials and exchange rates

are readily observable economic variables, Proposition 3.5 of the target zone model can be tested directly.

The above link between exchange rates and interest rate differentials implies that the target zones for the instantaneous and expected future exchange rates translates into a target zone for the term structure of interest rate differentials. This fact, combined with the intrinsic dynamics of the exchange rates within the band then leads to Propositions 3.6 and 3.7, as derived in Svensson (1991b).

Proposition 3.6

In models of fully credible target zones the probability density distributions of interest rate differentials are bi-modal or U-shaped inside the interest rate differential bands, and tend to be more compressed for longer terms.

Proposition 3.7

In models of fully credible target zones the conditional standard deviations of interest rate differentials are unimodal or inversely U-shaped inside the interest rate differential's band, and tend to be more compressed for longer terms.

The above seven propositions have been the focus of much of the early empirical literature on exchange rate target zones. The literature has failed on a 'grand scale' in producing any evidence that is consistent with any of these propositions relating to fully credible target zone models.

In order to close the obvious gap between the theory of a fully credible target zone and the empirical facts, a variety of models have been put forward which introduce realignments and imperfect credibility into the target zone model. A number of these models has been discussed in chapter 2. What stylised facts do these models suggest in connection with the above seven propositions of the fully credible target zone model? The answer is fairly simple: all propositions are turned on their head when non-credible target zones with high realignment probabilities are considered.

In the Bertola and Caballero (1990) model, which permits realignments to occur with a given probability, the S-shaped relationship between exchange rates and fundamentals still holds in relatively credible target zones with a low realignment probability, but an inversely S-shaped relationship emerges for non-credible target zones with high realignment probabilities. This allows us to modify Propositions 3.1 to 3.3 as follows:

Proposition 4.1

In models of imperfectly credible target zones the exchange rate is a non-linear, S-shaped function of the fundamentals only for low realignment probabilities, whilst for high realignment probabilities an inversely S-shaped function results.

Proposition 4.2.

In models of imperfectly credible target zones the exchange rate's probability density distribution inside the exchange rate band has a U-shape only for low realignment probabilities, whilst for high realignment probabilities an inversely U-shaped function results.

Proposition 4.3.

In models of imperfectly credible target zones the exchange rate's conditional standard deviation inside the exchange rate band has an inverted U-shape only for low realignment probabilities, whilst for high realignment probabilities an U-shaped function results.

Bartolini and Bodnar (1991) formalise the link between exchange rates and the term structure of interest rate differentials in such imperfectly credible target zones. They show that a negative non-linear relationship between exchange rates and interest rate differentials again emerges in relatively credible target zones with a low realignment probability, but that a positive non-linear relationship results in non-credible target zones with high realignment probabilities. Bartolini and Bodnar (1991) further demonstrate that whilst the relationship between the exchange rate and the interest rate differential is in principle non-linear and has a hump-shaped profile, it becomes flatter and less non-linear for longer maturities, regardless of whether relatively credible or non-credible target zones are concerned. This allows us to modify Propositions 3.4 to 3.7 as follows:

Proposition 4.4

In models of imperfectly credible target zones the term structure of interest rate differentials is a negatively sloped non-linear (hump-shaped) function of the fundamentals only for low realignment probabilities, whilst for high realignment probabilities a positively sloped non-linear (hump-shaped) function results. In both cases the slope of the function is flatter and less non-linear for longer maturities.

Proposition 4.5

In models of imperfectly credible target zones the term structure of interest rate differentials is a negatively sloped non-linear (hump-shaped) function of the exchange rate only for low realignment probabilities, whilst for high realignment probabilities a positively sloped non-linear (hump-shaped) function results. In both cases the slope of the function is flatter and less non-linear for longer maturities.

Proposition 4.6

In models of imperfectly credible target zones the probability density distributions of the term structure of interest rate differentials are bimodal or U-shaped inside the interest rate differential bands only for low realignment probabilities, whilst for high realignment probabilities unimodal and inversely U-shaped functions result. In both cases the probability distributions are more compressed for longer terms.

Proposition 4.7

In models of imperfectly credible target zones the conditional standard deviations of the term structure of interest rate differentials are unimodal or inversely U-shaped inside the interest rate differential band only for low realignment probabilities, whilst for high realignment probabilities bimodal and U-shaped functions result. In both cases the standard deviations are more compressed for longer terms.

The above Propositions 3.1 to 3.7 for fully credible target zones and their counter-Propositions 4.1 to 4.7 from models of imperfectly credible target zones may be used to obtain some indirect evidence on the degree of target zone credibility. Since Propositions 4.1 to 4.7 include Propositions 3.1 to 3.7 as special cases, the analysis below will focus on them. The problem with these propositions is that they allow only rather informal testing, since with the exception of Propositions 4.1, 4.4 and 4.5 only the sample properties of the distributions of the first and second moments of the exchange rate and interest rate differentials series are examined. Propositions 4.1 and 4.4 are furthermore not testable without arbitrarily specifying a measure of fundamentals. The only proposition which allows more rigorous econometric testing is Proposition 4.5 on the link between interest rate differentials and exchange rates in target zones, which will be the focus of the analysis below. Incorporating expected devaluation rates into the basic target zone model thereby allows a more direct testing of the credibility of target zones.

3.4.2. Direct Evidence on Target Zone Credibility

Svensson's (1991b) study uses a linear approximation⁶ of equation (9.1) in Box 9 for testing Proposition 3.5 of the perfectly credible target zone model. This equation is displayed as equation (13.1) in Box 13, and is reproduced here as Box 19 for convenience. According to theory, the coefficients $b(\tau)$ should be negative and decreasing in term. Furthermore, in the absence of any fundamental drift ($\mu=0$), the constant $c(\tau)$ should be zero for all τ if no devaluation risks exist. In order to obtain estimate of $c(\tau)$ and $b(\tau)$ ordinary least squares regression may be used.

Box 19
Empirical Implications of Target Zone Models with Respect to the Relationship between Interest Rate Differentials and Exchange Rates

Svensson (1991b)

$$\delta_i(\tau) = c(\tau) + b(\tau)e_i + \varepsilon_i(\tau) \quad (19.1)$$

- the slope coefficient $b(\tau)$ are negative and increasing in term.
- in the absence of any fundamental drift ($\mu=0$), the the intercept coefficient $c(\tau)$ should be zero for all τ if there is no devaluation risk..

Svensson (1991b)

$$\delta_i(\tau, \nu g) = c(\tau, \nu g) + b(\tau)e_i + \varepsilon_i(\tau), \quad (19.2)$$

- the intercept coefficient is negative and depends on both the term τ and the product of the probability intensity of a realignment (ν) and the expected size of the realignment (g):

Svensson and Bertola (1991)

$$\delta_i(g_i, \sigma_g^2 / \sigma_f^2; \tau) = c(g_i, \tau) + b(\sigma_g^2 / \sigma_f^2, \tau)e_i + \varepsilon_i(\tau), \quad (19.3)$$

- the time-varying intercept $c_i(\tau)$ may take positive and negative values
- the slope coefficient where $b(\sigma_g^2 / \sigma_f^2, \tau)$ is negative and increasing in term for low degrees of variability of expected devaluations (σ_g^2 relative to σ_f^2),
- in the absence of fundamental drift ($\eta=0$) the intercept $c(g_i, \tau)$ should largely reflect devaluation risks.

Bartolini and Bodnar (1991)

$$\delta_i(g_i, \pi_i, \sigma_g^2 / \sigma_f^2; \tau) = c(g_i, \pi_i, \tau) + b(\pi_i, \sigma_g^2 / \sigma_f^2, \tau)e_i + \varepsilon_i(\tau) \quad (19.4)$$

- the slope coefficient $b(g_i, \pi_i, \sigma_g^2 / \sigma_f^2; \tau)$ is negative and decreasing in term for low realignment probabilities π_i and low degrees of variability of expected devaluation rates σ_g^2 relative to σ_f^2), but positive and decreasing in term for high realignment probabilities π_i and high degrees of the variability of expected devaluation rates (σ_g^2) relative to the fundamentals (σ_f^2)

Key to symbols: i_t interest rate, i_t^* foreign interest rate, δ_t interest rate differential, e_t exchange rate, f_t fundamentals, $\sigma_t^\delta(\delta)\eta$ instantaneous conditional standard deviation of δ_t , σ^2 instantaneous variance of f_t , $\delta(f)$ interest rate differential function, δ_f (δ_{ff}) first (second) derivative of δ with respect to f , $\varphi^f(f)$ density distribution of fundamentals, $\varphi^\delta(\delta)$ density distribution of interest rate differential, f_L and f_U (δ_L and δ_U) upper and lower bound of fundamentals (interest rate differentials), τ maturity, α parameter, π realignment probability ($0 \leq \pi \leq 1$), realignment size $2f_U$ ($c_1 = c_0 + 2f_U = f_0 + 2f_U$).

Bertola and Svensson (1991) introduce stochastic devaluation risk g_t as a second source of time variation in exchange rates and interest rate differentials. The interesting point about the model of Bertola and Svensson (1991) is that the negatively sloped instantaneous interest rate differential in Graph 4 fluctuates vertically as the expected rate of devaluation g_t changes over time, so that combined with the simultaneous fluctuations in the fundamentals f_t almost any pattern of exchange rate and interest rate differential observations may result. More specifically, as the variability of g_t relative to f_t increases, the correlation between the instantaneous interest rate differential and the exchange rate will be less negative, and may vanish or even become positive. For positive and finite terms a similar result is obtained under certain assumptions about the time-series properties of the expected rate of devaluation g_t .⁷ The Bertola and Svensson (1991) model may be incorporated into the above linearized estimating equation by assuming a time-varying intercept $c_t(g_t, \pi)$ and a constant slope coefficient $b(\sigma_g^2/\sigma_f^2, \tau)$, which is negative and increasing in term only for low degrees of variability of expected devaluations (σ_g^2) relative to the fundamentals (σ_f^2). As indicated in equation (19.3), the time-varying intercept $c(g_t, \tau)$ should largely reflect devaluation risks in the absence of fundamental drift ($\eta=0$).

Another approach to modelling devaluation risks is adopted in Bertola and Caballero (1991). In their model the imperfectly credible target zone is defended by the monetary authority only with probability $1-\pi$ ($0 \leq \pi \leq 1$) by discrete marginal intervention, whilst with probability π a realignment is initiated.⁸ Extending the work of Bertola and Caballero (1991), Bartolini and Bodnar (1991) show that both the intercept and the sign of the slope coefficient now strongly depend on the realignment probability π , as indicated in equation (19.4) of Box 19. The slope coefficient $b(g_t, \pi_t, \sigma_g^2/\sigma_f^2; \tau)$ is negative and increasing in term for low realignment probabilities π_t and low degrees of variability of expected devaluation rates (σ_g^2) relative to the fundamentals (σ_f^2), but positive and decreasing in term for high realignment probabilities π_t and high degrees of the variability of expected devaluation rates (σ_g^2) relative to the fundamentals (σ_f^2). Variations in the intercept term $c(g_t, \pi_t; \tau)$ should largely reflect variations of devaluation expectations g_t and the likelihood of a realignment.

The empirical section below aims at quantifying the time-paths of expected devaluation rates implicit in EMS interest rate differentials by estimating the above augmented target zone models using time-varying parameter regression. As in the theoretical model of Bertola and Svensson (1991), this requires the specification of the future time-paths of the expected rate of devaluation g_t , as reflected in interest rate differentials by movements of c_t . According to Bertola and Svensson (1991) the expected devaluation rates are driven by a Brownian motion process, the continuous time equivalent of a random walk (with drift), whilst the simulations of Bertola and Svensson (1991) use some mean-reverting process⁹ in order to obtain stationary interest rate differentials. The empirical section below uses a flexible form, which allows expected devaluation rates and hence interest rate differentials to be a mixture of both stationary and non-stationary components, the composition of which may change over time. In particular, the expected devaluation rates c_t implied by interest

rate differentials are modelled as a probability weighted average of a stationary (random) process and a non-stationary (random walk) process, as indicated by equations (20.1) and (20.2), respectively.

Box 20
Time Series Properties of Expected Devaluation Rates Implied by Interest Rate Differentials

(a) stationary (random) process

$$c_t = \bar{c} + v_{it}, \quad E(v_{it}) = 0, E(v_{it}v_{it}^T) = \sigma_v^2, E(v_{it}v_{it-j}^T) = 0 \forall j \neq 0, \quad (20.1)$$

(b) non-stationary (random walk) process

$$c_t = c_{t-1} + u_{it}, \quad E(u_{it}) = 0, E(u_{it}u_{it}^T) = \sigma_u^2, E(u_{it}u_{it-j}^T) = 0 \forall j \neq 0, \quad (20.2)$$

(c) probability β_t ($0 < \beta_t < 1$) weighted average of the stationary process and non-stationary process

$$\begin{aligned} c_t &= c_{t-1} - \beta_t(c_{t-1} - \bar{c}) + \beta_t v_{it} + (1 - \beta_t)u_{it} \\ &\Rightarrow c_t - c_{t-1} = -\beta(c_{t-1} - \bar{c}) + w_t. \end{aligned} \quad (20.3)$$

Box 20 shows that for a given probability β_t of the stationary process (and hence a given probability $1 - \beta_t$ for the non-stationary process) this may be combined to obtain the coefficient process (20.3). This process has mean reverting properties as long as β_t takes intermediate values ($0 < \beta_t < 1$). The advantage of this set-up is that it allows the data to determine both the degree and the time-pattern of mean reversion of the expected devaluation rates implied by interest rate differentials.

To obtain a time-varying estimate of expected devaluation rates implied by interest rate differentials in a target zone, a learning algorithm, the so-called Bayesian multi-process Kalman filter of Harrison and Stevens (1971, 1976), is employed. The basic structure of this algorithm is the same as that described in section 3.1 above. However, in order to use the algorithm outlined in Box 17 the state space model of the target zone has to be adapted to the Kalman filter specification. For a formal description of this method and for references to other applications in economics the discussion in Weber (1988, 1992b) is referred to.

The working of the algorithm may best be explained by transforming the linearized approximation of the Bertola and Svensson (1991) target zone model (19.3), on which the estimates will be based, into its general state-space representation (21.1a) and (21.1b), where the specifications of (21.2) apply. For $q_1 = 0$ and $h_1 = 1$ this Kalman filter model implies $a_t = a_{t-1} = \dots = a$, which is equivalent to a model with constant expected devaluation rates, a variant of which is estimated in Svensson

(1991b). For $h_1=0$ and $q_1=1$, on the other hand, expected devaluation rates and hence interest rate differentials are non-stationary and driven by a random walk stochastic process.

The multi-process Kalman filter approach now requires these two alternative process models to be set-up as sub-models of a hybrid model. The sub-model M_t^1 with constant devaluation expectations ($h_1=1, q_1=0$) may thereby be viewed as the reference model, against which the alternative model M_t^2 with time-varying devaluation expectations is to be judged in terms of explaining those component of interest rate differentials that the standard target zone model leaves unexplained. Given these two alternative specifications of the variance-covariance matrices Q^i and H^i ($i=1,2$), estimates of the unobservable state vectors a_t^i and their variance-covariance matrices $\sigma^2 P_t^i$ may then be extracted from the observable interest rate differentials δ_t by using the Kalman filter. The possibility of stochastic process switching from stationary to non-stationary devaluation expectations, for example under speculative attacks, is thereby explicitly taken into account.

Box 21

State Space Representation of the Relationship Between Expected Devaluation Rates and Interest Rate Differentials

(a) State Space Representation of Equation (19.3)

$$\delta_t = z_t a_t + S_t v_t, \quad E(v_t) = 0, E(v_t v_t^T) = \sigma^2 H, E(v_t v_{t-j}^T) = 0 \forall j \neq 0, \quad (21.1a)$$

$$a_t = T a_{t-1} + R u_t, \quad E(u_t) = 0, E(u_t u_t^T) = \sigma^2 Q, E(u_t u_{t-j}^T) = 0 \forall j \neq 0, \quad (21.1b)$$

(b) Matrix and Vector Conventions

$$a_t = [c_t \quad b_t], \quad z_t = [1 \quad e_t], \quad v_t^T = [v_{1t} + \varepsilon_t \quad v_{2t}] v_t, \quad u_t^T = [u_{1t} \quad u_{2t}], \quad (21.2)$$

$$S_t = z_t = [1 \quad e_t], \quad H = \begin{bmatrix} h_1 & 0 \\ 0 & 0 \end{bmatrix}, \quad T = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad R = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad Q = \begin{bmatrix} q_1 & 0 \\ 0 & 0 \end{bmatrix}.$$

Given these specifications, the algorithm of Box 17 is then directly applicable. The multi-process Kalman filter regression model then allows an estimate of the unobservable expected devaluation rates implicit in interest rate differentials to be obtained from a linearized structural target zone model. The algorithm assumes that devaluation expectations vary over time and may switch between being stationary and non-stationary, say in periods of speculative attacks. The degree of time-variability in expected devaluation rates is estimated recursively by searching for that process mix (or probability weighted average) of stationary and non-stationary parameter variation which best explains the observable interest rate differential data.

Under the reference model of purely constant expected devaluation rates the algorithm reduces to recursive least squares, whilst under the alternative model it is identical to the pure random walk parameter regression model. The intermediate case of mixed transitory and permanent parameter variation has mean reverting properties and is close in spirit to the time-varying regression model with return-to-normality coefficients.

Having described the various theoretical propositions and empirical procedures, I now turn to the empirical analysis of reputation and credibility. The focus of the empirical analysis thereby is on countries participating in the European Monetary System, but results for a control group of non-EMS countries are also reported.

Endnotes to Chapter 3

¹ Vickers (1986) states that in such pooling equilibria the public has no basis for updating the reputation measure ψ_t . Such a constant ψ_t follows from equation (2.7) in Box 2 of the Backus and Driffill (1985a,b) model only if the inflationary policymaker is known to behave like the anti-inflationary type with probability one ($\delta_t=1$). See also Barro (1986) on this point.

² In the empirical reputation estimates such low initial inflation rates μ_0 are ensured by choosing the start of the sample period in the early 1960s.

³ Clearly the latter type of shocks may not be very relevant to most OECD countries. The Bayesian learning of the MPKF then ensures that the probability weight attached to this process model will decline drastically and that it will be almost completely disregarded after some time.

⁴ To be precise, the ARIMA(0,2,2) sub-version of the state space model (15.1a) to (15.1d) was used, with P_t being replaced by m_t . This implies the restriction $d_t=d_{t-1}=d_0$ in the more general ARIMA(0,3,3) model. In terms of the theoretical model from equations (18.1a) and (18.1b) in Box 18 this implies that some restrictive assumptions, such as $\rho<1$ and absence of permanent shocks to money growth rates, were relaxed. The motivation behind this is that in Weber (1993) permanent shocks to money growth rates are found to play an important role in the post-war period.

⁵ See Weber (1990a) for a detailed analysis of these issues. Some further discussion is also found in Weber (1991a).

⁶ This may be justified by the fact that the relationship between finite term interest rate differentials and exchange rates is approximately linear, in particular for longer terms.

⁷ In order to obtain stationary interest rate differentials, Bertola and Svensson (1991) assume some type of mean reverting properties (or re-setting at a realignment) of g_t .

⁸ Bertola and Caballero (1990) model central bank intervention in foreign exchange markets as discrete (large and infrequent) marginal intervention, as in the Flood and Garber (1989) model, instead of infinitesimal (small and frequent) marginal intervention, as in the Krugman (1991) and Svensson (1991b) models.

⁹ To obtain a stationary interest rate differential, Bertola and Svensson (1991) choose an ad-hoc mechanism which re-sets g_t to g_0 at each realignment. However, a (regulated) mean-reverting process, such as the Ornstein-Uhlenbeck process used in Froot and Obstfeld (1989), may be preferable for modelling expected realignment risks implicit in stationary interest rate differentials.

4

EMPIRICAL EVIDENCE ON POLICY CREDIBILITY

This section aims at providing empirical evidence on the various propositions discussed above. The main aim of the analysis is to quantify empirically the proposed credibility measures derived from the policy game and target zone literature. In the context of target zones for exchange rates this evidence is supplemented by reporting less formal indirect evidence on credibility found by looking at distributions and variability of exchange rates and interest rate differentials within explicit or implicit bands.

4.1. Evidence about Counterinflation Reputation

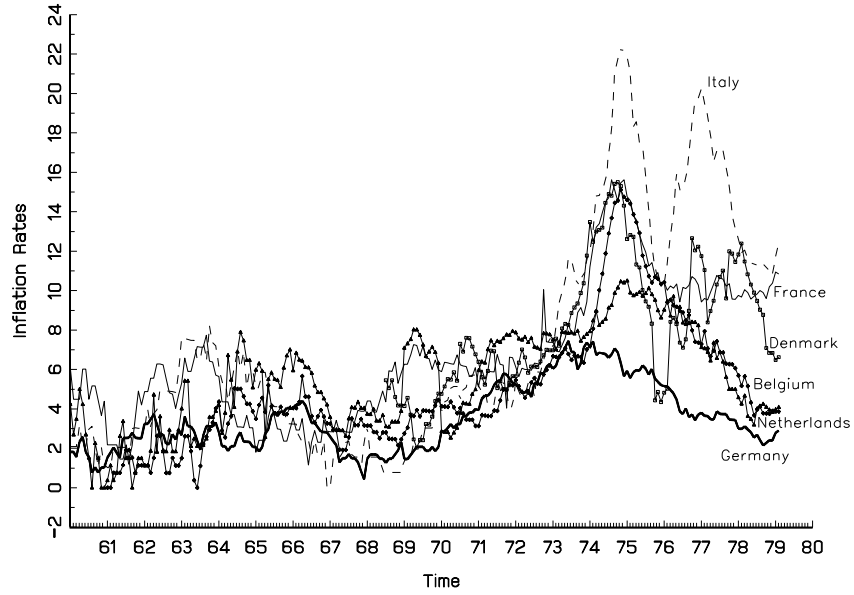
Before presenting any estimates, it is important to take a closer look at the data in order to get some intuition on the question of whether and how the European Monetary System (EMS) may have helped member countries to disinflate during the 1980s. Giavazzi and Giovannini (1987) and Giavazzi and Pagano (1988) were the first to formulate the 'borrowing credibility' hypothesis. In their opinion the EMS represents an institutional arrangement which has enabled the non-German EMS member countries to borrow counterinflation reputation from the Bundesbank by pegging their bilateral exchange rates relative to the German mark.

4.1.1. The Inflation Experience

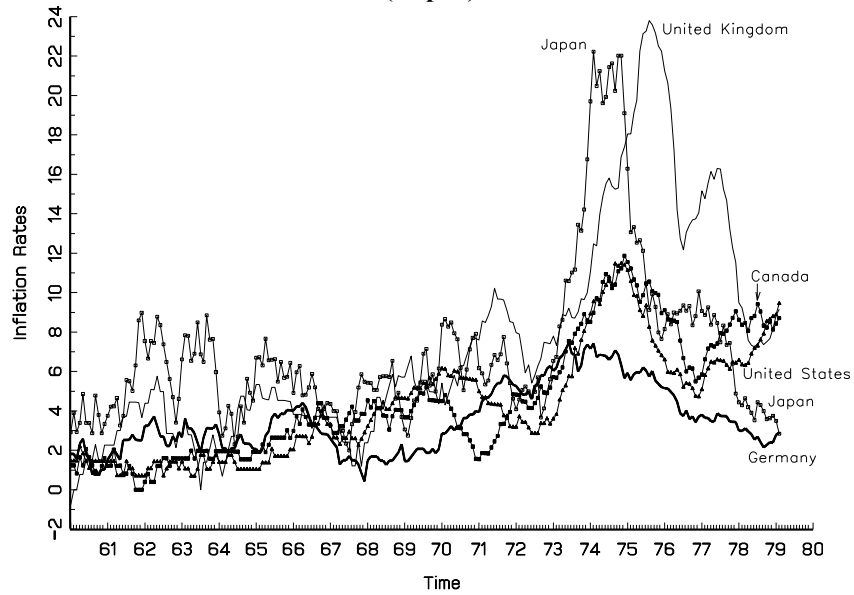
At a purely descriptive level, the 'borrowing reputation' hypothesis does not appear to be inconsistent with the time-paths of EMS inflation rates, as shown in panel (b) of Figure 4.1. For most of the EMS period Germany clearly has had the lowest inflation rates of all EMS countries. Throughout the EMS period Dutch inflation rates moved very closely in line with those in Germany, whilst the remaining EC countries experienced substantially higher inflation. Both Germany and the Netherlands did not accommodate the oil price shock of 1979 to any great extent, whereas the rest of the EC countries inflated substantially. After this initial adverse impact of the oil price

Figure 4.1.
Inflation Rates

(a) ERM Participants During the Bretton Woods and Snake Period (% p.a.)



(b) Non-ERM Participants During the Bretton Woods and Snake Period (% p.a.)



shock between 1979 and 1982, all EMS countries have had considerable success in reducing inflation between early 1982 and late 1986. This is precisely what the 'borrowing reputation' view of the EMS, formulated in Giavazzi and Giovannini (1987) and Giavazzi and Pagano (1988), is all about. But the inflation data raise some additional questions: first, why did EMS countries in March 1979 enter the exchange rate mechanism (ERM) with such vast differences in inflation rates. Second, why did inflation rates initially diverge between 1979 and 1982? Third, why has inflation convergence to the low German levels been so slow and, for some countries, less than complete during 1982-87? Fourth, does the post-1987 EMS experience reject the 'borrowing reputation' view, given that German deflation resulted in full convergence of EMS inflation rates by mid 1990 and continuing divergence thereafter?

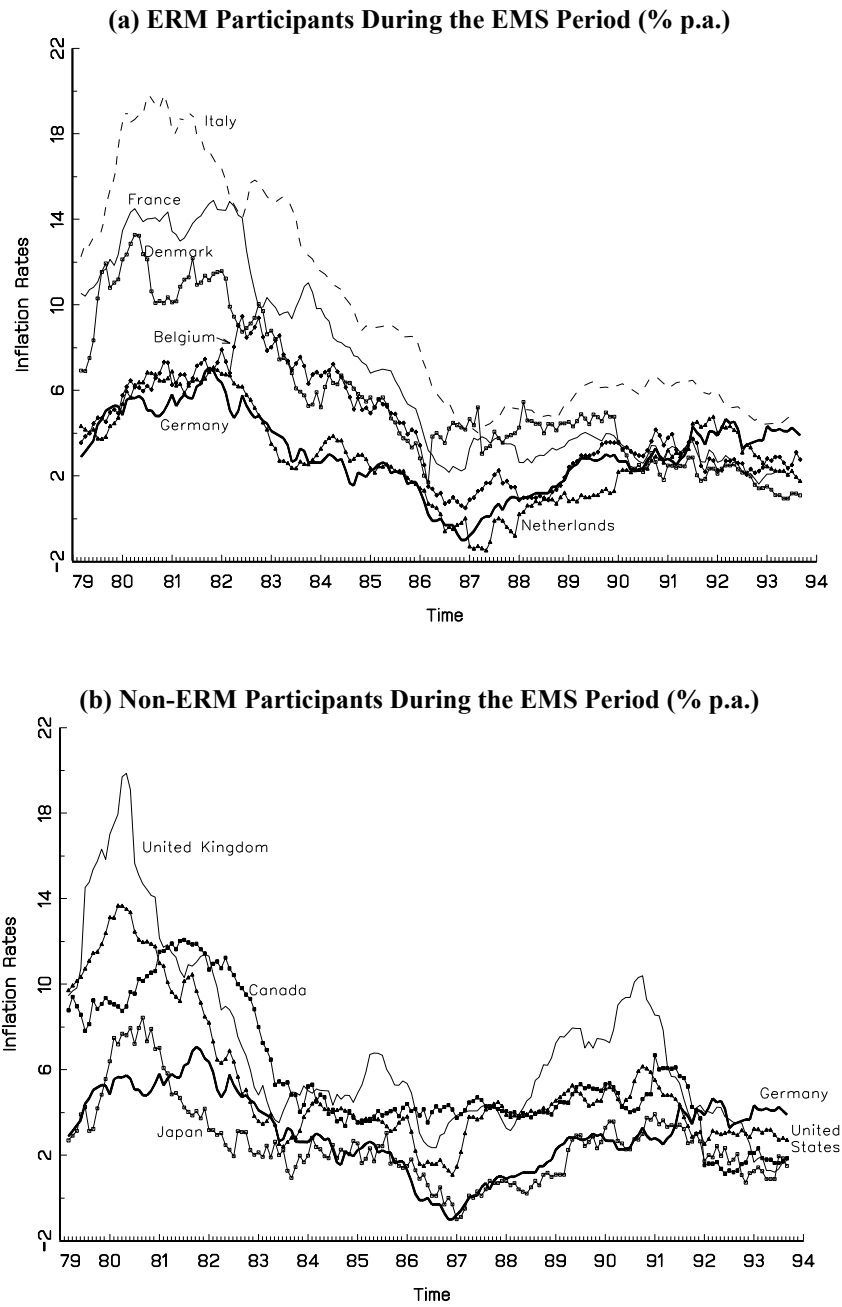
The pre-EMS history of inflation experience in the initial EMS member countries is displayed in panel (a) of Figure 4.1. Most countries experienced relatively low inflation rates during the Bretton Woods period. Throughout the 1960's inflation rates in EMS countries fluctuated roughly around their initial values, even though the size and relative smoothness of these inflation swings differed substantially between countries. On average, German inflation rates were both the lowest and least erratic, when compared with the remaining EMS countries. Towards the end of the Bretton Woods period inflation emerged in all countries. German inflation rates, for example, rose steadily from 2 percent in early 1970 to roughly 7 percent prior to the oil price shock in 1973. The remaining countries experienced somewhat higher inflation during this period, but in early 1973 all EMS inflation rates were within one percentage point of the German inflation rate. The oil price shock of 1973 then caused a drastic divergence of inflation rates due to the vastly different degrees of monetary accommodation. German monetary policy clearly did not accommodate the oil price shock at all, because already by the end of 1973 German inflation rates started declining steadily until 1979. On the other hand, inflation in Italy, and to a slightly lesser extent in France, Denmark and Belgium, rose drastically in response to the oil price shock. Inflation rates in these countries also became much more erratic and exhibited huge fluctuations during 1973 to 1979. Compared to Germany, the Netherlands initially also accommodated the oil price shock to a larger extent, but to substantially lesser degree than the remaining countries. However, after 1975 Dutch inflation rates fell sharply. A similar sharp disinflation was experienced by Belgium, where during 1975-79 inflation rates moved closely in line with those in the Netherlands. Moreover, inflation in the Benelux countries furthermore almost reached the low German levels by 1979. Italy and France, on the other hand entered the EMS with substantially higher inflation rates.

Virtually at the same time as the EMS was started the European economies were hit by the second round of oil price shocks. Inflation rates rose steeply in Italy, France and Denmark, and, by comparison, modestly in Germany and the Benelux countries. As in 1973, differing degrees of monetary accommodation of the oil price hikes caused a massive divergence of inflation rates, which greatly destabilised EMS exchange rates and initiated several rounds of realignments during this early EMS period, as can be seen from Figure 4.18 below. For Belgium the drastic devaluation of the Belgian franc relative to all other EMS currencies had a strong inflationary impact, and ended the close co-movement of Belgian inflation rates with those in the Netherlands and Germany.

Disinflation in the EMS started in late 1981. This European disinflation period is studied empirically in Rogoff (1985b), Ungerer et al. (1983, 1986, 1990), Collins (1988), Artis (1987) and Weber (1990b). These studies find that, as far as disinflation is concerned, the EMS countries have not differed substantially from the other advanced economies. The same is true for the inflationary response of non-EMS countries to the oil price shocks of 1973 and 1979, as displayed in panels (a) and (b) of Figure 4.2. If anything, disinflation during the 1980's has been slower in the EMS. De Grauwe (1990) explains this by the fact that the exchange rate constraint has prevented EMS member countries from adopting a 'short sharp shock' treatment, which was resorted to in the U.K. under the Thatcher government. Panel (b) of Figure 4.2 shows that most of the inflation reduction in the United Kingdom and the United States was achieved relatively quickly in the short period of mid-1980 to mid-1983. In contrast, the German and French disinflations only started in late 1981 and were not completed until late 1986. The importance of borrowing German counterinflation reputation in this process is not obvious. If the borrowing reputation hypothesis were true, it remains a puzzling fact that despite of joint disinflation the EMS countries did not experience a faster and more complete convergence of inflation to the low German levels.

The German reflation period between 1987 and 1993 is also quite interesting to analyse in conjecture with the borrowing reputation hypothesis. In Weber (1991a) it is stated that whilst disinflation in the EMS has been slower, it also has been somewhat longer lasting, as exemplified by the strong reflation in the United Kingdom and the United States relative to Germany and the remaining EMS countries between 1987 and 1991. Interestingly, EMS inflation rates converge after 1987, whilst no such convergence is not observed outside the system. Wyplosz (1989) suggests that this may be attributed to the disciplinary effects arising from relatively fixed exchange rates. When looking at the data it is obvious that inflation convergence in the EMS continued for two reasons: on the one hand, the former inflationary EMS members, such as France and Denmark, have resisted reflation and belatedly embraced a more counterinflationary policy stance. On the other hand, Germany's anti-inflation policy stance appears to have mellowed slightly during 1987-90 and has decayed considerably in the aftermath of German unification. Full inflation convergence in the EMS was achieved by mid 1990, ironically as a result of German reflation to French inflation levels. During time, the rising German inflation rate dragged up with it inflation in Belgium and the Netherlands. The unification shock added to German reflation and divergence of EMS inflation rates started to emerge, with German inflation in 1991-92 exceeding inflation rates in all remaining ERM countries except Italy. The German mark thus no longer provided the hard-currency anchor of the system. More importantly, during 1990-1993 inflation was rising in Germany, whilst it was relatively stable or declining in the remaining EMS countries and other advanced economies. Even the Benelux countries appear to have recently moved away from following the German inflation lead. In my view these data clearly refute the 'borrowing reputation' hypothesis for recent years: given the differential behaviour of German inflation rates, the 'borrowing reputation' hypothesis implies that the other EMS member countries could only have borrowed a bad reputation. After German unification pegging to the mark became undesirable because it no longer implied a reputation bonus, given the Bundesbank's tolerance of inflation.

Figure 4.2.
Inflation Rates



Summarising the above, discussion it can be stated that Germany clearly was the country with the best and most consistent counterinflation record prior to and during the EMS. This should be reflected in a high counterinflation reputation estimate. On the other hand, most other EMS countries, in particular Italy and France, experienced two major inflation hikes when monetary policy strongly accommodated both rounds of oil price shocks in 1973 and 1979, and this should have greatly depressed counterinflation reputation. Finally, inflation rates in the Netherlands followed the German inflation pattern relatively closely, at least during the 1980's, whilst the inflation experience of the remaining EMS countries appears to have been less closely related to that of Germany. The implications of this for counterinflation reputation in these countries is not obvious, and the empirical analysis below aims at making some quantitative data-based statements on this issue by estimating and comparing the reputation measure derived in chapter 3.

4.1.2. Estimates of Counterinflation Reputation

The first empirical issue to be discussed here is whether or not the German Bundesbank was indeed the central bank with the highest anti-inflation reputation, as implied by the 'borrowing reputation' hypothesis. If so, have other EMS countries gained counterinflation reputation during the EMS period? Moreover, have such gains in reputation materialised due to purely domestic policy U-turns or due to the rules of the EMS?

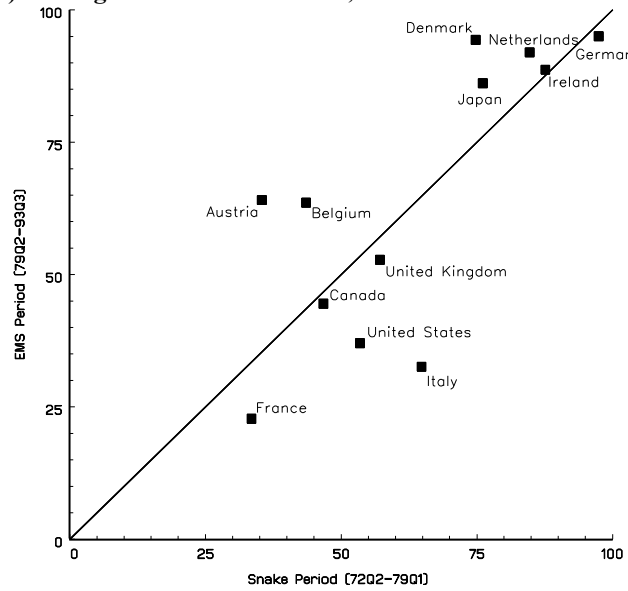
As noted above, counterinflation reputation is defined as the probability that policymakers consistently pursue low-inflation policies. This probability is estimated here by using the Bayesian Kalman filtering procedure described in chapter 3. This procedure consists of finding out how inflation may best be forecasted under various alternative assumptions about the degree to which inflation shocks are allowed by the central bank to be permanent. Clearly, monetary accommodation of permanent real shocks, such as the oil price hikes or the German unification shock, strongly undermines counterinflation reputation in this context. Econometrically such reputation losses are captured by the fact that the probability of forecasting inflation accurately with a model which only allows for transitory inflation shocks will deteriorate rapidly if inflation rises permanently. Since the model with exclusively transitory inflation shocks is used here to capture inflation outcomes under a counterinflationary policymaker, the probability updating procedure of the Bayesian multi-process Kalman filter yields the desired measure of counterinflation reputation.

4.1.2.1. Period-Averages of Counterinflation Reputation

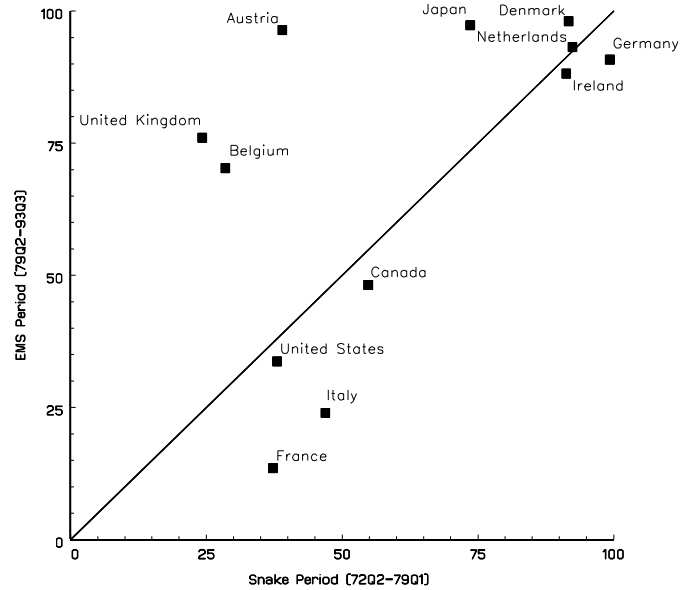
The estimates of counterinflation reputation derived by applying the Bayesian multi-process Kalman filter (MPKF) to consumer price indices¹ from EMS and non-EMS countries are presented in Figure 4.3 for a pre-EMS period (72Q2-79Q1) on the horizontal axis and the EMS period (79Q2-93Q2) on the vertical axis. Panel (a) displays the period averages of reputation, panel (b) the end-of-period reputation estimates. The 45° line is added to make it easier to see how reputation has changed from one period to another. Three main findings emerge: first, on average Germany has the highest anti-inflation reputation prior to and during the EMS period. Second,

Figure 4.3.
Counterinflation Reputation Measure:
Prior Probability of Inflation Stationarity (in %)

(a) Average of Period Estimates, Snake versus EMS Periods



(b) End of Period Estimates, Snake versus EMS Periods



the small EMS economies Belgium, the Netherlands, Denmark and Ireland have gained some anti-inflation reputation during the EMS period. Finally, France and Italy have the lowest counterinflation reputation and have not increased their reputation during the EMS period.

The estimates of counterinflation reputation are largely consistent with the actual inflation performances in Figure 4.1. Germany and the Netherlands entered the EMS with low inflation rates. The relatively low inflationary impact of the 1979 oil price shock, followed by a smooth disinflation (1982-1986) explains the preservation of counterinflation reputation in both countries. France and Italy, on the other hand, entered the EMS with high inflation, experienced double-digit inflation rates up to 1983 and improved their inflation record only quite lately in the EMS period. The key point is that only the smaller EMS member countries have gained reputation under the EMS, while for the larger EMS countries there is no evidence of substantial reputation losses for Germany or reputation gains for France and Italy. In Weber (1992b) this is interpreted as evidence rejecting the 'borrowing credibility' hypothesis for the large EMS countries. The 'hard-currency' option provided by the EMS seems to have enabled the smaller inflation prone EMS countries, in particular Belgium and Denmark, to establish some anti-inflation reputation and to gain counterinflationary credibility by locking into German anti-inflation policies. From panel (a) a similar statement applies to Austria, which pursued a unilateral exchange rate pegging policy with respect to the German mark throughout the 1980's. Finally, the end-of-period results in panel (b) suggest that the United Kingdom, which joined the EMS in October 1990, has also managed to gain counterinflation reputation recently. In order to examine these issues in more depth, it is instructive to take a closer look at the time-paths of the various reputation measures.

The evidence reported so far only supports the 'borrowing reputation' view of the EMS in two respects: as postulated by Giavazzi and Pagano (1988), Germany is found to be the low-inflation high-reputation centre of the EMS, and has largely managed to maintain this high reputation. Furthermore, the smaller EMS countries have gained counterinflation reputation, but such reputation gains are not found for the two large EMS countries, France and Italy. This is hardly surprising since for large economies 'tying the policymakers' hands on monetary policy', as is required by the 'borrowing reputation' hypothesis, is obviously a less attractive policy option. This view is also consistent with the fact that both France and Italy have continued to resort to precommitted monetary quantity targeting policies throughout the EMS period.

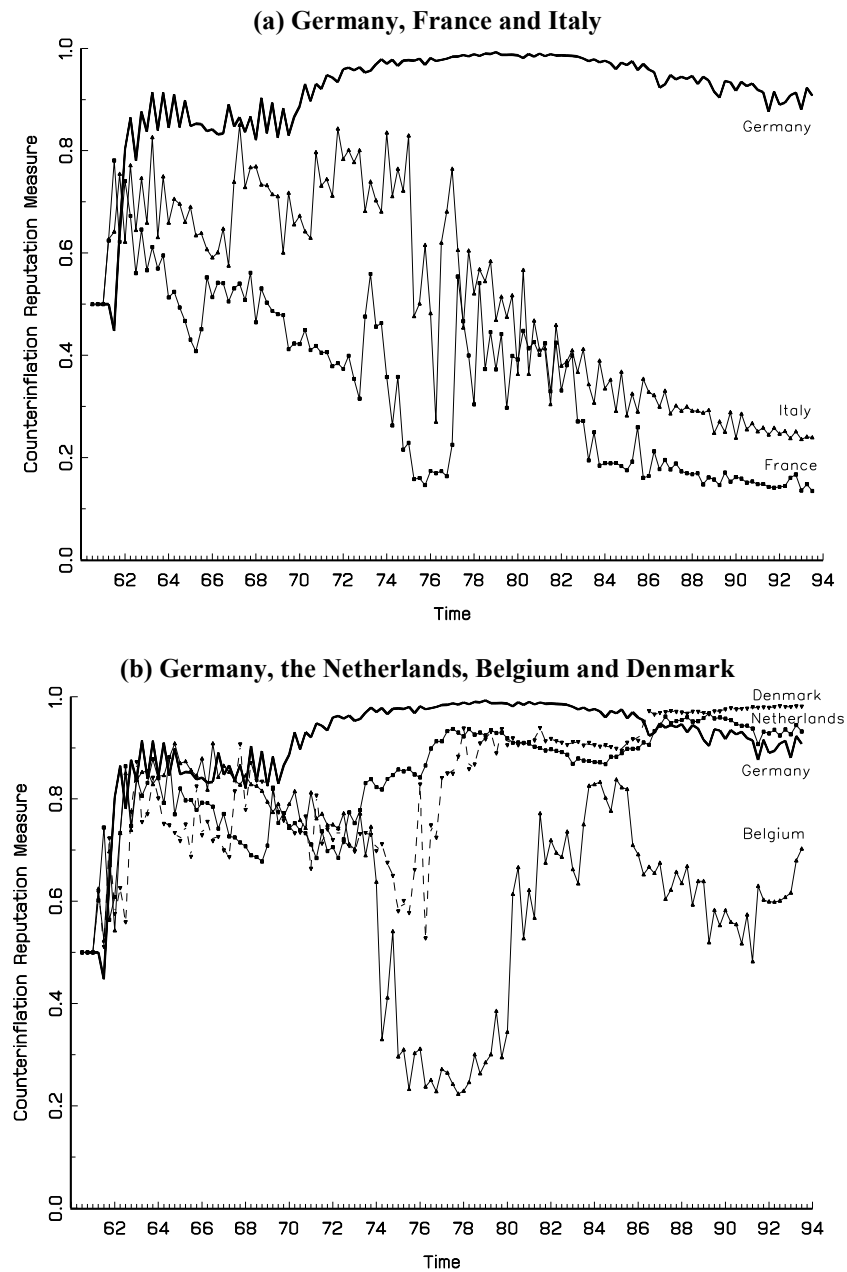
4.1.2.2. Time-Paths of Counterinflation Reputation

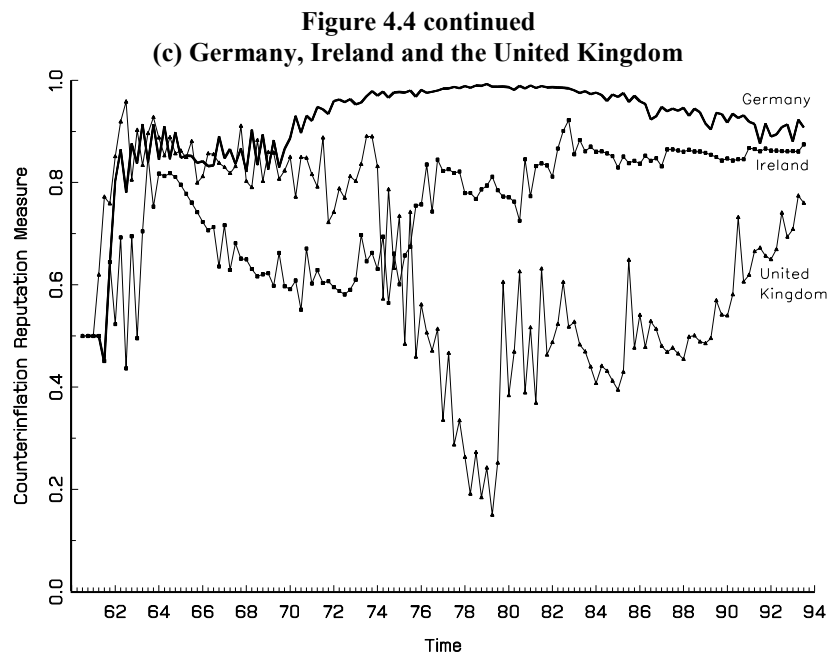
Given the apparent difference between the counterinflation reputation estimates for the large and small non-German EMS countries, it is interesting to compare how reputation has evolved over time. For this purpose the time-paths of the counterinflation reputation measures are displayed in Figures 4.4.

Germany, France and Italy

Panel (a) of Figure 4.4 compares the reputation estimates for Germany, France and Italy. Clearly, German counterinflation reputation is very high throughout the sample period, but declines slightly after the end of the EMS deflation period after 1986, as

Figure 4.4.
Counterinflation Reputation Measure:
Prior Probability of Inflation Stationarity (in %)





German reflation emerged. The French reputation for counterinflation policies is considerably lower than German reputation. The French reputation measure fluctuates around its initial level prior to March 1973, but declines after the occurrence of the first oil price shock and the French withdrawal from the 'snake' in early 1974. It reaches its minimum in mid 1976, and remains relatively low thereafter. The Italian reputation measure is relatively high in the first half of the sample, declines strongly after the mid-1970s and largely resembles the behaviour of the French reputation measure during the EMS period. Both France and Italy lost counterinflation reputation primarily because of their high inflation rates in the 1960's and their monetary accommodation of the two oil price shocks in 1973 and 1979. The frequent switching between drastic inflation and steep disinflation furthermore is responsible for the fact that both countries failed to establish counterinflation reputation during disinflation episodes in the pre-EMS (1975-79) and EMS (1982-86) period. This feature of the reputation estimates is caused by the fact that a highly erratic policy environment with long runs of permanent positive inflation shocks and subsequent long runs of permanent disinflation shocks does not command the same counterinflation reputation as an environment where such huge swings in inflation rates do not occur.

The Netherlands, Belgium, Denmark and Ireland

The smaller EMS countries, such as the Netherlands, Belgium, Denmark and Ireland, traditionally place a higher weight on external stability and can therefore be expected to gain more than the larger countries from the provision of a 'hard currency' standard within the EMS. However, in Weber (1991a) it is argued that the EMS must be viewed as a bipolar system, which in addition to the 'hard currency' option of pegging to the DM also offered the 'soft currency' alternative of pegging to a 'weak currency',

such as the French Franc. Depending on this choice, the smaller EMS countries may have borrowed 'good' or 'bad' counterinflation reputation.

The relevance of this proposition may best be illustrated by referring to panel (b) of Figure 4.4, which displays the reputation estimates for the former snake member countries, that is, Belgium, the Netherlands and Denmark relative to Germany. For the Bretton Woods period the Dutch counterinflation reputation estimate lies below the German estimate, but increases considerably after the European currency 'snake' arrangement is established between these countries in April 1972 (see Box 22 for details). Throughout the snake period the Dutch reputation measure moves slightly below the German reputation measure. The onset of the EMS in March 1979 also has little impact on the apparent symmetry between the German and Dutch reputation measures. Finally, during the EMS disinflation period (1983-86) the Dutch reputation measure increases slightly and rises above the German reputation estimate after late 1986, when inflation rates in the Netherlands were lower than those in Germany. The Danish and Belgian reputation measures closely resemble the Dutch reputation measure prior to 1973, but decline strongly as inflation rises sharply in the aftermath of the oil price shock. Danish counterinflation reputation soon rises again and closely follows the Dutch measure for the remainder of the sample period. Belgian counterinflation reputation follows the French measure during the pre-EMS snake period, but there is a sharp increase in Belgian counterinflation reputation at the onset of the EMS, when Belgian inflation rates closely follow those in Germany and the Netherlands. Between 1983 and 1988 Belgian counterinflation declines somewhat, but rises again after 1991.

Box 22

From Bretton Woods to the European Monetary System

The Smithsonian agreement of the 'Group of Ten' of December 1971 widened the bilateral fluctuation margins against the U.S. dollar from $\pm 1\%$ to $\pm 2.25\%$. In the Basle agreement of April 1972 the central banks of the EC countries Germany, France, Italy, the Netherlands, Belgium, and Luxembourg agreed on narrower bilateral fluctuation margins of $\pm 1.125\%$ ($\pm 0.75\%$ between the Netherlands and the Belgian-Luxembourg Economic Union, BLUE) around their spot parities. In this 'snake in the tunnel' arrangement the narrow bilateral margins (the 'snake') were equal to half the size of the U.S. dollar margins (the 'tunnel'). In May 1972 Denmark, the United Kingdom and Ireland joined the snake, but the latter two countries withdrew from both the snake and the tunnel in June 1972. Denmark withdrew from the snake in June 1972, but rejoined in October 1972. Italy left the snake in February 1973 and in March 1973 the remaining snake countries decided to let their currencies float jointly against the U.S. dollar, which terminated the period of the 'snake in the tunnel'. France withdrew from the system in January 1974 (French sample 72M4-73M12) rejoined in July 1975 but withdrew again in March 1976. The sample period considered here for the European currency snake system covers both the 'snake' and the 'snake in the tunnel' and runs from April 1972 to February 1979 with the exceptions indicated above.

The overall impression suggested by panel (b) of Figure 4.4 is that after maintaining an intermediate position throughout the Bretton Woods period the major gains in Dutch anti-inflation reputation were obtained by committing monetary policy to the 'hard currency' option of pegging the Dutch guilder to the German mark at the onset of the European currency 'snake' in 1972 and by continuing this commitment under the EMS arrangement after 1979. The Belgian reputation estimate, on the other hand, seems to switch from a similar intermediate position to closely following the French reputation estimates prior to the EMS, when both countries to a similar degree accommodated the oil price shock of 1973. Recently Belgian reputation appears again to follow a more intermediate path, with some reputation gains towards the sample end. For Denmark, as for the Netherlands, the main gains in counterinflation reputation materialised during the 'snake' period, when the Benelux countries and Denmark targeted the exchange rate *vis-a-vis* the German mark. Few additional reputation gains arose during the early EMS period. However, in a similar way to the Netherlands, the Danish reputation measure rises above the German measure towards the end of the EMS disinflation period, when the Danish government enforced legal upper-limits for wage increases in 1985. This belated EMS effect on Danish anti-inflation reputation is consistent with the findings of Artis (1987), who suggests that Denmark appears to have used the EMS initially more as a crawling peg² and only later moved to a more strongly counterinflationary stance by pursuing level pegging policies.

The Irish reputation measure is displayed in Figure 4.4 together with the German and British reputation measures. During the Bretton Woods and the snake period the Irish pound was linked one-for-one to the British pound, but this link was dissolved when Ireland entered the ERM in 1979, whilst the United Kingdom chose to stay outside the system. On the whole, Irish and British inflation rates moved relatively closely together prior to 1979, with two major exceptions: whilst Ireland experienced higher inflation during the 1960's, the United Kingdom accommodated the oil price shocks in 1973 and 1979 to a larger extent and consequently had higher inflation in the late 1970's and early 1980's. This is reflected in the reputation measures: after its initial increase, Irish counterinflation reputation declines continuously between 1964 and 1972. Following a transitory rise in 1973-74, the estimate displays a sharp permanent increase during 1975-76, which is largely due to the substantial cuts in selected VAT rates and subsidies,³ as well as strong external deflationary forces.⁴ Reputation then roughly fluctuates around 0.8 between 1977 and 1982, and thereafter stabilises at a relatively high level. This post 1982 Irish consolidation, which is also reported in Dornbusch (1989), has been re-enforced towards the end of the EMS deflation period in 1986. Thus, as in the case of Denmark above, one may argue that the recent increase in Irish counterinflation reputation can be attributed to the Irish policy shift from an accommodating exchange rate policy to a determined effort to reduce inflation. The results reported here are thus not inconsistent with the view of Dornbusch (1989), who states that for Ireland the EMS clearly has become an instrument of deflation.

The above evidence clearly points to counterinflation gains for all smaller EMS member countries, whilst no such evidence exists for France and Italy. But what about counterinflation reputation outside the system?

The United Kingdom

In Figure 4.4 the British reputation is roughly as high as that for Germany prior to the collapse of the Bretton Woods system. But with the oil price shock in 1973 and the election of the Labour government in February 1974 British inflation rates rise steeply to the highest level of all G7-countries. This is seen in the steep decline of the counterinflation reputation measure between 1973 and 1979. After the election of the Conservative government under Thatcher in May 1979 the counterinflation reputation measure rises sharply and thereafter fluctuates strongly between 1979 and 1985. After 1985 these fluctuations become less erratic and there is a continuing upward trend in British counterinflation reputation throughout the second half of the Thatcher period. It is commonly believed that this gain in British counterinflation reputation has been materialised independently and without resort to foreign entanglements, as Minford (1988) and Currie (1988), amongst others, state.

The United States and Canada

The time path of the reputation measure for United States in Figure 4.5 is very similar to that of the United Kingdom, except for very recent years. American counterinflation reputation was relatively high during the Bretton Woods system until early 1973, but with the strong inflationary impact of the oil price shocks the reputation measure falls drastically. Counterinflation reputation then fluctuates strongly for some years, but remains roughly constant until the end of the sample period. The adoption of a strict monetarist policy stance in October 1979 and its abolition in October 1982 have little impact on the mean of the reputation measure, but its volatility is reduced considerably after 1983. A similar constancy of counterinflation reputation is displayed by the estimate for Canada throughout the entire sample period.

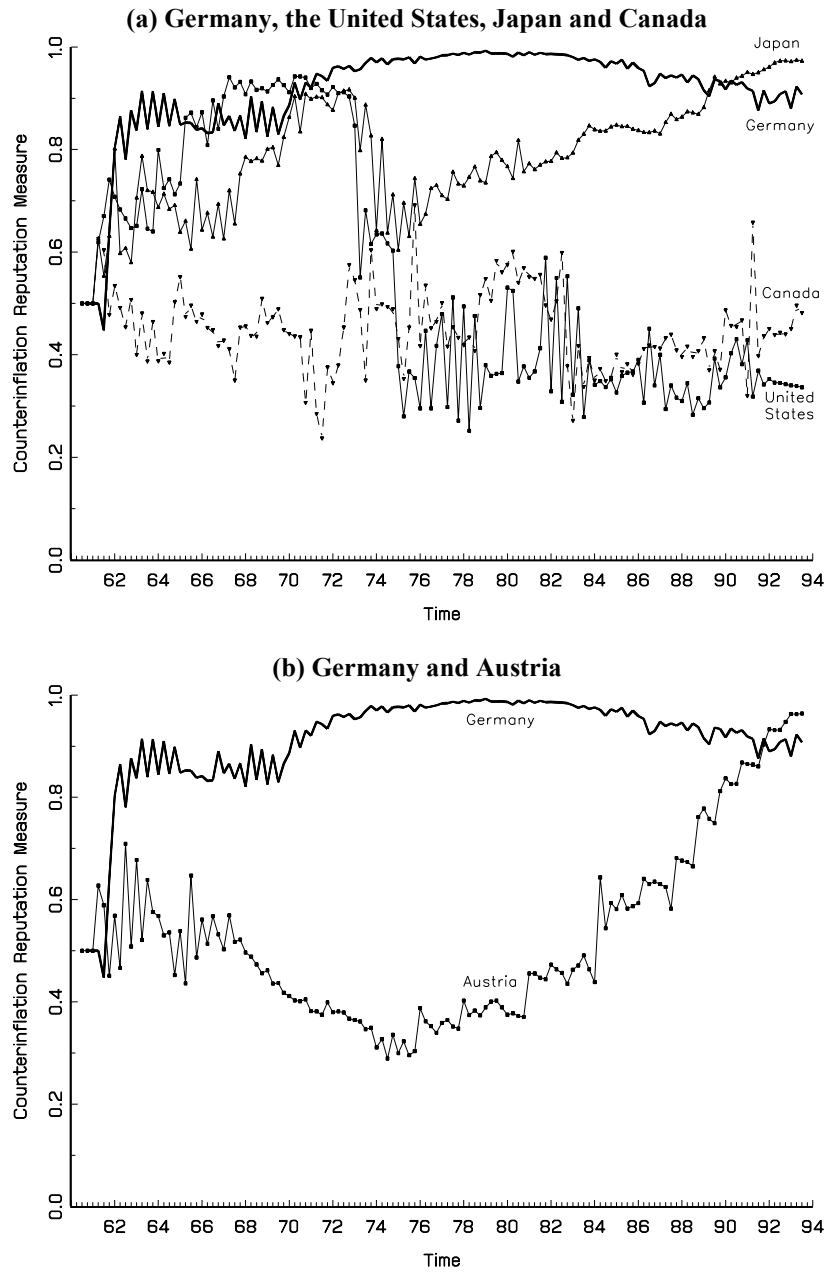
Japan

The counterinflation reputation measure in Figure 4.5 for Japan throughout the Bretton Woods period, but almost reaches its value in early 1971. As for the United Kingdom and the United States, Japan initially accommodates the oil price shock in 1973 to a large extent, and inflation rises drastically. Consequently, Japan's counterinflation reputation declines sharply after the oil price shock in mid 1973. After major changes in monetary policy in early 1975, when Japan abandoned most of its activist policies and moved to a new counterinflationary policy regime, the reputation measure begins a steady and recently less erratic increase, and in 1989 surpasses the German reputation measure.

Austria

The example of Austria in Figure 4.5 is interesting because during the 1980's Austria has unilaterally targeted the German mark exchange rate without a formal institutional arrangement such as the ERM. The success of this policy of 'shadow-targeting' the EMS in an effort to gain counterinflation reputation is obvious from Figure 4.5. After the oil price shock of 1973 Austrian counterinflation reputation was at an all-time low. During the late 1970's and throughout the 1980's Austria has continuously gained counterinflation reputation by pegging to the German Mark. During the peak of the German post-unification reflation Austrian counterinflation reputation even has

Figure 4.5.
Counterinflation Reputation Measure:
Prior Probability of Inflation Stationarity (in %)



exceeded that of Germany due to lower Austrian inflation rates. The example of Austria, which will be dealt with in more detail below in the context of the credibility of exchange rate targeting, impressively demonstrates that gaining counterinflation reputation by pegging the exchange rate *vis-a-vis* a low inflation centre country does not require a formal institutional exchange rate arrangement, but true commitment and devotion. Without the latter, the former is meaningless and bound to fail.

To summarise the above evidence from the ERM and non-ERM G7-countries,⁵ it can be stated that for France, Italy, the United States and Canada no significant gains in counterinflation reputation were found, whilst the United Kingdom and Japan had some success in reputation building. With respect to Germany, counterinflation reputation was established in both countries entirely by domestic policy U-turns. In Japan and the United Kingdom, as well as in the smaller EMS countries, the timing of the gains in counterinflation reputation suggests that stabilisation policies in response to the inflationary impact of the 1973 oil price shock played a key role. Maintaining high or low counterinflation reputation during the EMS period appears to have been a matter of not repeating the mistakes of the years 1973-75 in the event of the second oil price shock in 1979. Japan and the United Kingdom achieved this by domestic policy U-turns between the two rounds of oil price hikes. For the Netherlands, Belgium, Denmark and Ireland, the high counterinflation reputation of Germany combined with the disciplinary effects of relatively fixed exchange rates within the ERM appear, at varying degrees, to have played a role in this process. The same applies for Austria, where a unilateral commitment instead of a formal institutional exchange rate arrangement, appears to have helped in containing inflation. All in all, the estimates suggest that rather than 'borrowing credibility' for disinflation it appears to be the case that 'borrowing discipline' for resisting inflation may have been an equally important feature of the EMS.

4.2. Evidence about Policy Credibility

Having ascertained that some countries have gained counterinflation reputation during the EMS period, the next step is to establish whether there exists a link between the counterinflation reputation of the monetary authorities and the credibility of their policy announcements. To address this issue the credibility of money stock, exchange rate and interest rate targeting policies is evaluated empirically in the next three sections.

4.2.1. The Credibility of Monetary Target Announcements

The move to monetary growth targets may be viewed as an attempt by central banks to resolve their credibility problem. Has this form of signalling policy intentions helped EMS central banks to establish credibility? In answering this question it is important to note that money stock targeting, which was adopted by Germany, France and Italy in the mid-1970s before the advent of the EMS, has remained part of their practices. However, within the EMS, all monetary authorities cannot independently

target both the exchange rate and the money stock at the same time. This may render one of the two policy targets non-credible if both are set inconsistently to one another.

Under what conditions can monetary target announcements be expected to command credibility? Andersen and Risager (1988) state that continuity is an important factor for the success of any stabilisation policy. In practice, however, different money and credit aggregates with differing degrees of controllability have been targeted. All countries occasionally switched from one monetary aggregate to another in order to improve monetary control, as will be discussed in detail below.

4.2.1.1. The Experience with Monetary Targeting

In late 1974, the German Bundesbank was the first central bank to announce a formal monetary target in terms of the growth of a monetary aggregate for a period as long as a year. This example was followed by the Federal Reserve of the United States in early 1975, where the initiative for the move to monetary growth announcements came from the legislature rather than from the central bank. Also in 1975, the Swiss and Canadian central banks announced formal monetary targets and in 1976 the monetary authorities of the United Kingdom and France followed suit.

In addition to the above six countries with formally announced targets for monetary aggregate a number of borderline cases may also be observed: the Italian central bank chose a total domestic credit aggregate rather than a monetary aggregate as a formal intermediate target for monetary policy after 1974 but switched to monetary quantity targets in 1986. Since 1978 the Bank of Japan has made 'projections' for a monetary aggregate. Finally, the Dutch Central Bank after early 1977 focused on a national liquidity ratio, defined in terms of a monetary aggregate relative to national income. In the analysis below this second group will be considered in the same fashion as the first group in order to facilitate an international comparison. This may, of course, can be criticised on various grounds: with respect to the Netherlands, it is unclear whether the monetary authority actively seeks to control the monetary aggregate or national income to achieve the desired liquidity ratio in the long run. In the case of Japan it is uncertain whether or not the actual monetary policy is subsequently adjusted to try and validate the 'projections' for the monetary aggregates.

A further drawback for a direct international comparison is given by the fact that the different countries under study focus on different monetary aggregates with different degrees of potential controllability. For example, the Swiss National Bank and more recently also the Bank of England focus on a monetary base target, over which central banks have almost perfect control. The majority of central banks, however, have attempted to target wider and less directly controllable monetary aggregates. M1 was targeted by both Canada and the United States. The United States also announced targets for M2, as did France, Italy and the Netherlands. Broadly defined monetary aggregates were targeted by Germany (M3), France (M3), Japan (M2 plus certificates of deposits), the United Kingdom (Sterling M3, M4) and the United States (M3). An intermediate case is the Bundesbank's targeting of the German central bank money stock (CBM), which comprises cash and reserve requirements on the components of M3 and hence is broadly defined but more directly controllable

than the broad monetary aggregates above. Finally, Italy initially targeted ceilings for total domestic credit (TDC), which is not a monetary but a credit aggregate.

Another complication for an international comparative evaluation of the credibility of monetary target announcements is given by the previously mentioned discontinuities. Minor changes in the definition of the targeted monetary aggregate were observable in France (from M2 to M2R) and the United Kingdom (from £M3 to M3).⁶ Major shifts between different monetary aggregates took place in virtually all countries. The Swiss central bank focused on M1 targets at the beginning of its target announcements between 1975 and 1978, abolished target announcements altogether in 1979 and announced targets for the monetary base (MB) for 1980 and for the adjusted monetary base (MBA) between 1981 and 1988, as well as M3 after 1987. The French central bank announced targets for M2 from 1977 until 1982, for M2R in 1984 and 1985, for M3 in 1986 and for M2 again since 1987. The German Bundesbank switched from announcing targets for the central bank money stock (CBM) between 1975 and 1987 to announcing targets for M3 since 1988. The monetary authority of the United Kingdom announced targets for M3 from 1976 until 1987, for M1 from 1985 to 1987 and for M0 and M4 from 1987 onwards. The Italian central bank switched from announcing targets for total domestic credit (TDC) ceilings between 1974 and 1990 to also announcing targets growth rates for M2 after 1984.

Finally, the abolition of official monetary target announcements was decided upon by the central banks of Canada and the Netherlands. In the case of the Netherlands, the onset of the European Monetary System (EMS) with its Exchange Rate Mechanism (ERM) in March 1979 led to a policy stance where exchange rate considerations, especially with respect to the German Mark were given priority over independent monetary policy objectives. As a result, official announcements of M2 targets were not made after December 1981. Increased orientation of monetary policy towards an exchange rate target *vis-a-vis* the U.S. dollar was also the reason behind the abolition of M1 target announcements in Canada in November 1982. Due to the very short sample spans, however, both Canada and the Netherlands will therefore not be considered in the quantitative evaluation below.

After having highlighted some of the problems of the attempted comparative study on the credibility of monetary announcements, it is important to briefly discuss the experience of G7 countries with monetary targeting before turning to the estimates of the credibility measures.

Germany

Between December 1974 and 1987 the Bundesbank has announced an annual growth target for the adjusted central bank money stock (CBM), an aggregate consisting of currency in circulation and required reserves on domestic bank deposits at constant reserve ratios.⁷ As indicated in Table 4.1 and Figure 4.6 central bank money growth mostly overshoot the fixed 8 percent target between 1975 to 1978. The Bundesbank attributed these target misses to both imperfect control as well as a deliberate reaction to external developments, mainly interventions to damp the appreciation of the D-Mark.⁸ Furthermore, monetary targeting at that time was still considered to be at an experimental stage. After the 1975-1978 experience with constant fix-point targets, the Bundesbank adopted target ranges for CBM growth between 1979-1987 in order to allow for some flexibility to address unexpected economic developments, such as

Table 4.1.
German Announced Money Growth Targets and Realizations, Year on Year
(y.o.y.) and Annual Average (avg.) of Monthly Growth Rates (in % p.a.).

year	target	target range		concretized	outcome	
		y.o.y.	avg.	target	y.o.y.	avg.
1975	CBM ¹	8.0	-	-	9.9 ⁿ	(7.8)
1976	CBM ²	-	8.0	-	-	9.3 ⁿ
1977	CBM ²	-	8.0	-	-	9.0 ⁿ
1978	CBM ²	-	8.0	-	-	8.5 ⁿ
1979	CBM ³	6.0-9.0	-	lower limit	6.4 ^y	(8.5) [†]
1980	CBM ³	5.0-8.0	-	lower limit	4.9 ^y	(4.8) [†]
1981	CBM ³	4.0-7.0	-	lower half	3.6 ^y	(4.4) [†]
1982	CBM ³	4.0-7.0	-	upper half	6.1 ^y	(4.9) [†]
1983	CBM ³	4.0-7.0	-	upper half	7.0 ^y	(7.3) [†]
1984	CBM ³	4.0-6.0	-	-	4.6 ^y	(4.8) [†]
1985	CBM ³	3.0-5.0	-	-	4.5 ^y	(4.6) [†]
1986	CBM ³	3.5-5.5	-	-	7.7 ⁿ	(6.4)
1987	CBM ³	3.0-6.0	-	-	8.0 ⁿ	(8.1)
1988	M3 ³	3.0-6.0	-	-	6.5 ⁿ	(6.2) [†]
1989	M3 ³	-	5.0	-	4.5 ⁿ	(5.6)
1990	M3 ³	4.0-6.0	-	-	5.2 ^y	(4.4) [†]
1991	M3 ³	3.0-5.0	-	-	18.2 ⁿ	(18.2)
1992	M3 ³	3.5-5.5	-	-	9.2 ⁿ	(7.9)
1993	M3 ³	4.5-6.5	-	-	-	(7.8)
1994	M3 ³	4.0-6.0	-	-	-	-

Sources: Deutsche Bundesbank, *Geschäftsbericht*, various issues, OECD *Country Surveys, Germany*, various issues, Neumann (1988) and own calculations using data of OECD *Main Economic Indicators*, various issues.

Notes: CBM is the central bank money stock, comprising of currency in circulation and required reserves on domestic liabilities, calculated at constant reserve ratios (base January 1974). M3 comprises cash holdings of non-banks, domestic non-bank sight deposits at banks, time deposits (up to 4 years maturity) and saving deposits (at statutory notice).

¹ December of preceding year to December of current year.

² Annual average.

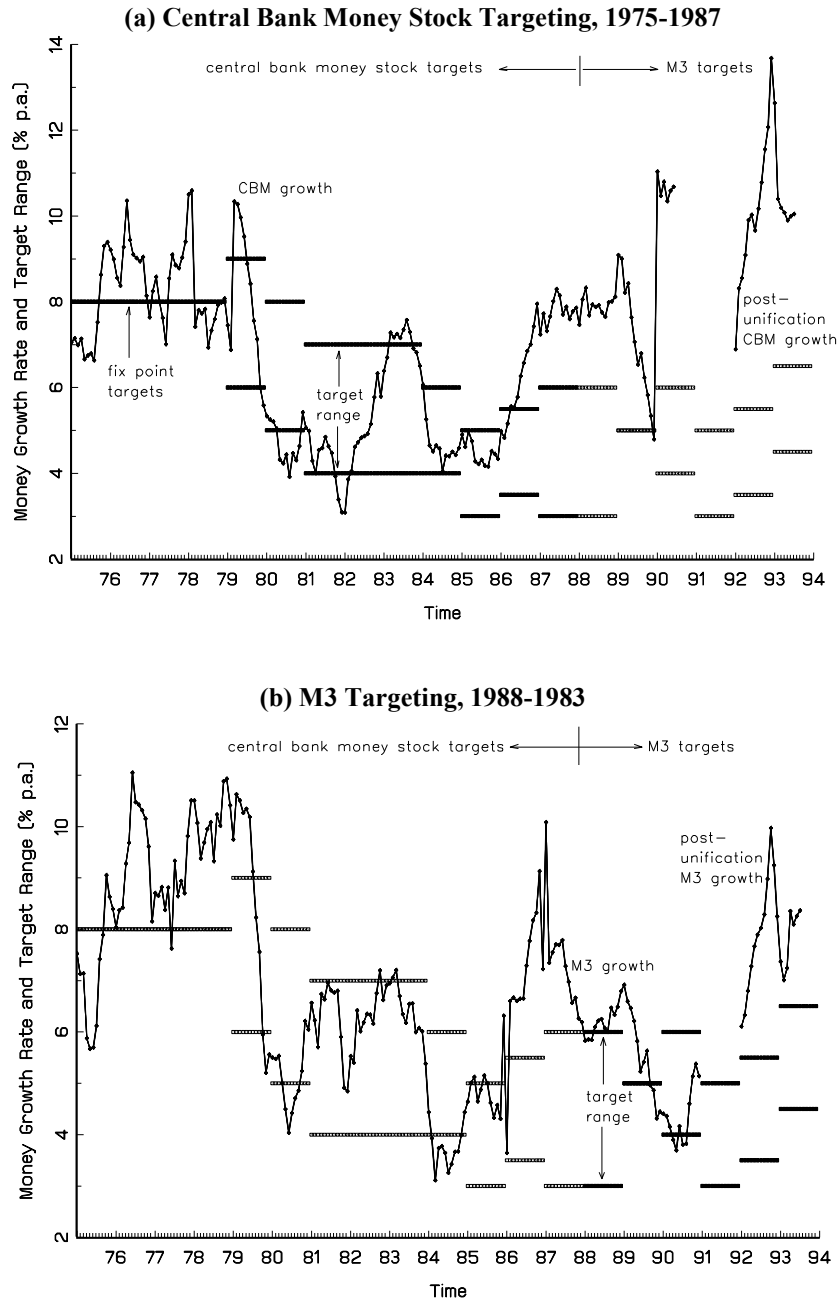
³ Fourth quarter of preceding year to fourth quarter of current year.

^y Actual target achieved (in terms of integer values).

ⁿ Actual target missed (in terms of integer values).

[†] Annual average of target achieved (in terms of integer values).

Figure 4.6.
Money Stock Targeting in Germany



exchange rate movements. Furthermore, the upper bound of the target range was lowered during 1979-85 from 9 to 5 percent as part of the Bundesbank's anti-inflation policy stance. In addition, to clearly indicate its policy intentions while adopting target ranges, the Bundesbank between 1979 and 1983 announced in mid-year where within the target range it would aim monetary growth.

As indicated in Table 4.1 and Figure 4.6 the Bundesbank was quite successful in achieving its monetary targets during the years 1979-85. To counteract the inflationary impact of the oil price shock the Bundesbank tightened monetary policy in 1979 and CBM growth came down within the target range in the second half of the year, and fluctuated around the lower bound of the target corridor in 1980 and 1981. CBM growth then moved to the upper bound of the range in 1982, stayed there during 1983 and lay well within the target range during 1984 and 1985. After two years of massive target overshooting in 1986 and 1987 the Bundesbank finally terminated MCB targeting in January 1988 and switched to announcing target ranges for the monetary aggregate M3. Panel (b) of Figure 4.6 indicates that prior to German economic and monetary unification in 1990, the new policy stance of M3 targeting was relatively successful. However, the massive M3 target overshooting in the aftermath of the unification shock during 1992 and 1993 suggests there are serious problems with respect to the Bundesbank's ability to regain monetary control.

France

With the election of Raymond Barre as prime minister in March 1976 and the adoption of the so-called 'Barre Plan', an orthodox deflationary stabilisation policy package, in September 1976, the Banque de France began setting formal monetary targets. In December 1976 a growth rate target for M2 without bands was first publicly announced. Between 1977 and 1981 the target for M2 growth was successively reduced as monetary policy became more stringent and relied increasingly on selective credit controls and credit ceilings in order to achieve the monetary targets. With the election of President Mitterand in May 1981 economic policies were geared towards a reduction of unemployment by expansionary fiscal policies. Monetary policy was relaxed in June 1981, the M2 growth targets (set by the previous government) were revised upwards, and credit ceilings were eased. During most of this time M2 growth rates were rising, but remained within the specified corridor. Reflation, the October 1981 devaluation of the Franc and the speculative pressure on the Franc in early 1982 led to a tightening of policy, with the reduction of inflation being restored as the main policy objective after the second Franc devaluation in June 1982. In addition, prices and wages were frozen from June until the end of October 1982 and the freeze was gradually phased out during 1983. After the third devaluation of the Franc in March 1983 there was a turnaround in French macro policy with the austerity program introduced under Prime Minister Mouroy shortly afterwards. Fiscal and monetary policy were severely tightened and strict foreign exchange controls were adopted. The monetary contraction of 1983-84 was mainly achieved by keeping interest rates so high that credit ceilings were not binding. During 1985-86 the credit ceiling system was then replaced by a system of progressive reserve requirements and increased reliance on open market operations rather than direct credit controls. At the same time, French monetary policy was primarily directed towards the exchange rate.⁹ Throughout the 1983-86 disinflation

Table 4.2.
French Announced Money Growth Targets and Realisations, Year on Year
(y.o.y.) and Annual Average (avg.) of Monthly Growth Rates (in % p.a.).

year	target	target range	outcome	
			y.o.y.	avg.
1977	M2 ¹	12.5	13.9 ^{n†}	(12.3)
1978	M2 ¹	12.0	12.2 ^y	(13.2)
1979	M2 ¹	11.0	14.4 ⁿ	(13.4)
1980	M2 ¹	11.0	9.8 ^{n†}	(11.6)
1981	M2 ¹	10.0-12.0	11.4 ^{y†}	(12.6)
1982	M2 ¹	12.5-13.5	11.5 ^{y†}	(12.3)
1983	M2 ²	9.0-10.0	10.2 ^{y†}	(10.2)
1984	M2R ²	5.5-6.5	7.6 ⁿ	(9.9)
1985	M2R ²	3.0-5.0	6.9 ⁿ	(8.7)
1986	M3 ²	4.0-6.0	4.2 ^{y†}	(5.3)
1987	M2 ²	4.0-6.0	4.2 ^y	(7.3)
	M3 ²	3.0-5.0	9.9 ⁿ	(9.0)
1988	M2 ²	4.0-6.0	4.0 ^y	(7.4)
1989	M2 ²	4.0-6.0	4.1 ^{y†}	(4.0)
1990	M2 ²	3.5-5.5	-0.5 ⁿ	(1.3)
1991	M3 ³	5.0-7.0	3.7 ^{n†}	(6.1)
1992	M3 ³	4.0-6.0	5.4 ^{n†}	(4.8)
1993	M3 ³	4.0-6.5	-	(3.9)
1994	M3 ³			

Sources: OECD Country Surveys, France, various issues, Wyplosz (1988b), and own calculations using data of IMF *International Financial Statistics*, various issues.

Notes: M2 is currency, demand deposits, savings deposits and all time deposits, certificates of deposits plus short-term non-negotiable financial instruments. M2R is that part of M2 which is held by residents. M3 is total liquidity.

¹ December of preceding year to December of current year.

² Quarter centred around December of preceding year to the same quarter of the current year.

³ Fourth quarter of preceding year to fourth quarter of current year.

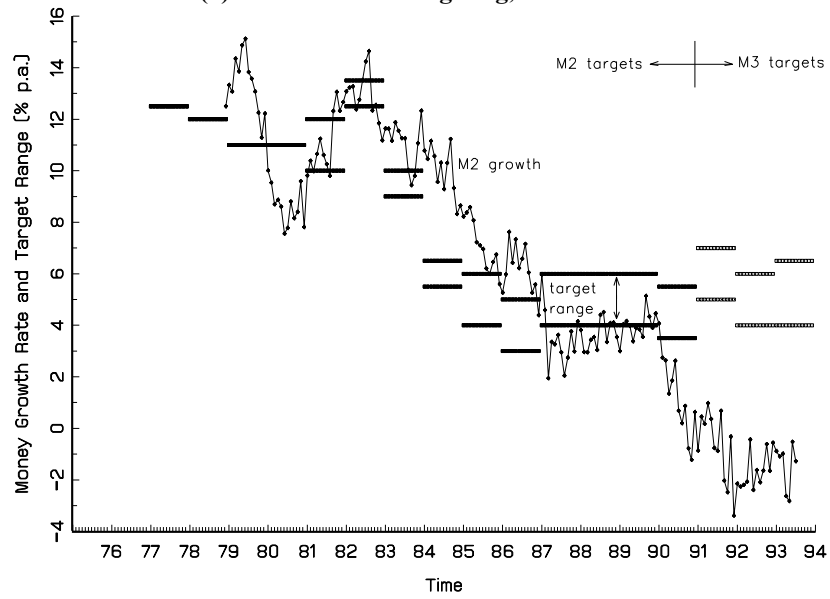
^y Actual target achieved (in terms of integer values).

ⁿ Actual target missed (in terms of integer values).

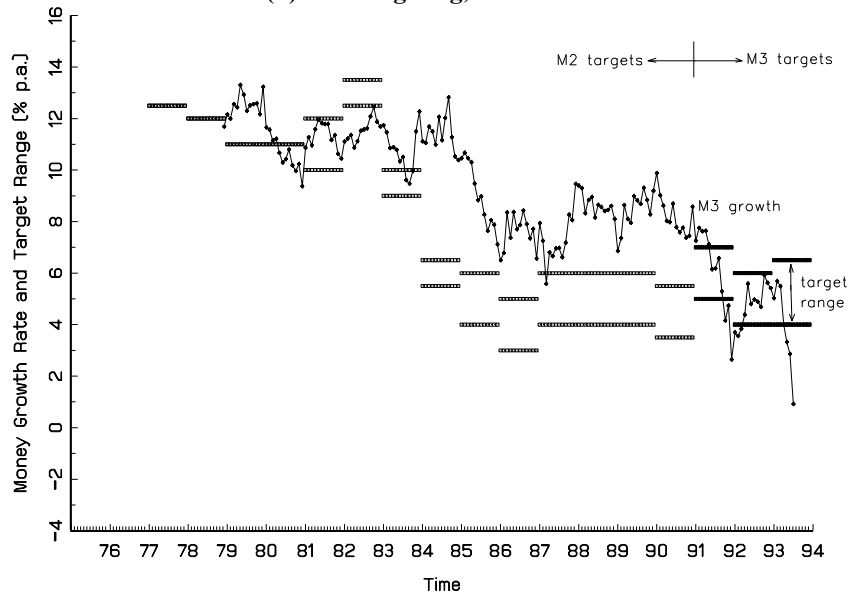
[†] Annual average of target achieved (in terms of integer values).

Figure 4.7.
Money Stock Targeting in France

(a) M2 and M2R Targeting, 1977-1990



(b) M3 Targeting, 1991-1993



period French money growth substantially overshoot the announced target ranges. After 1987 the removal of capital controls and the introduction of proportional reserve requirements on bank deposits appears to have substantially stabilised M2 growth, which fluctuated around the lower bound of the target range between 1987 and 1990, and fell substantially thereafter. This recent instability of M2 led to the adoption of M3 targets in France. Figure 4.7 shows that with the exception of the recent 1993 ERM crisis these M3 targets were implemented with relative success.

Italy

After having previously targeted the monetary base, the Banca d'Italia in 1974 decided to set a monetary objective in terms of a total domestic credit (TDC) ceiling. This decision to target credit aggregates was supplemented by recourse to a progressively more sophisticated system of direct credit controls and bank credit ceilings. Following the onset of the EMS in 1979, a system of compulsory reserves on deposits and a limit on the increase of financing in foreign exchange for imports were introduced. During the entire pre-EMS period the ceiling for total credit growth was consistently overshoot by substantial amounts. However, with a few exceptions total credit growth fell well below the ceilings during the EMS period, even though the Banca d'Italia until 1983 continued to frame its monetary policy mainly in the form of credit targets and interest rate objectives, and at the same time publicly rejecting a policy of strictly targeting some monetary aggregate. However, explicit monetary targets were adopted from 1984 onwards, when the Banca d'Italia started announcing growth targets for M2. Furthermore, the conduct of monetary policy was shifted more towards open market operations. Panel (b) of Figure 4.8 shows that the new policy of targeting M2 growth rates was implemented initially with some success, but after 1991 massive target overshooting occurred.

United Kingdom

In the United Kingdom monetary targets were used internally by the Bank of England from 1973 onwards, but were first announced publicly for the monetary aggregate M3 in the Budget of 1976 and for Sterling M3 (£M3) in the Budgets from 1977 onwards. For the 1974-1979 Labour Government these monetary targets were viewed as part of an anti-inflation programme which relied primarily on income policies. After the election of the Conservative Party under Margaret Thatcher in May 1979, the new government gave priority to controlling the growth of monetary aggregates as the centrepiece of its new economic policy. The March 1980 Budget established the so-called 'Medium Term Financial Strategy (MTFS)', an annually renewed five year forward-looking stabilisation plan aimed at gradually lowering inflation by limiting the growth of monetary aggregates and subordinating fiscal policy to the achievement of the monetary target. Under the Thatcher government financial markets were deregulated and foreign exchange as well as direct credit controls, the so-called "Corset", were abolished. Due to this deregulation £M3 growth consistently overshoot its target ranges during 1979-83. As a reaction the March 1982 Budget introduced a multiplicity of monetary growth targets by setting growth corridors for Sterling M3, M1 and Private Sector Liquidity (PSL2). In addition the importance of the exchange rate was explicitly mentioned. Despite these indications of a move to a more discretionary policy stance, £M3 grew closer to the upper bound of the target range

Table 4.3.
Italian Announced Money and Credit Growth Targets and Realisations, Year on Year (y.o.y.) and Annual Average (avg.) of Monthly Growth Rates (in % p.a.).

year	target	target level	outcome	target	target range	outcome
1975	TDC	17.9	13.6 ⁿ	-	-	-
1976	TDC	17.5	22.0 ⁿ	-	-	-
1977	TDC	15.1	16.8 ⁿ	-	-	-
1978	TDC	12.9	5.2 ⁿ	-	-	-
1979	TDC	18.4	17.1 ^y	-	-	-
1980	TDC	17.4	22.7 ⁿ	-	-	-
1981	TDC	16.0	17.2 ⁿ	-	-	-
1982	TDC	15.2	8.6 ^y	-	-	-
1983	TDC	18.3	15.5 ^y	-	-	-
1984	TDC	17.5	21.6 ⁿ	M2	11.0	11.7 ⁿ
1985	TDC	16.2	14.1 ^y	M2	10.0	13.1 ⁿ
1986	TDC	13.2	9.0 ^y	M2	7.0-11.0	8.6 ^y
1987	TDC	11.1	12.6 ⁿ	M2	6.0- 9.0	10.4 ⁿ
1988	TDC	9.4	12.2 ⁿ	M2	6.0- 9.0	7.7 ^y
1989	-	-	-	M2	6.0- 9.0	10.1 ⁿ
1990	-	-	-	M2	6.0- 9.0	9.2 ^y
1991	-	-	-	M2	5.0- 8.0	10.2 ⁿ
1992	-	-	-	M2	5.0- 7.0	13.5 ⁿ
1993	-	-	-	M2	5.0- 7.0	-
1994	-	-	-	M2	-	-

Sources: OECD *Country Surveys*, Italy, various issues, and own calculation using data of OECD *Main Economic Indicators*, and IMF *International Financial Statistics*, various issues.

Notes: TDC is total domestic credit, announced in terms of a ceiling, and consists of bank and special credit institution loans plus bonds issued by local authorities, public and private companies (net of loans consolidating debt of local authorities) less state sector borrowing requirement. M2 is currency in circulation plus demand and time deposits.

¹ Annual average of growth rate

² Data taken from OECD *Country Surveys*, Italy, various issues.

³ Calculated as annual average of monthly growth rates from OECD *Main Economic Indicators*, various issues.

^y Actual target achieved (in terms of integer values).

ⁿ Actual target missed (in terms of integer values).

Figure 4.8.
Money Stock and Credit Ceiling Targeting in Italy

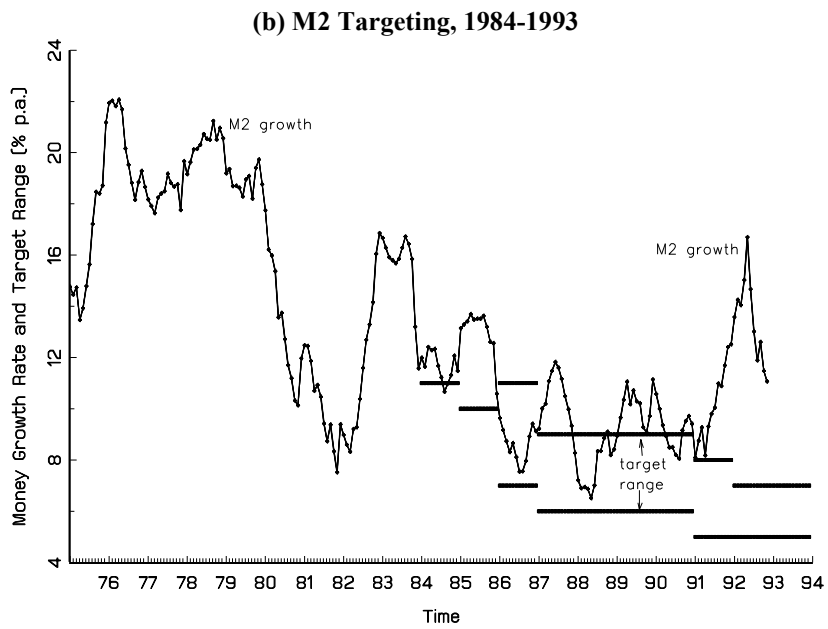
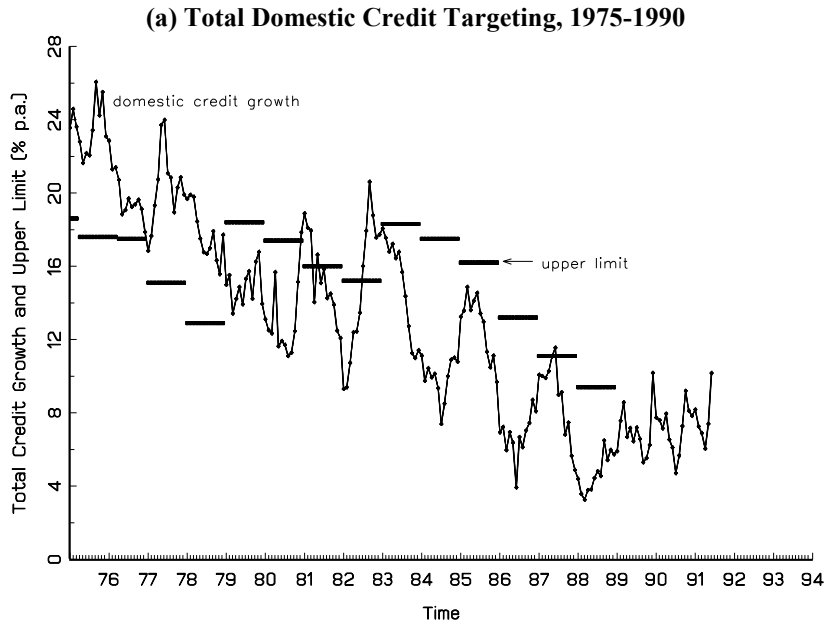


Table 4.4.
United Kingdom Announced Money Growth Target Projections and
Realisations, Annual Average (avg.) of Monthly Growth Rates (in % p.a.).

year	target	target range	outcome
1976	-	-	-
1977	-	-	-
1978	-	-	-
1979	M2+CD's	11.8-12.3	-
1980	M2+CD's	9.5-9.8	-
1981	M2+CD's	8.0-8.8	10.9 ⁿ
1982	M2+CD's	9.5-9.5	10.1 ^y
1983	M2+CD's	7.0-7.5	8.6 ⁿ
1984	M2+CD's	7.8-7.8	9.3 ⁿ
1985	M2+CD's	8.0-8.0	9.2 ⁿ
1986	M2+CD's	8.5-8.5	8.8 ^y
1987	M2+CD's	9.5-9.5	10.1 ^y
1988	M2+CD's	11.0-11.5	11.6 ^y
1989	M2+CD's	10.0-11.0	11.2 ^y
1990	M2+CD's	11.0-11.0	13.4 ⁿ
1991	M2+CD's	4.3-4.3	3.1 ⁿ
1992	M2+CD's	1.3-1.3	-0.7 ⁿ
1993	M2+CD's		
1994	M2+CD's		

Sources: OECD *Country Surveys, United Kingdom*, various issues, Fischer (1988) and own calculations using data of OECD *Main Economic Indicators*, various issues, and IMF *International Financial Statistics*, various issues.

Notes: M3 is currency plus private sector demand and time deposits. M3 is currency plus private sector sterling demand and time deposits. M1 is currency plus private sector demand deposits. M0 is notes and coins in circulation and in banks, and bank's operational balances with the Bank of England.

¹ Annual average of growth rate during the financial year, that April of preceding year to March of the current year.

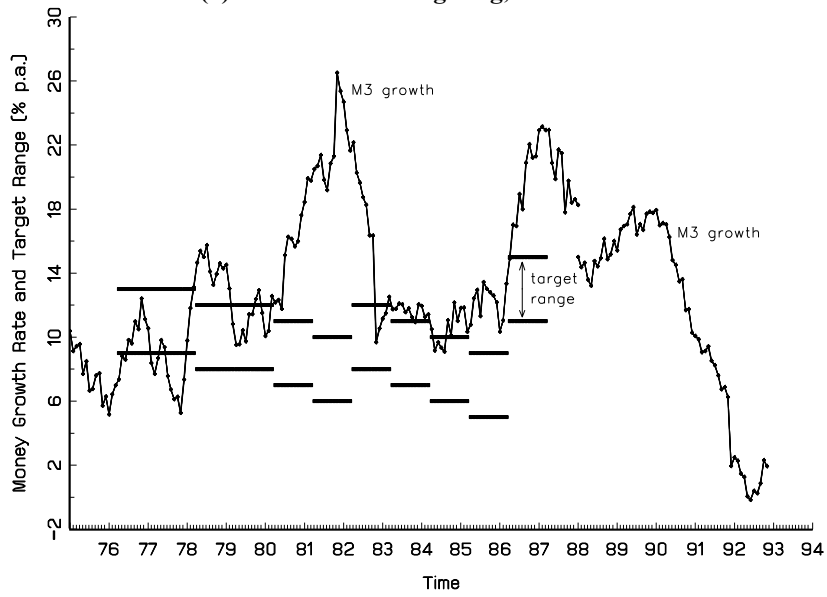
² Calculated as average of monthly growth rates of the financial year using data of IMF *International Financial Statistics*, various issues.

^y Actual target achieved (in terms of integer values).

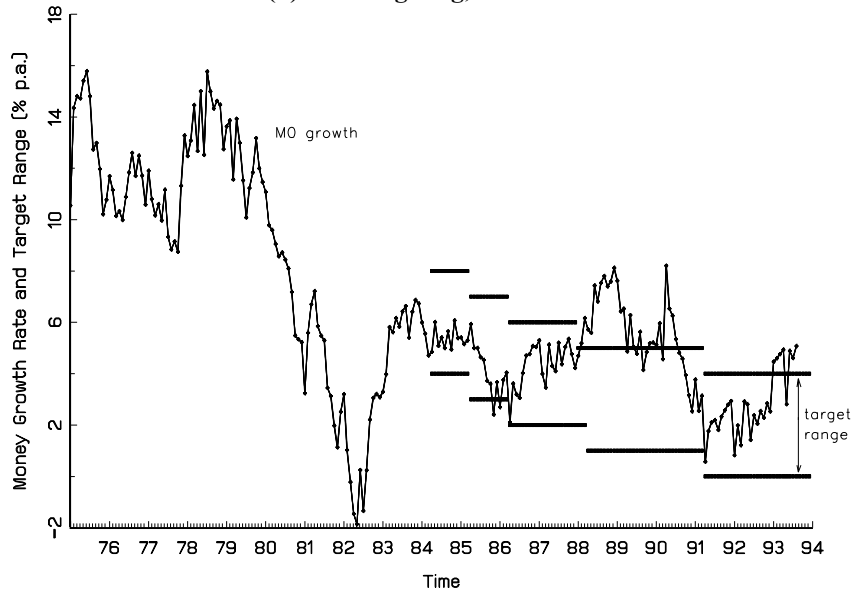
ⁿ Actual target missed (in terms of integer values).

Figure 4.9.
Money Stock Targeting in the United Kingdom

(a) M3 and £M3 Targeting, 1976-1986



(b) M0 Targeting, 1994-1993



than it had been at any time during the previous years of strict monetary targeting. After the March 1984 Budget, target ranges for both Sterling M3 and M0 were announced and the Sterling M3 target was finally abolished in March 1987 because of renewed massive target overshooting. After 1987 the Bank of England moved to announcing target ranges for M0 as the main monetary aggregate. On average, the M0 target has been implemented with considerable success in recent years, as panel (b) of Figure 4.9 indicates.

The United States.

During 1975 to 1977 the growth rates of M1 were slightly below or within the target range, whilst M2 and M3 consistently overshoot their respective targets. Subsequently the implementation of monetary policy underwent three changes. The first, albeit minor, change resulted from the Humphrey-Hawkins Act of 1978, which required the Fed to establish calendar year growth targets to prevent the phenomenon of infra-year 'base drift'. Secondly, on October 6, 1979, the Fed announced its intention to adopt a more monetarist policy stance with strict adherence to M1 targets (and the abandonment of interest rate targets) in order to reduce the inflation rate. Three years later, on October 5, 1982, this strict monetarist policy was officially changed and the Fed decided to 'de-emphasise' M1 in favour of the broader aggregates, M2 and M3, but the commitment to low inflation was re-iterated. During the 1978-83 period M1 grew consistently above the announced target range, whilst M2 and M3 lay mostly within the announced corridors, as shown in Figure 4.10. After 1983 M1 growth remained erratic and until its abolition in 1987 mostly overshoot its targets by substantial proportions. M2 and M3 growth rates, on the other side, lie mostly within their target ranges in recent years, indicating relatively successful monetary targeting.

Japan

In early 1975 the Bank of Japan abandoned most of its discretionary, activist policies adopted after the collapse of the Bretton Woods system and the oil price shock in 1973, and moved to a new policy stance with monetary targeting. A broad money, (M2+CD's) was chosen as the intermediate target for monetary policy. Moreover, price stability was adopted as the first policy priority. In its management of the money supply, the Bank of Japan's main operating targets were the inter-bank interest rates (call and bill rates), and monetary control was implemented by manipulating the discount rate and reserve ratios. The Bank of Japan also used open market operations, occasionally supplemented by the use of 'window guidance', that is, direct controls of bank lending to the private non-bank sector. Even though the Bank of Japan has a monetary target, which is set for the period of a year, not the monetary target itself but 'forecasts' of the targeted aggregate M2(+CD's) are announced to the public.¹⁰ The publication of these money growth projections is announced quarterly, and concerns the percentage increase of the average money stock over the same quarter of the previous year. In May 1979 banks were permitted to issue negotiable certificates of deposits (CDs) and secondary trading in these instruments started in April 1982. The CD component in Japan is under quantitative restrictions and relatively small.

Table 4.5.
American Announced Money Growth Targets and Realisations, Average Annual Growth Rates for the Fourth Quarter of the Year (in % p.a.).

year	tar- get	target range	out- come	tar- get	target range	out- come	tar- get	target range	out- come
1975	M1	5.0-7.5	4.9 ^y	M2	8.5-10.5	11.4 ⁿ	M3	10.0-12.0	8.9 ^y
1976	M1	4.5-7.0	6.0 ^y	M2	7.5-10.0	12.5 ⁿ	M3	9.0-12.0	10.8 ^y
1977	M1	4.5-6.5	7.8 ⁿ	M2	7.0-9.5	10.6 ⁿ	M3	8.5-11.5	11.8 ^y
1978	M1	4.0-6.5	7.9 ⁿ	M2	6.5-9.0	7.7 ^y	M3	7.5-11.5	11.1 ^y
1979	M1	3.0-6.0	7.6 ⁿ	M2	5.0-8.0	7.9 ^y	M3	6.0-9.0	9.9 ⁿ
1980	M1	4.0-6.5	7.0 ^y	M2	6.0-9.0	8.6 ^y	M3	6.5-9.5	9.1
1981	M1	6.0-8.5	5.0 ⁿ	M2	6.0-9.0	8.8 ^y	M3	6.5-9.5	11.6 ⁿ
1982	M1	2.5-5.5	8.3 ⁿ	M2	6.0-9.0	8.7 ^y	M3	6.5-9.5	9.4 ^y
1983	M1	4.0-8.0	9.7 ⁿ	M2	7.0-10.0	11.4 ⁿ	M3	6.5-9.5	9.3 ^y
1984	M1	4.0-8.0	5.2 ^y	M2	6.0-9.0	7.6 ^y	M3	6.0-9.0	10.2 ⁿ
1985	M1	4.0-7.0	11.4 ⁿ	M2	6.0-9.0	8.4 ^y	M3	6.0-9.5	7.4 ^y
1986	M1	3.0-8.00	14.2 ⁿ	M2	6.0-9.0	8.6 ^y	M3	6.0-9.0	8.5 ^y
1987	-	-	-	M2	5.5-8.5	4.5 ⁿ	M3	5.5-8.5	5.7 ^y
1988	-	-	-	M2	4.0-8.0	5.5 ^y	M3	4.0-8.0	6.3 ^y
1989	-	-	-	M2	3.0-7.0	4.7 ^y	M3	3.5-7.5	3.6 ^y
1990	-	-	-	M2	3.0-7.0	3.7 ^y	M3	2.5-6.5	1.7 ^y
1991	-	-	-	M2	2.5-6.6	2.7 ^y	M3	1.0-5.0	1.0 ^y
1992	-	-	-	M2	2.5-6.5	1.7 ^y	M3	1.0- 5.0	0.2 ⁿ
1993	-	-	-	M2	1.0-5.0	0.4 ^y	M3	1.0- 5.0	-0.8 ⁿ
1994	-	-	-	M2			M3		

Sources: OECD *Country Surveys, United States*, various issues, Fischer (1988) and own calculations using data of IMF *International Financial Statistics*, various issues.

Notes: M1 is currency plus private sector demand deposits, M2 is M1 plus time deposits. M3 is M2 plus savings demand. National money stock definitions were used.

¹ Calculated as average of monthly growth rates of the last quarter of each year relative to the same quarter of the previous year using data of IMF *International Financial Statistics*, various issues.

^y Actual target achieved (in terms of integer values).

ⁿ Actual target missed (in terms of integer values).

Table 4.6.
Japanese Announced Money Growth Target Projections and Realisations,
Annual Average (avg.) of Monthly Growth Rates (in % p.a.).

year	target	target range	outcome
1976	-	-	-
1977	-	-	-
1978	-	-	-
1979	M2+CD's	11.8-12.3	-
1980	M2+CD's	9.5-9.8	-
1981	M2+CD's	8.0-8.8	10.9 ⁿ
1982	M2+CD's	9.5-9.5	10.1 ^y
1983	M2+CD's	7.0-7.5	8.6 ⁿ
1984	M2+CD's	7.8-7.8	9.3 ⁿ
1985	M2+CD's	8.0-8.0	9.2 ⁿ
1986	M2+CD's	8.5-8.5	8.8 ^y
1987	M2+CD's	9.5-9.5	10.1 ^y
1988	M2+CD's	11.0-11.5	11.6 ^y
1989	M2+CD's	10.0-11.0	11.2 ^y
1990	M2+CD's	11.0-11.0	13.4 ⁿ
1991	M2+CD's	4.3-4.3	3.1 ⁿ
1992	M2+CD's	1.3-1.3	-0.7 ⁿ
1993	M2+CD's		
1994	M2+CD's		

Sources: OECD *Country Surveys, Japan*, various issues, Fischer (1988) and own calculations using data of IMF *International Financial Statistics*, various issues.

Notes: M2 is currency plus private sector demand and time deposits, CD's are certificates of deposit.

¹ Calculated as annual average of monthly growth rates using data of IMF *International Financial Statistics*, various issues.

^y Actual target achieved (in terms of integer values).

ⁿ Actual target missed (in terms of integer values).

Figure 4.10.
Money Stock Targeting in the United States

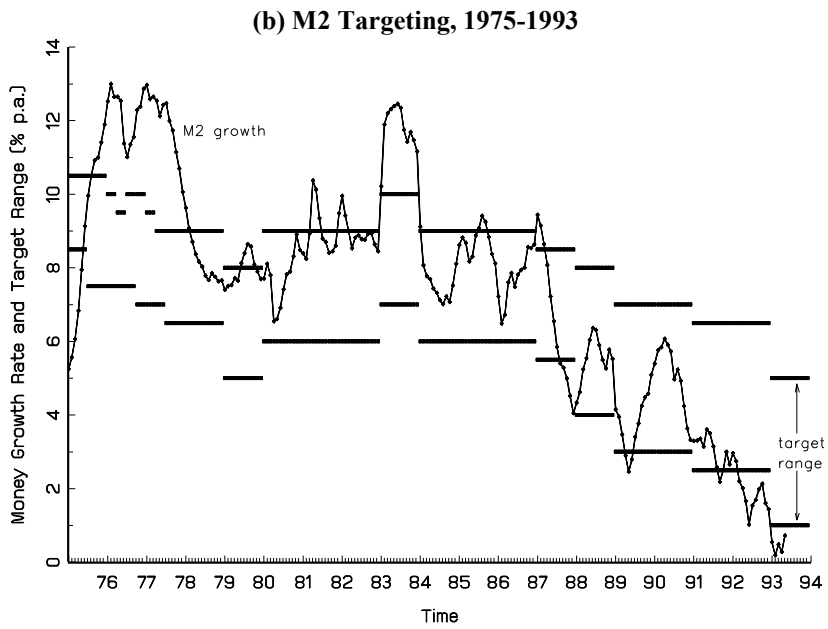
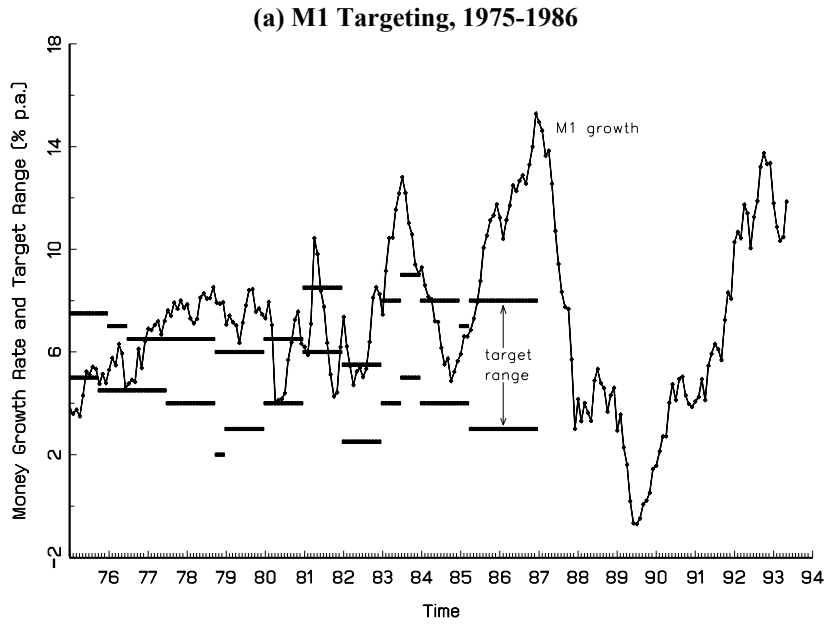
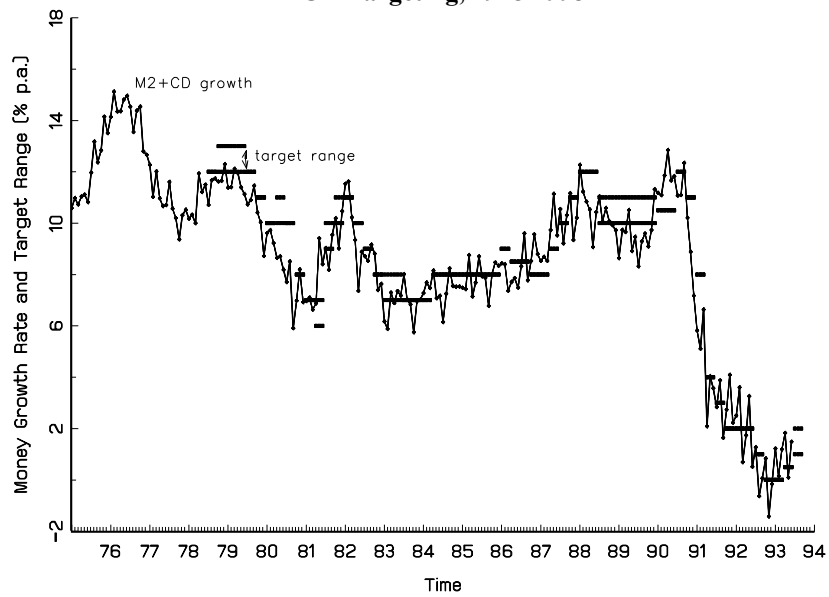


Figure 4.10 continued

(c) M3 Targeting, 1975-1993



Figure 4.11.
Money Stock Targeting in Japan:
M2+CD Targeting, 1978-1993



During 1978 Japanese monetary policy was eased as the yen appreciated relative to the U.S. dollar. As inflationary pressure re-emerged in the wake of the depreciation of the yen and the marked increase in oil and other international commodity prices during the first half of 1979, monetary policy was tightened. Money growth rates started falling after mid 1979 and declined drastically during 1980, leading to a quicker disinflation with much less extra unemployment in Japan relative to other OECD countries. Once inflation was under control, the Bank of Japan eased its restrictive course in early 1981 with severe cuts in the discount rate, a reduction of compulsory reserve requirements and an easing of 'window guidance' ceilings on bank lending. Money growth accelerated in 1981, but declined again during 1982 and 1983, when monetary policy was dominated by the authorities' objective not to weaken the yen. Between early 1984 and late 1986 M2+CD's growth rates fluctuated around 8 percent and accelerated again during 1987-1990. During 1990 money growth rates dropped sharply from about 10 to only 3 percent, and recently have fluctuated around zero. During this recent period attempts to stabilise the strong yen together with the concern about inflation, have progressively influenced the conduct of Japanese monetary policy. Figure 4.11 shows that throughout the entire sample period, the Japanese quarterly announcements of the target range for M2+CD's growth rates have been pretty accurate, and have tracked actual growth rates much more closely than announcements in any of the other G7-countries.

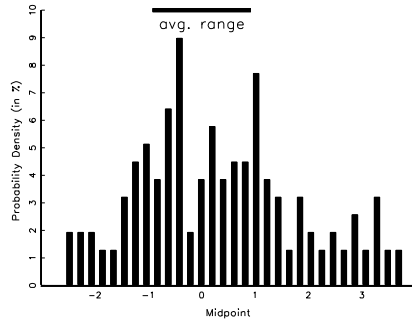
The above non-formal evidence about the credibility of monetary target announcements can easily be supplemented by some more structured evidence derived from the probability distributions of money growth rates relative to the average target ranges. This is depicted in Figure 4.12 for the three EMS countries, and in Figure 4.13 for the remaining three non-ERM countries. The evidence clearly indicated that money growth rates distributions are typically uni-modal, but the actual money growth rates frequently lie outside the announced target ranges, both with the midpoint and the peak of the distributions. This suggests that money growth target announcements have lacked credibility in most countries.

4.2.1.2. Estimates of the Credibility of Monetary Target Announcements

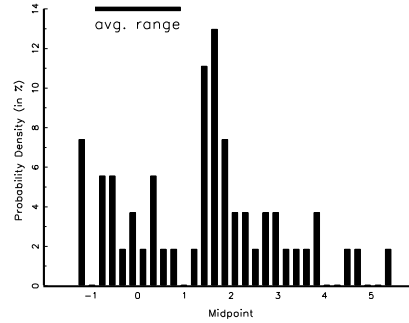
For any measure of the credibility of money growth announcements to make sense, the above general descriptive evidence should somehow be captured by the estimates. In the present study this a measure for the credibility of such monetary target announcements is derived by regressing the actual money growth rate m_t on announced money growth rates m_t^a and on the optimal prediction of money growth rates based on past information m_{t-1}^* , as described in chapter 3. According to theory, the coefficients on m_t^a and m_{t-1}^* should add to unity. In Weber (1990a) the adequacy of this coefficient restriction is tested formally by likelihood ratio tests and not rejected at the 5 percent level for a single case. As in Weber (1990a), the updated estimates reported below are thus based on the restricted model by regressing $m_t - m_{t-1}^*$ on a constant and the announcement bias $m_t^a - m_{t-1}^*$, which yields the desired marginal credibility estimate (MC) as the coefficient of the announcement bias in this regression.

Figure 4.12.
Probability Distributions of Money Growth Rates Within and Outside
Announced Target Ranges, ERM Countries

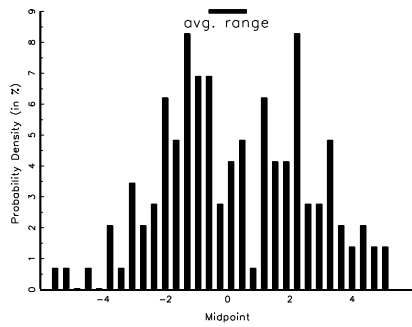
(a) German CBM Target, 1975-87



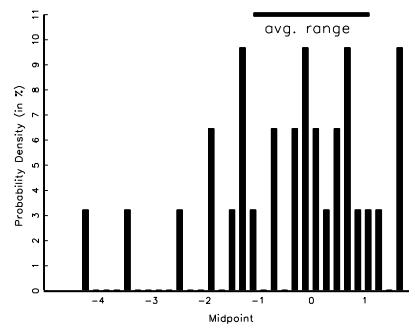
(b) German M3Target, 1988-93



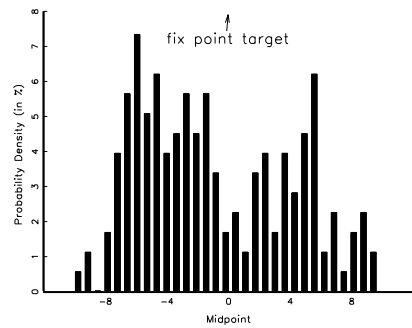
(c) French M2/M2R Target, 1979-90



(d) French M3Target, 1991-93



(e) Italian TDC Target, 1975-88



(f) Italian M2Target, 1984-93

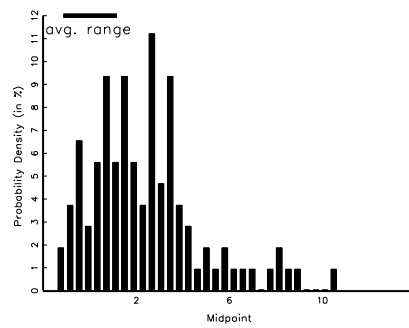
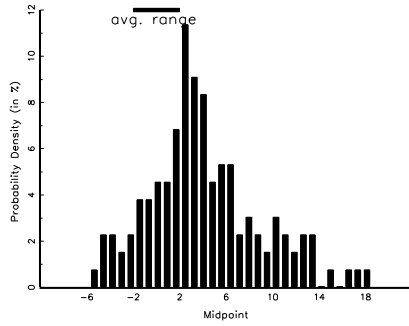
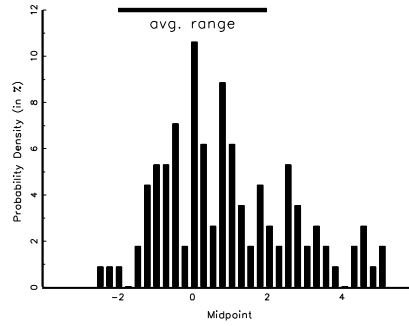


Figure 4.13.
Probability Distributions of Money Growth Within and Outside
Announced Target Ranges, Non-ERM Countries

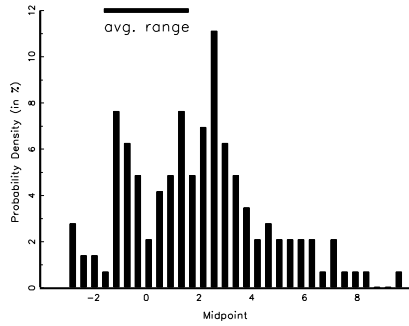
(a) British £M3 Target, 1976-87



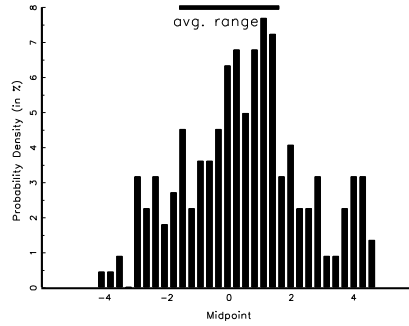
(b) British M0 Target, 1984-93



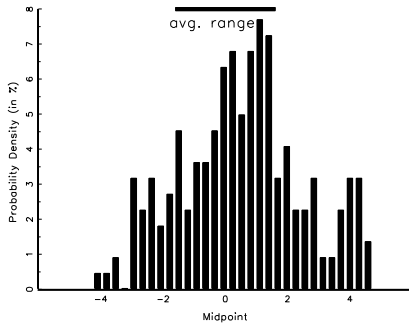
(c) American M1 Target, 1975-86



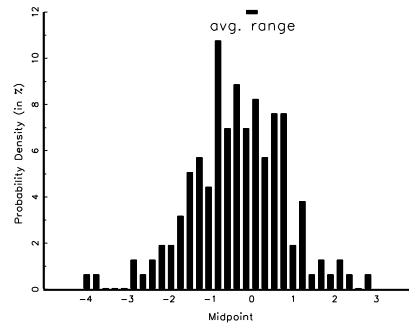
(d) American M2 Target, 1975-93



(e) American M3 Target, 1975-93



(f) Japanese M2CD Target, 1977-93



4.2.1.2.1. Period Averages of the Credibility Measures

Table 4.7 presents the estimates for the G7 countries except Canada, which is not considered owing to its short sample period. Not surprising, the credibility of monetary announcements is highest for Japan in the overall period (0.49), and in the various EMS sub-periods (0.47, 0.51, 0.55), with all estimates being statistically significant at least at the 5 percent level. Japan is also the only country which has recently issued 'credible' money growth announcements in the sense of a MC credibility measure being above 50 percent, which implies that in forming money growth expectations a higher weight is placed on the current central bank announcement than on extrapolations of past money growth. The credibility of money growth target announcements in the remaining countries is by comparison relatively low. For most countries significant MC credibility estimates are found in the overall period and in the various sub-periods, but these estimates frequently lie below 10 percent. Given the various target switches and the volatile history of monetary targeting described above, this is hardly surprising.

It is instructive to analyse the credibility estimates in more detail. For Germany, CBM growth announcements were initially relatively credible ($MC=0.33$), but this credibility declined steadily during the EMS period. The switch to M3 target announcements is found so far to have failed to re-establish the credibility of the Bundesbank's monetary targeting. France, Italy and the United Kingdom, on the other hand, never really succeeded in commanding credibility for their monetary or credit targeting policies, even though the credibility of M0 targeting has recently risen considerably in the United Kingdom (to $MC=0.21$). Finally, the United States is found to have had severe problems in establishing credible monetary targets initially, but the move to strict monetary targeting during 1979-1982 succeeded in overcoming this credibility gap to some extent, as reflected by a rise of the MC estimates for M1 and M2 to 0.31 and 0.35 respectively. Interestingly, the credibility of M2 targeting during this period exceeded that for the M1 target, which was the prime policy objective. This finding is consistent with the fact that M1 was subsequently de-emphasised and the Federal Reserve switched to M2 as its prime monetary target. In the post-1982 period the credibility of monetary targeting declines again, but not as strongly for M2 as for M1 or M3.

To summarise, the evidence reported in Table 4.7 is mostly in line with the descriptive evidence about the experience with monetary target announcements reported above. This suggests that the credibility measure proposed here is able to capture features of the data and thus to provide a tool for formally evaluating the credibility of monetary policy commitments.

An important drawback of any econometric policy evaluation is that the structure of the econometric model may change as policies change over time, as pointed out by Lucas (1976) in his famous 'Lucas critique'. In order to check the relevance of this proposition in the present context, Table 4.8 reports the results of a search for structural breaks in the estimated equation by using the switching regression techniques developed in Goldfeld and Quandt (1973a,b, 1976). Switching regression estimation looks for the most likely point in time at which a break in the estimated relation occurs by estimating the relationship separately over the overall period and over any two sub-periods determined by every possible break-point. A

Table 4.7.
Regression Estimates for the Credibility of Money Growth Target Announcements, MC Credibility Measure (maximum sample: Jan. 1975-July 1993)

Country	Mo- ney	Max. Sample Beginn/Ende	Overall Period	Snake Period	EMS Period	Early EMS	Interm. EMS λ	Late EMS
Germany	CBM	Jan. 1975	0.112	0.329	0.069	0.147	0.036	
		Dec. 1987	(0.030)	(0.085)	(0.029)	(0.067)	(0.033)	
	M3	Jan. 1988	0.038		0.038			1.046
		July 1993	(0.057)		(0.057)			(0.091)
France	M2	Jan. 1979	0.098		0.098	0.181	0.113	
		Dec. 1990	(0.032)		(0.032)	(0.065)	(0.041)	
	M3	Jan. 1991	0.073		0.073			0.073
		July 1993	(0.012)		(0.012)			(0.012)
Italy	TDC	Jan. 1975	0.042	0.142	0.113	0.173	0.132	
		Dec. 1988	(0.023)	(0.076)	(0.044)	(0.081)	(0.055)	
	M2	Jan. 1984	0.061		0.061		0.094	0.064
		July 1993	(0.029)		(0.029)		(0.047)	(0.053)
U.K.	£M3	Apr. 1976	0.080	0.163	0.101	0.094	0.139	
		Mar. 1987	(0.024)	(0.053)	(0.031)	(0.042)	(0.064)	
	M0	Apr. 1984	0.118		0.118		0.094	0.205
		Oct. 1992	(0.048)		(0.048)		(0.048)	(0.123)
U.S.A.	M1	Jan. 1975	0.114	0.095	0.135	0.311	0.056	
		Dec. 1986	(0.025)	(0.040)	(0.003)	(0.061)	(0.034)	
	M2	Jan. 1975	0.087	0.062	0.118	0.350	0.143	0.138
		June 1987	(0.015)	(0.021)	(0.021)	(0.066)	(0.026)	(0.048)
	M3	Jan. 1975	0.042	0.027	0.049	0.167	0.090	0.018
		June 1993	(0.011)	(0.017)	(0.014)	(0.049)	(0.021)	(0.056)
Japan	M2	June 1980	0.493		0.049	0.466	0.510	0.550
		CD's	June 1993	(0.090)		(0.090)	(0.156)	(0.120)

Notes: The marginal credibility measures for the overall period and the four sub-periods (start-Feb.1979, Mar.1979-Feb.1983, Mar.1983-Dec.1989, Jan.1990-end) are obtained as the coefficients estimates from the ordinary least-squares regression $(m_t - m_{t,t-1}^*) = c + (m_t^a - m_{t,t-1}^*) + v_t$, $v_t \sim N(0, \sigma_v^2)$ with m_t and m_t^a as actual and announced money growth rates and $m_{t,t-1}^*$ as the optimal multi-process Kalman filter prediction of money growth based on a ARIMA(0,2,2) time series model. Refer to Chapter 3 for details of the estimates. The numbers in parenthesis below the credibility estimates are t-values (5 percent significance level). Estimates above 0.5 indicate credible announcements. For details of these tests see Weber (1990a, 1991a).

Table 4.8.
Switching Regression Estimates of the Credibility of Money Growth Target
Announcements (maximum sample: Jan. 1975-July 1993)

Country	Mo- ney	break- point	MC _T t(MC _T)	MC ₁ t(MC ₁)	MC ₂ t(MC ₂)	Chow F -2lnλ	CSF CSB	H _{n,m} H _{1,t-k}
Germany	CBM	Nov.	0.112 (3.716)	0.323 (3.883)	0.046 (2.177)	8.637*** 27.90***	0.663*** 0.235***	4.745*** 0.065
France	M2	Jan.	0.098 (3.052)	0.129 (3.794)	0.411 (2.134)	6.324*** 5.966*	0.843 0.075	1.160 0.001
Italy	TDC	Aug.	0.042 (1.788)	0.070 (1.878)	0.123 (2.891)	4.086*** 7.783***	0.674* 0.278***	1.969*** 0.193
	M2	Apr.	0.061 (2.151)	0.121 (2.741)	0.204 (2.227)	5.349*** 7.086**	0.631*** 0.275	2.086** 21.36***
U.K.	£M3	Jan.	0.080 (3.329)	0.185 (3.680)	0.113 (3.437)	6.391*** 6.463**	0.245 0.664	1.401* 0.142
	M0	July	10.11 (2.434)	0.513 (3.119)	0.168 (2.610)	3.598** 5.828*	0.128 0.810	1.959*** 1.328
U.S.A.	M1	Jan.	0.114 (4.565)	0.087 (2.427)	0.133 (3.833)	1.156 9.831***	0.194*** 0.790***	2.933*** 0.151
	M2	Jan.	0.087 (5.785)	0.124 (5.843)	0.166 (5.087)	10.99*** 11.55***	0.657 0.251	1.373* 0.256
	M3	Sep.	0.042 (3.706)	0.020 (1.240)	0.054 (3.661)	1.151 5.137*	0.161 0.829	1.738* 0.220
Japan	M2	Sep.	0.493 (5.463)	0.427 (4.781)	0.754 (2.754)	1.073 5.490*	0.615*** 0.371***	2.300*** 0.101
	CD's	1990						

Notes: The marginal credibility measures for the overall period (MC_T) and the two sub-periods (MC₁, MC₂) are obtained as the coefficients estimates from the ordinary least-squares regression $(m_t - m_{t,t-1}^*) = c + (m_t^a - m_{t,t-1}^*) + v_t$, $v_t \sim N(0, \sigma_v^2)$ with m_t and m_t^a as actual and announced money growth rates and $m_{t,t-1}^*$ as the optimal multi-process Kalman filter prediction of money growth based on a ARIMA(0,2,2) time series model. Refer to Chapter 3 for details of the estimates. The numbers in parenthesis below the credibility estimates are t-values (5 percent significance level). Estimates above 0.5 indicate credible announcements. The timing of the most likely point of structural break is estimated by switching regression and judged on the basis of the likelihood-ratio test statistic (-2lnλ) of Quandt (1960). A significant structural break is assumed when the majority of six parametric stability tests point towards instability. These stability tests are given by the Chow (1960) F-test, the likelihood-ratio test -2lnλ of Quandt (1960), the forward and backward CUSUM-of-squares tests CSF and CSB of Brown, Durbin and Evans (1975), the test for heteroscedasticity H_{n,m} of Goldfeld and Quandt (1965) and a heteroscedasticity test H_{1,t-k} based on a regression of the squared residuals from the above equation on the squared fitted values. For details of these tests Weber (1990a).

likelihood ratio test procedure then identifies the point in time at which the three estimated money growth equations differ most from one another. These points in time are indicated in Table 4.8, together with the estimated MC credibility measures and a number of stability test statistics.¹¹

The main result from Table 4.8 is that highly significant structural breaks, as indicated by the majority of stability tests, are found for Germany (CBM), Italy (TDC, M0), the United States (M1) and Japan (M2+CD's). It is therefore instructive to consider evidence for the G3 countries in more detail.

4.2.1.2.2. Time Paths of the Credibility Measures

The detailed analysis in this section will focus on the G3-countries, Germany, the United States and Japan. All three countries have experienced significant breaks in the credibility of their commitment to monetary targeting. Also, all three countries managed to command some degree of credibility for their monetary targets during the 1980's and 1990's, but whilst Japan has managed to preserve and even increase the credibility of its monetary target announcements, credible target announcements are no longer part of the monetary policy stance in Germany or the United States.

Germany

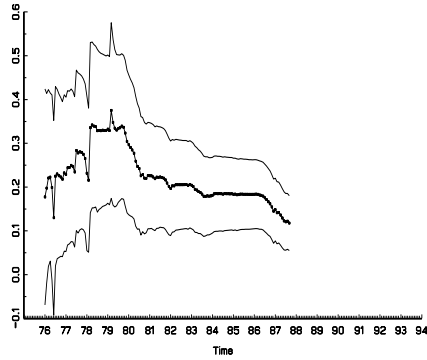
Table 4.8 indicates that a change in the Bundesbank's commitment to monetary target announcements occurred in November 1979, when monetary policy was tightened considerably in order to counteract the inflationary impact of the oil price shock. This structural break is indicated by both the likelihood ratio test in panel (d) and the Chow test in panel (c) of Figure 4.14. In panels (e) and (f) of Figure 4.14 the two Cusum-of-Squares tests also both cross the 10, 5 and 1 percent significance lines, indicating significant structural instability around the year 1979. The heteroscedasticity test $H_{n,m}$ in Table 4.8 furthermore points towards a significant change in the residual variance of the equation. Thus, the majority of parametric stability tests identifies 1979, the year of the onset of the EMS and the second round of oil price shocks, as the year in which the German monetary policy stance underwent major significant changes.

What happened to the credibility of monetary targeting? Panel (a) reports the recursive estimates of the MC credibility measure (and its standard error band) when the sample size is increased period by period, holding fixed the start of the sample. For samples prior to 1979 the MC estimate increases and reaches its peak of $MC=0.33$ in March 1979. The credibility of monetary target announcements then decline after the onset of the EMS, in particular from 1979 to 1981, when CBM growth fluctuated around the lower bound of the target corridor. During the EMS disinflation the MC credibility measure stabilised at a lower level, as CBM growth for most of the time stayed within the target range. The MC credibility estimate then declined again during 1986 and 1987, when the Bundesbank, on account of two years of massive target overshooting, finally terminated CBM targeting.

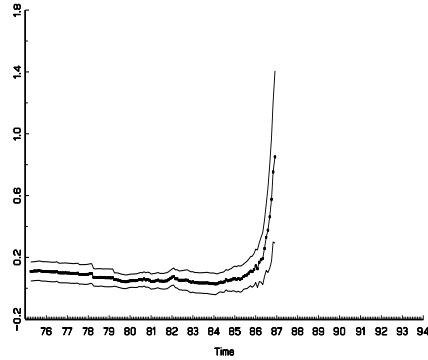
The low estimate of the credibility of the Bundesbank's CBM target announcements is consistent with Trehan's (1988) finding that the Bundesbank's concern over inflation has not bound it to strict adherence to monetary targets, since targets have been missed frequently, and that the Bundesbank has thus retained a

Figure 4.14.
Switching Regression Estimates of the Credibility of German Central Bank
Money Stock Growth Target Announcements (Jan. 1975-Dec. 1987)

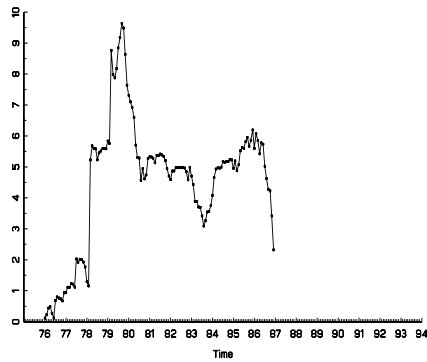
(a) MC Forward Estimate



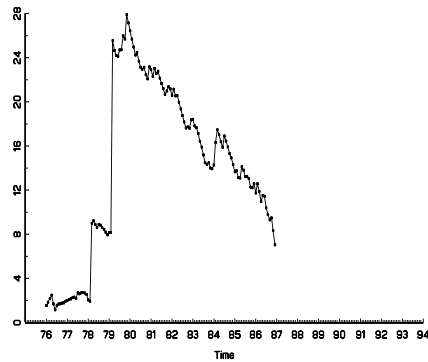
(b) MC Backward Estimate



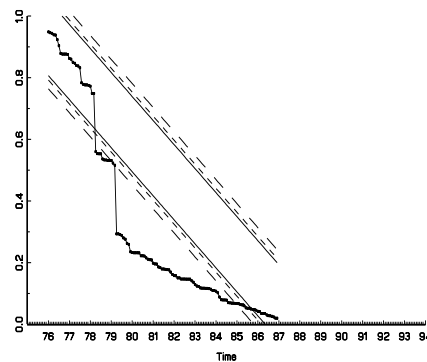
(c) Chow F-Test



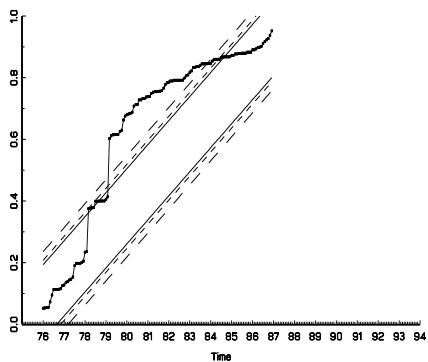
(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test



considerable level of discretion in the implementation of monetary targeting. Furthermore, the credibility of monetary target announcements discussed here has to be distinguished from the credibility of the Bundesbank's anti-inflation policy stance. The credibility of this anti-inflation commitment is indisputable for most of the pre-unification period, as has been demonstrated in Weber (1990a, 1991a) and in the section 4.1 above. Two possible explanations for the low credibility estimate found have been proposed in the literature: Fischer (1988) suggests that the lack of credibility could perhaps be due to the fact that the Bundesbank had tolerated too high an inflation in the late seventies. This argument is not supported by the above analysis of counterinflation reputation. Secondly, the fact that the periods of major target misses and subsequent credibility losses are connected to undesired exchange rate developments (1978, 1986-1987) is consistent with the view of Gleske (1987), who fears that increasingly exchange rate considerations have been given too much weight in the formulation and implementation of German monetary policy. The decline of the credibility during the entire EMS period strongly supports this view.

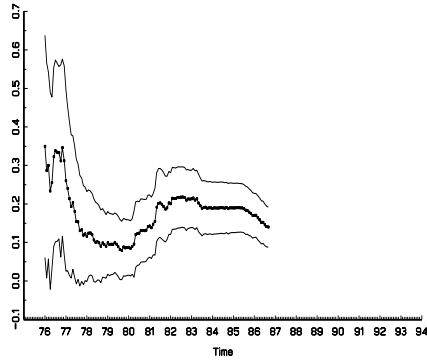
The United States.

For the United States Table 4.8 indicates that the period of the 'monetarist experiment' between October 1979 to October 1982 is of major importance with respect to the credibility of monetary targeting. Table 4.8 indicates December 1980 to be the most likely point of structural break. The likelihood ratio test in panel (d) of Figure 4.15 in addition to the policy U-turn in early 1980 also points towards a second, almost equally likely break-point in 1982-83. The 1982-83 policy U-turn is also indicated by the F-test of Chow (1960), whilst the two Cusum-of-Squares tests CSF and CSB definitely favour the 1979 break point. Whatever the exact timing, according to the stability tests the implementation of monetary policy underwent significant changes during the 1979-83 period.

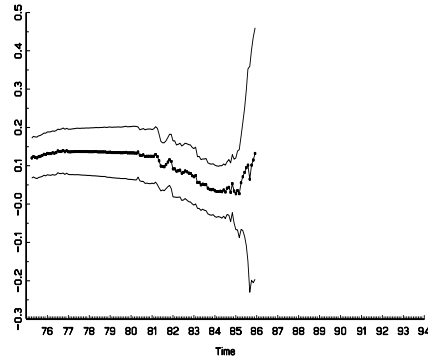
The recursive estimate of the credibility of M1 target announcements are displayed in panel (a) of Figure 4.15. The estimates are consistent with Axilrod's (1985) finding that initially credibility was being eroded by the consistency at which M1 growth overshot the target ranges. In October 1979 this downward trend of the credibility of M1 announcements is brought to a halt by the Fed's adoption of a more monetarist policy stance with strict adherence to M1 targets. At precisely the time of this policy U-turn the estimate of the credibility of M1 target announcements is found to have increased between early 1980 and late 1982. This supports Axilrod's (1985) assertion that the monetarist experiment of 1979-82 increased the Fed's credibility. Furthermore, the estimates show that these credibility effects are minor in the period between October 1979 to December 1980, but relatively large in the first half of 1981, when the new Reagan administration was elected. This in turn supports Blanchard (1984, 1987) view that while monetary disinflation was set in motion under President Carter, the role of President Reagan was to give it more credibility. The evidence is also in line with the results of Hardouvelis and Barnhart (1987), who find that the October 1979 announcement of a policy change did not provide the Federal Reserve with instant credibility, but that the Fed established credibility slowly over time, apparently after markets began verifying that the new Fed policy was successful.

Figure 4.15.
Switching Regression Estimates of the Credibility of United States M1 Growth Target Announcements (Jan. 1975-Dec. 1986)

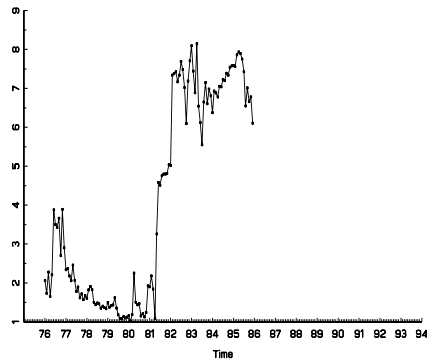
(a) MC Forward Estimate



(b) MC Backward Estimate



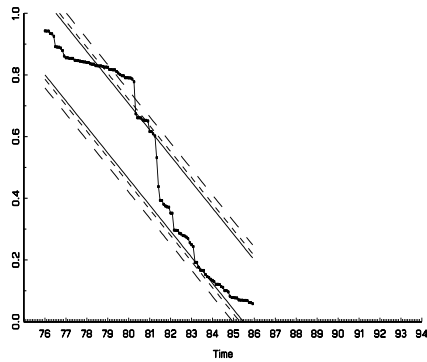
(c) Chow F-Test



(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test

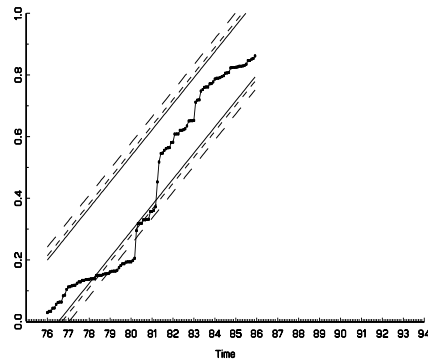
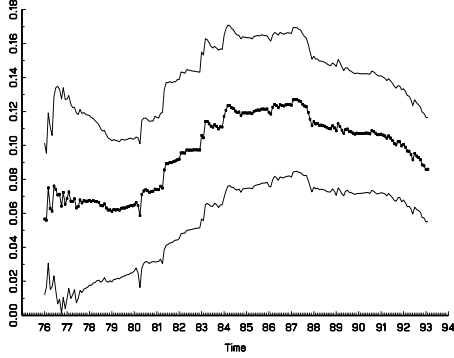
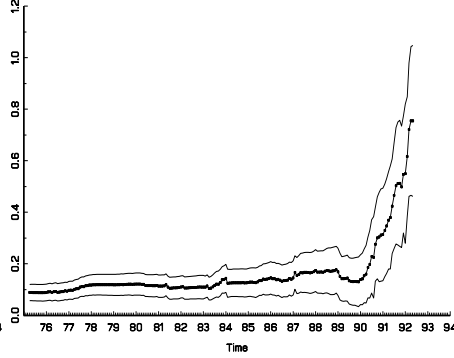


Figure 4.16.
Switching Regression Estimation Results for the Credibility of United States M2
Growth Target Announcements (Jan. 1975-July 1993)

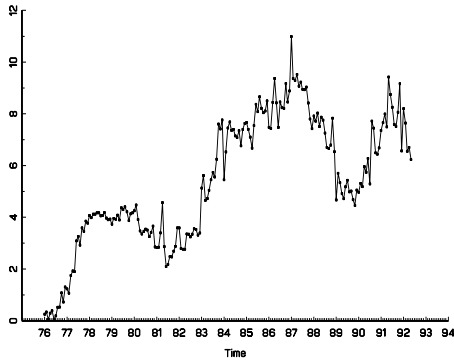
(a) MC Forward Estimate



(b) MC Backward Estimate



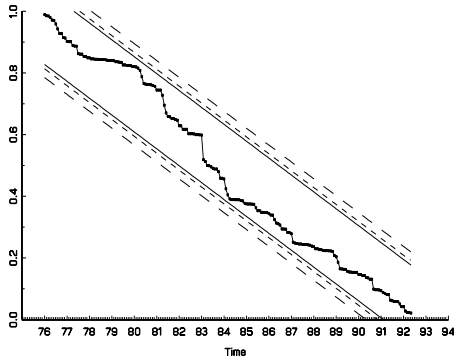
(c) Chow F-Test



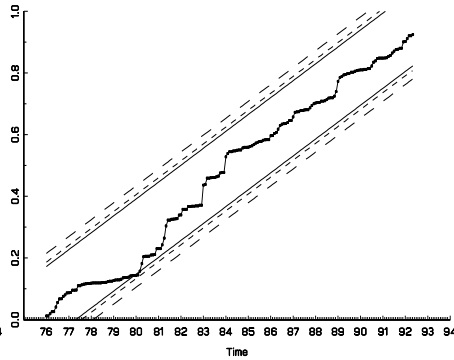
(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test



In October 1982 the Fed announced its decision to abandon its monetarist policy stance, and to de-emphasise M1 in favour of the broader monetary aggregates, M2 and M3. The estimate of the credibility of M1 target announcements subsequently declined until M1, due to its apparent instability, was abolished as a formal monetary target in late 1986. The evidence reported here is thus consistent with Hardouvelis and Barnhart (1987), who suspected but found no evidence on credibility effects arising from the 1982 policy shift.

Interestingly, the credibility of M2 target announcements, displayed in panel (a) of Figure 4.16, increased continuously throughout 1979-87. Table 4.8 and the Chow and likelihood ratio tests in panels (c) and (d) of Figure 4.9 point towards a structural break in the commitment towards M2 targeting in January 1987, precisely when M1 targets were abolished. Thereafter the credibility of M2 target announcements declined. This provides some tentative support for the view of Loeys (1984), Friedman (1985), Goodfriend (1986) and Blanchard (1987) that possibly after 1982, but definitely after 1987, the Fed did not replace M1 targets by M2 or M3 targets, but shifted from monetary targeting to its pre-1979 practice of interest rate targeting instead.

Japan

The highest credibility estimates of all G7-countries have been found for Japanese M2+CD's targeting. In recent years credibility exceeded 50 percent, indicating that these announcements are an important factor in the public's assessment of the Bank of Japan's monetary policy stance.

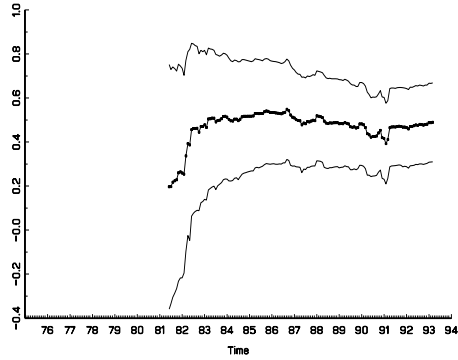
Table 4.8 indicates that the steep decline in money growth in September 1990 presents a possible structural break. This is also indicated by the Chow test and the likelihood ratio test in panels (c) and (d) of Figure 4.17. However, both test statistics in Table 4.8 are not significant at the 5 percent level, whilst the two Cusum-of-squares tests CSF and CSB in panels (e) and (f) of Figure 4.17 are. These conflicting tests therefore provide no clear evidence of structural instability in the case of Japan.

In panel (a) of Figure 4.17 the credibility estimate initially increases during 1981-82 and remains relatively stable at a high level between 1982 and 1987. Credibility declines slightly between 1987 and 1991, but rises again thereafter. All in all, the estimates obtained here are consistent with the finding of Fisher (1988) that the Bank of Japan clearly had achieved credibility during the 1980's. The Bank of Japan typically achieved rates of growth close to its projections,¹² thereby enhancing credibility. Until 1985 this credibility was not undermined by the Bank of Japan's increasing concern over the exchange rate. However, after September 1985,¹³ as the Bank of Japan massively intervened in foreign exchange markets, there was some minor decline in the credibility. However, after the pre-announced steep decline in the growth rates of M2+CD's in 1991 the credibility of the Bank of Japan has recently started to rise again.

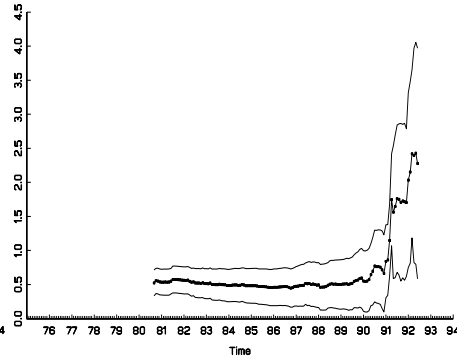
To summarise, the Japanese monetary policy stance with fairly accurate and relatively frequent (quarterly instead of annual) monetary target announcements appears to have been successful in commanding credibility. The remaining G7-countries, and in particular France, Italy and the United Kingdom, have largely failed to achieve a similar degree of credibility for their statements of monetary policy

Figure 4.17.
Switching Regression Estimation Results for the Credibility of Japanese
M2+CD's Growth Target Announcements (July 1980-July 1993)

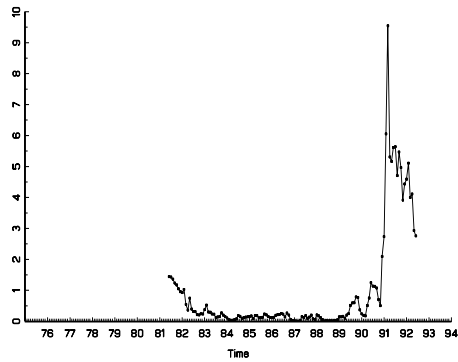
(a) MC Forward Estimate



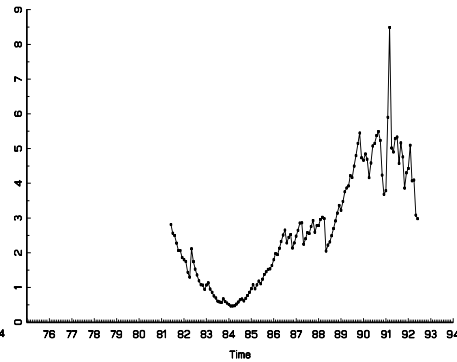
(b) MC Backward Estimate



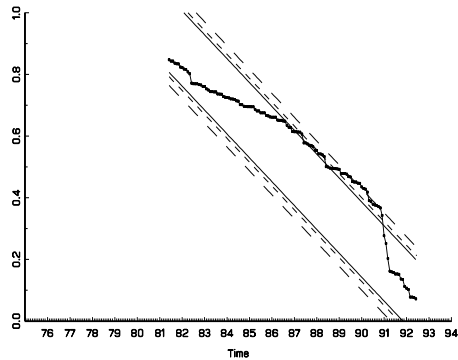
(c) Chow F-Test



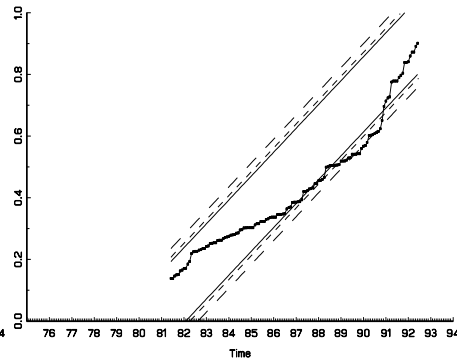
(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test



intentions. Monetary targeting in these countries has exhibited a large degree of discontinuity, which is a serious obstacle to establishing credibility. These European countries also had only limited success in achieving their monetary targets, but so also did the Germany and the United States. In view of the volatile history and limited success of monetary targeting in G7-countries, the low credibility estimates are hardly surprising.

Why then did central banks so uniformly fail to establish credibility through monetary target announcements? One possible explanation is 'Goodhart's law', a modification of the 'Lucas critique'. It asserts that the attempt to control the supply of any monetary aggregate destabilises its demand. This argument has frequently been mentioned in connection with the target switches of the Bank of England, the Banque de France, the Bundesbank and the Fed. An alternative explanation is that central banks during the 1980's had practically given up monetary targeting, but preferred to keep monetary growth target announcements as some fix-points, even if they overshoot them. De Boissieu (1988) explains this by stating that the loss of credibility would have been greater in the case of the abolition of monetary target announcements than it would be with overshooting. The logic of the Cukierman and Meltzer (1986b) model, as well as the estimates reported above, do not support this view: target overshooting reduces credibility, and massive target misses result in low and insignificant credibility estimates. Indeed, under these circumstances, monetary target announcements no longer provide the public with useful information, and might just as well be abolished.

4.2.2. The Credibility of Exchange Rate Target Announcements

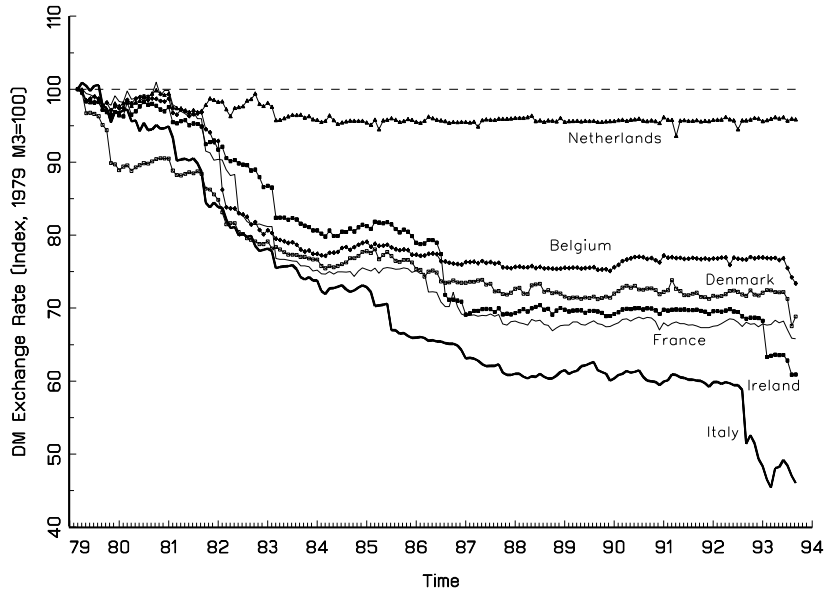
If money targeting is not particularly credible, how could reputation be improved? The borrowing reputation hypothesis of Giavazzi and Giovannini (1987) or Giavazzi and Pagano (1988) suggests that credible exchange rate pegging may increase counterinflation reputation. For example, Giavazzi and Spaventa (1989) argue that France and Italy joined the EMS on the belief that exchange rate targets are more credible than monetary targets, maybe because violations are more conspicuous. This clearly motivates the attempt of the following section to measure the credibility of official exchange rate target announcements. Before turning to the credibility estimates, however, it is instructive to again take a closer look at the data.

4.2.2.1. Experiences with Exchange Rate Targeting

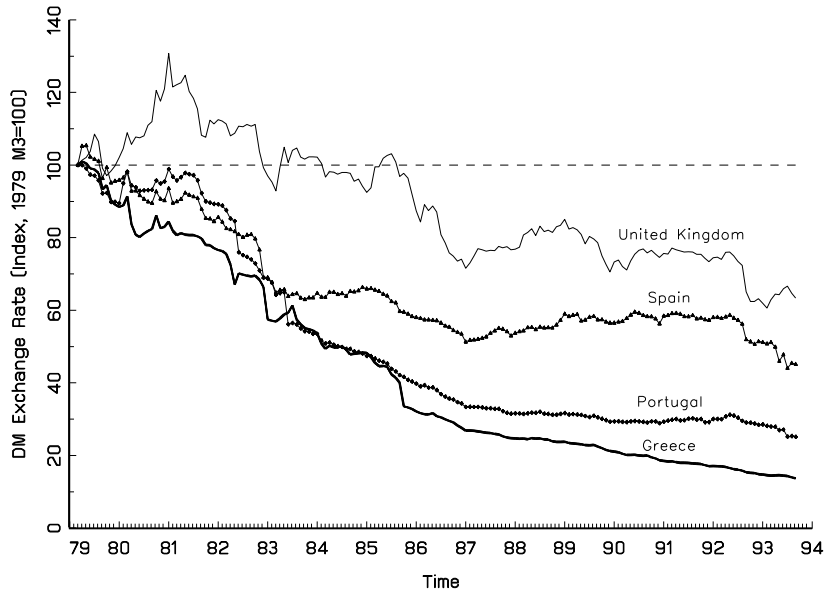
Figure 4.18 displays the time-paths of the bilateral nominal exchange rate indices (March 1979 = 100) of EMS currencies relative to the German mark. With the exception of some wavering in late 1980, the German mark clearly was the 'hard currency' of the EMS since all currencies depreciated relative to it. Figure 4.18 also identifies three groups of EMS currencies: first comes the Dutch guilder, which has remained quite stable *vis-a-vis* the mark; second, the Italian lira exchange rate exhibited a sharp downward trend throughout the whole EMS period; finally, the French franc, Belgian franc, Danish krona and Irish pound switched, at various points in time between late 1982 and early 1987, from a trend of successive devaluations to

Figure 4.18.
Nominal German Mark Exchange Rates

(a) EMS Period, Initial ERM Participants, Index (1979 M3=100)



(b) EMS Period, Remaining EC Countries, Index (1979 M3=100)



level pegging. Throughout this period, all the currencies in this last group, with the French Franc clearly being the weakest prior to 1993, experienced similar patterns of devaluation *vis-a-vis* the mark.

Trend devaluations against the mark were not limited to the initial members of the ERM club. Panel (b) of Figure 4.18 shows that all remaining EC countries, in particular Greece, but also Portugal, Spain and the United Kingdom, which joined the ERM at later stages, also experienced very substantial declines in their German mark exchange rate.

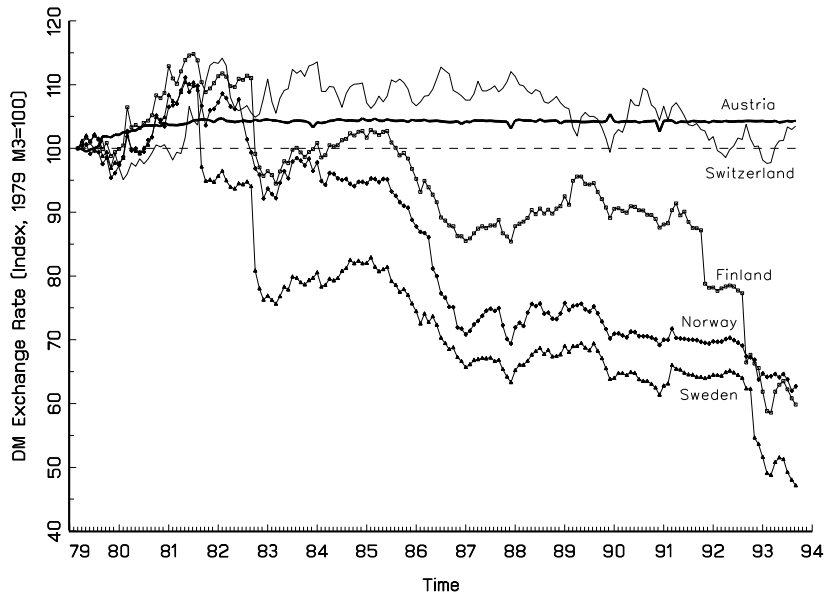
As shown in panel (a) of Figure 4.19 the Nordic EFTA countries, Finland, Norway and Sweden, which adopted unilateral exchange rate target zones with respect to a basket of currencies, have shared a similar fate. In Switzerland and Austria, on the other hand, there has been a slight appreciation *vis-a-vis* the mark, and they have maintained relatively stable exchange rates. It is interesting to note that despite not having a formal exchange rate agreement with Germany, Austria has managed to stabilise its German mark exchange rate to a degree which outperforms even the Dutch ERM exchange rate stabilisation. The pattern of exchange rate developments with respect to the non-European G7 countries, displayed in panel (b) of Figure 4.19, is distinctly different. Amongst these countries the United States and Canada have experienced huge exchange rate swings *vis-a-vis* the German mark, whilst the Japanese yen underwent a substantial trend appreciation.

The above mentioned similarity in the behaviour of the German mark exchange rates of European countries is not unique for the EMS system, it already existed under both the Bretton Woods system and the European currency snake arrangement, as shown in panels (a) and (b) of Figure 4.20. In all three post-war exchange rate regimes the German mark provided a hard-currency stance, and the Dutch guilder remained most stable with respect to the mark. The remaining initial ERM member countries experienced devaluations of various degrees against the mark, with the French franc once more being the weakest currency amongst those participating in both pre-EMS exchange rate regimes. However, those countries adhering to the snake system (France, Denmark, Belgium and the Netherlands) managed to avoid the huge devaluations *vis-a-vis* the mark which were experienced by Italy, Ireland and the United Kingdom after the collapse of Bretton Woods.

In Weber (1991a) the above pattern of exchange rate movements is interpreted as informal evidence for a bi-polar working of the EMS, as opposed to the 'DM-zone' view held by Giavazzi and Giovannini (1987) or Giavazzi and Pagano (1988). The 'bi-polarity' hypothesis of the EMS states that after some short initial transition phase the EMS has functioned as a bipolar system with a 'hard currency' option offered by the German Bundesbank and a 'soft currency' option supplied by the Banque de France. Whilst the Netherlands almost from the onset of the EMS have been committed to the 'hard currency' option, the 'soft currency' alternative has played an important role for the remaining small EMS economies, Belgium, Denmark and Ireland, at least during most of the deflation period 1983-86. In Figure 4.21 this is exemplified by the relative stability of the French franc exchange rates of these countries during the disinflation period. However, Weber (1991a) shows that in the last few years prior to 1990 this 'soft currency' bloc of the EMS has disintegrated and some countries, in particular Ireland and to a lesser extent France, have shifted towards the 'hard currency' standard of the Bundesbank, which itself has mellowed

Figure 4.19.
Nominal German Mark Exchange Rates

(a) EMS Period, EFTA Countries, Index (1979 M3=100)



(b) EMS Period, Non-ERM G7 Countries, Index (1979 M3=100)

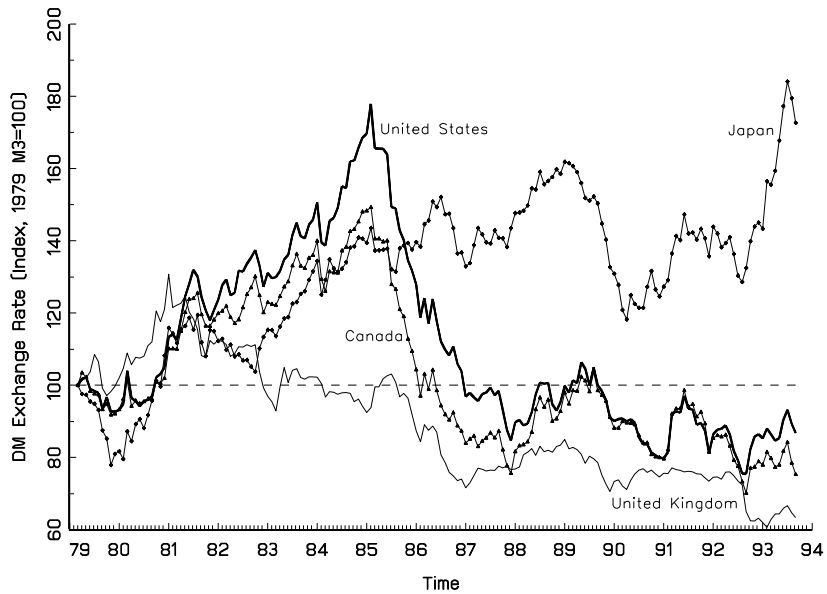
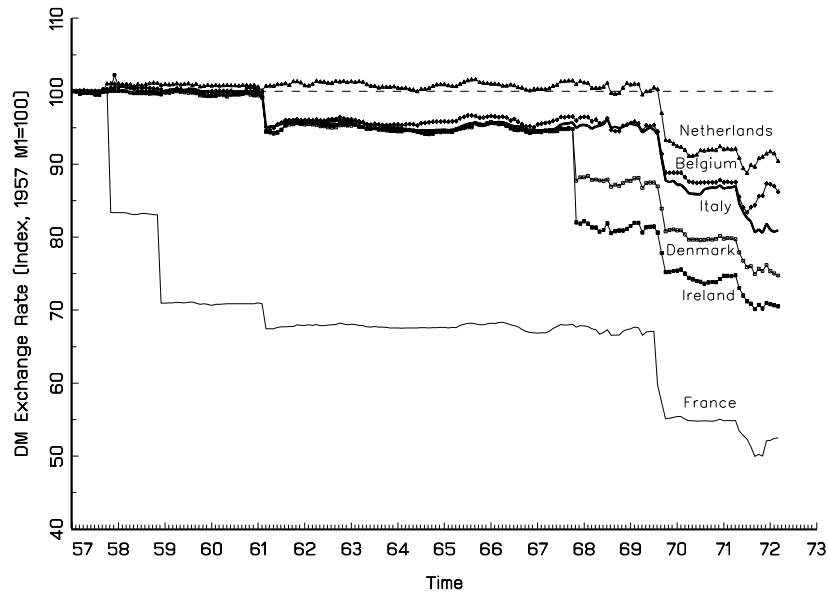


Figure 4.20.
Nominal German Mark Exchange Rates

(a) Bretton Woods Period, Index (1957 M1=100)



(b) European Currency Snake Period, Index (1972 M4=100)

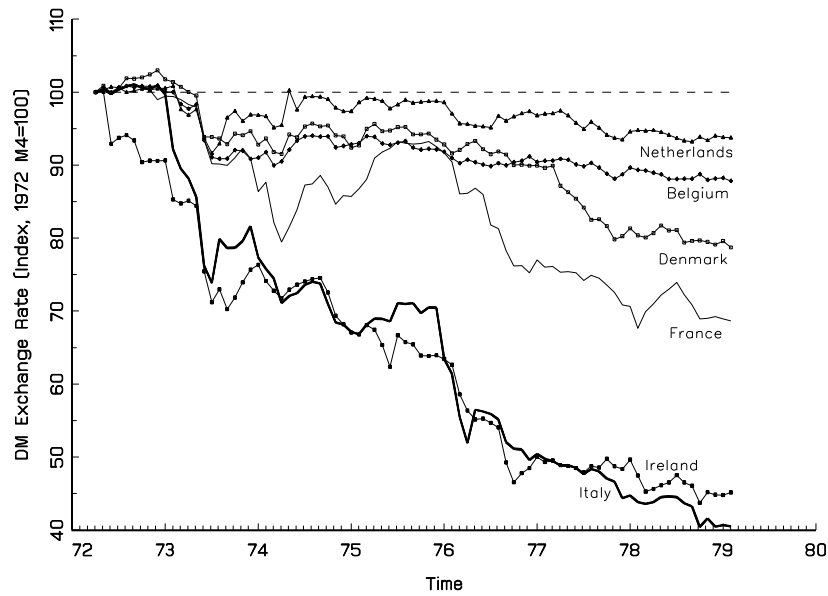
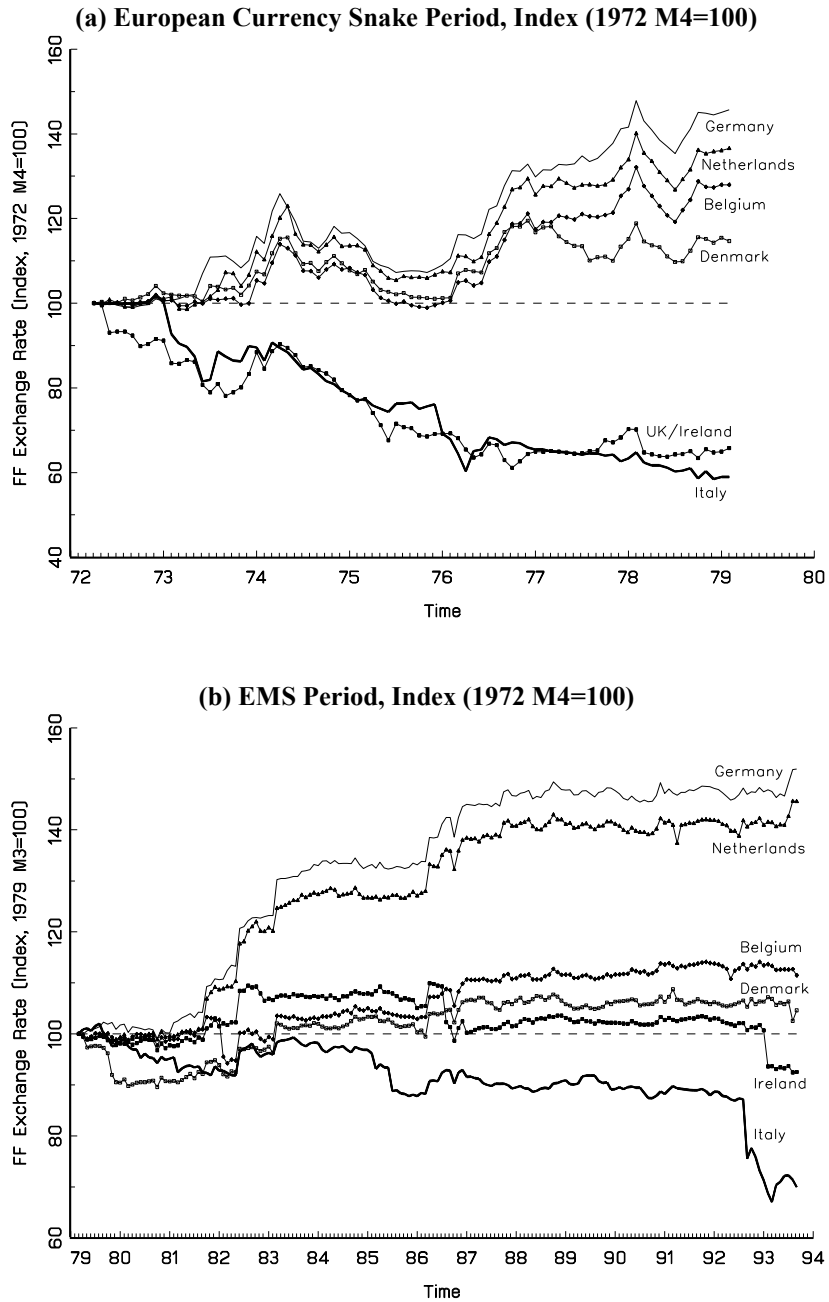


Figure 4.21.
Nominal French Franc Exchange Rates



somewhat. The fact remains that by 1990 the EMS was far from being a system of credibly pegged DM exchange rates. The following section therefore aims at providing new evidence on whether and to what extent the most recent events have changed the credibility of exchange rate targeting.

The problem with the post-1990 period is that, with the possible exception of Belgium, fostering exchange rate credibility was not the prime policy objective of ERM countries. Rather, the Delors plan for Economic and Monetary Union (EMU) shifted the political agenda more towards the fiscal convergence criteria, largely ignoring the problems and implications of the nominal convergence and exchange rate stability criteria in the face of the emerging massive German unification shock: Germany's temporarily diverging inflation performance, which was discussed in detail in section 4.1, made further monetary and inflation convergence undesirable for most ERM member countries. The present study argues that, as a result, the bipolar working of the EMS was reinforced rather than eliminated, although now the 'soft currency' option was supplied by the Germans whilst the French provided the 'hard currency' stance. The popular press at the time frequently made references to this reversed bipolarity by using the terms "Franc forte" on the one side and "Bundesbanque" on the other. This play on words simply reflects the fact that in the late EMS period pegging to the German mark no longer necessarily provided a disinflationary bias, at least not in the short run. On the contrary, borrowing Bundesbank credibility has involved the serious risk of an imported temporary inflationary bias. This has seriously undermined the commitment of ERM central banks towards exclusively targeting their respective DM exchange rates, due to German post-unification reflation. As German monetary policy turned extremely restrictive during 1992 and deflation was brought on its way, the commitment of ERM countries to follow this restrictive move amid emerging recessions came again under question. Massive speculative attacks on the Italian lira and the British pound during the ERM crisis in September 1992 and repeated attacks on many of the remaining ERM currencies during the following nine months finally resulted in the fall of the system in August 1993.

4.2.2.2. Estimates of the Credibility of Exchange Rate Target Announcements

The implication of the above interpretation of the history of exchange rate movements in the EMS is that the 'DM-zone' or 'borrowing credibility' view is unwarranted. Rather, owing to the co-existence of a 'hard currency' and a 'soft currency' option, which allowed for a crawling peg *vis-a-vis* the German mark, the EMS did not automatically imply a counterinflation bias. In principle the smaller EMS countries, Belgium, the Netherlands, Denmark and Ireland, were free to choose between the two options: credibly pegging to the German mark allowed countries to share German counterinflation reputation, but not credibly pegging to the German mark created some room for monetary autonomy and less steeper disinflations. The credibility of exchange rate pegging policies, to be confirmed below by harder evidence, is a key issue in understanding why disinflations in the EMS have been slower and less than complete for so many years. It also explains why divergence has occurred. The following section also argues that for the smaller EMS countries the credibility of exchange rate pegging policies and the existence of an external anchor may also play

a vital role in understanding why inflation emerged to such vastly differing degrees after the collapse of the Bretton Woods system.

4.2.2.2.1. Exchange Rate Credibility Across Exchange Rate Regimes.

Panel (a) of Figure 4.22 presents the average credibility (AC) estimates for a comparison of Bretton Woods with the European snake system and the EMS. The AC measure reflects the average deviation (in percentage points) of exchange rate projections from official parity announcements. The smaller this projected bias in the parity announcement, the higher is average exchange rate credibility. One result stands out: only the Dutch guilder exchange rate with respect to the mark is higher under the EMS than under either the Bretton Woods or the snake system. All remaining exchange rate pegs command less credibility when compared with Bretton Woods, and in the case of the 'wide band' participants of the ERM, Italy and the United Kingdom, the loss in exchange rate credibility is substantial.

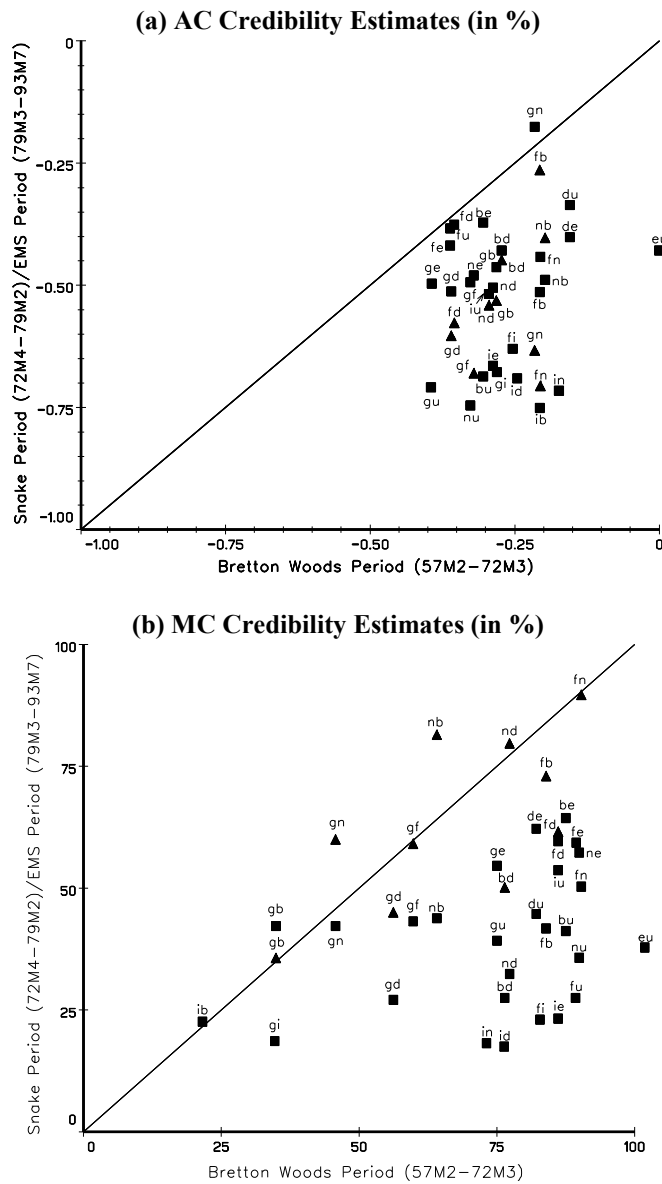
Panel (b) of Figure 4.22 presents the marginal credibility (MC) estimates. As indicated above, the MC measure is best viewed as the proportion (in percentage points) by which exchange rate projections are influenced by official parity announcements.¹⁴ A natural benchmark for judging credibility is MC equal to 50 percent: below that level announcements are dominated by other factors. Two main results emerge. First, if exchange rate fixity was mostly credible under both the Bretton Woods system (23 out of 27 MCs exceed 50%) and within the European currency snake system (8 cases out of 10), that is not the case under the EMS arrangement (only 7 out of 21 MCs are above 50%) Second, the MC measure reveals that the credibility of the exchange rate commitment has generally declined, in many cases significantly, in the EMS relative to the Bretton Woods or the European snake system.

Both results may be explained by the higher degree of exchange rate flexibility in the EMS, as reflected by the wider fluctuation margins of ± 2.25 percent as compared to ± 1 percent under the Bretton Woods system or ± 1.125 percent under the European currency snake system. The results also may be partly attributed to the fact that the EMS exhibited both a much higher frequency and size of parity realignments than the Bretton Woods system. In any case, the results indicate that amongst the historical post-war systems of fixed but adjustable exchange rates the EMS was the least credible system.

4.2.2.2.2. Hard and Soft Currency Options

Does this imply that the EMS did not provide a bonus for disinflation 'credibility'? To answer this question the overall EMS period (Mar. 1979-July 1993) has been split into three sub-periods (Mar.1979-Feb.1983, Mar.1983-Dec.1989, Jan.1990-July 1993). The resulting estimates of the MC and AC credibility measures are presented in panels (a) and (b) of Figure 4.23. The key result from Figure 4.23 is that the EMS has not functioned as a 'DM-zone'. Instead, the EMS is found to have operated as a bipolar system in which the French franc offered a 'soft currency' alternative to the 'hard currency' option of the German mark. With the exception of the Netherlands, which was almost from the onset of the EMS committed to the 'hard currency' option,

Figure 4.22.
Exchange Rate Credibility Across Regimes.
Bretton Woods Period versus Snake/EMS Period



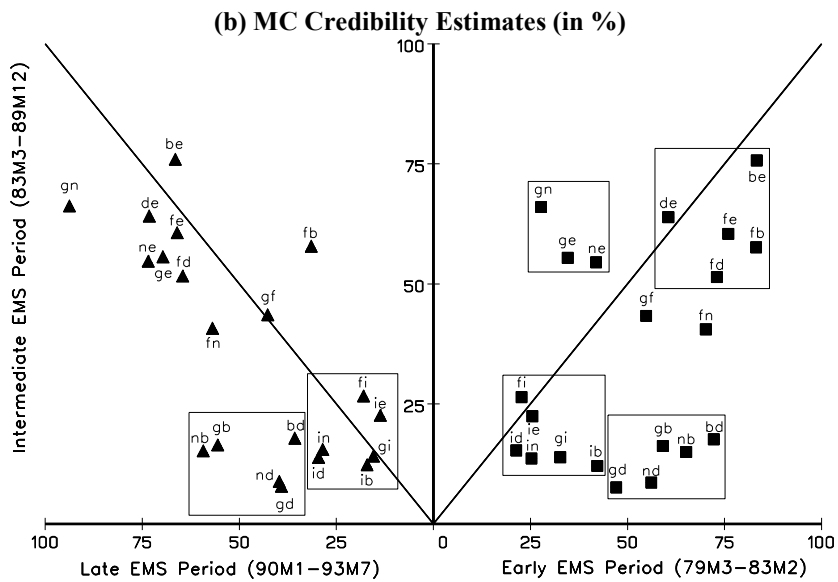
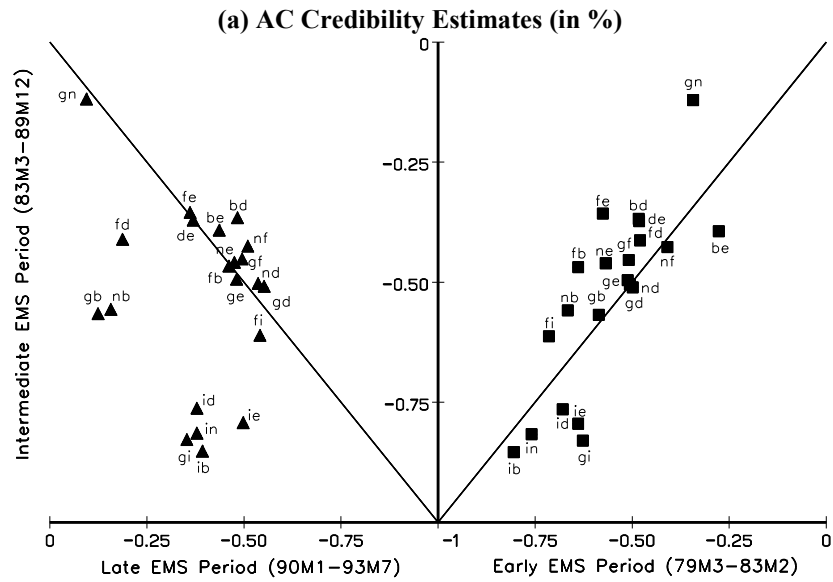
Key to symbols: g = Germany, f = France, i = Italy, n = Netherlands, b = Belgium,
 d = Denmark, e = Ireland, u = United Kingdom,
 bilateral rates are indicated by the combination of these symbols

the 'soft currency' option appears to have played an important role for the remaining smaller EMS economies (Belgium, Denmark and Ireland), at least in the early stages of the EMS. Panel (a) of Figure 4.23 clearly indicates the existence of a 'soft currency' bloc with France at its centre. Exchange rates in this 'soft currency' bloc of the EMS were credibly pegged, as is reflected by the high credibility estimates in both pre-1990 periods for the French franc exchange rates of Belgium (fb), Ireland (fe), Denmark (fd) and for the bilateral rates between these economies (be, de). Weber (1990) shows that these close French franc linkages of Denmark (fd) and Ireland (fe) and to a lesser extent of Belgium (fb), dissolve after 1987. For the post-1990 sample the process is in part reversed. Belgium now clearly drifts away from the former 'soft currency' bloc and strongly increases the credibility of its commitment to pegging to the German mark and the Dutch guilder, as can be seen on the left-hand side of Figure 4.23. The German-Dutch exchange rate link has an outstanding and almost perfect credibility in the post-1990 period. It is therefore not surprising that this exchange rate link is the only bilateral link which survived the ERM crisis of 1992-93 without having to abolish the narrow band of ± 2.25 percent. The remaining smaller EMS countries have also managed to gain credibility in their commitment to targeting the German mark, whilst similar gains are not to be found for France and Italy. Note that this result strikingly resembles the result obtained in section 4.1 with respect to gaining counterinflation reputation. Given the German reflation in excess of French inflation rates in the post-unification period, it is furthermore not surprising that France has not increased its commitment to pegging to the German mark. The same situation may also explain why Denmark and Ireland have re-iterated their commitment to the French franc in the post-1990 period.

Additional evidence on the existence of a 'soft currency' bloc during the EMS disinflation period is provided on the right-hand side of Figure 4.23 by the steep decline of the credibility of exchange rates targeting between the members of former 'snake' bloc: the initially relatively credible exchange rate pegs of Belgium and Denmark vis-a-vis Germany (gb,gd) and the Netherlands (nb,nd) become extremely non-credible as Belgium and Denmark switch to the 'soft currency' option of the EMS. The terms 'soft currency' option and 'French franc' zone are, however, not to be interpreted too literally. These labels do not mean to imply that EMS countries explicitly targeted their French franc exchange rate. Rather, the overriding objective of countries in this 'soft currency' bloc, like France, has been to implement disinflations which were less drastic than they would have been with level-pegging to the German mark, which in turn implies that their currencies shared the common fate of occasional devaluation and thus mimicked the French franc.¹⁵

The growing importance of the 'hard currency' option of the EMS may also be illustrated by referring to Figure 4.23: it is signalled by the increasingly credible commitments of all smaller EMS countries towards the German mark (gn, ge, gd, gb), in particular in the post-1990 period of the EMS. The outstanding credibility of the Dutch-German (gn) exchange rate peg is equally obvious, irrespective of whether it is evaluated on the basis of the AC or the MC credibility measure. In both cases the Dutch-German exchange rate link is close to being perfect in the late EMS period. This result suggests that both countries are already relatively close to a de facto monetary union, which also explains why this exchange rate link survived the 1992-93 ERM crisis without problems. The step toward Economic and Monetary Union

Figure 4.23.
Exchange Rate Credibility Across EMS Periods



Key to symbols: g = Germany, f = France, i = Italy, n = Netherlands, b = Belgium,
d = Denmark, e = Ireland, u = United Kingdom,
bilateral rates are indicated by the combination of these symbols

with irrevocably fixed exchange rates and hence perfectly credible pegs, as envisaged in stage 3 of the Delors plan, may further involve only minor credibility gains for the Netherlands.

Finally, panel (b) of Figure 4.23 reveals that the exchange rate commitment of the Banca d'Italia is not credible (in the sense of MC 0.5) for any of the cases reported. The post-1990 narrow bands of ± 2.25 percent for the lira have failed to command more credibility than the formerly wide bands of ± 6 percent. This low credibility is in general also confirmed by the AC credibility measures in panel (a) of Figure 4.23, but here some evidence of increasingly credible pegs relative to all EMS countries are found owing to the narrower bands.

4.2.2.2.3. Time-paths of the Credibility Estimates

So far it has been established that the EMS initially worked as a bipolar system with a 'hard' and a 'soft' currency option and that policy switches between these options appear to have occurred. In trying to understand the importance of exchange rate credibility for the EMS disinflations, it is necessary to analyse the timing of the policy shifts in the commitment of central banks to targeting their exchange rates.

According to the 'Lucas-critique' the structural parameters of a model change whenever the policy is changed. Thus, U-turns in exchange rate policies should show up in the credibility measures. The estimates reported below search for the most likely point in time at which such a policy shift may have occurred. Econometrically this is done by applying 'switching regression' analysis, which has been discussed in detail in the context of monetary target announcements above. Table 4.9 reports the evidence from this exercise for the EMS period, whilst Table 4.10 produces similar evidence from a longer sample for those countries which participated in both the snake and EMS arrangement.

Summarising this evidence, it can be stated that two major periods of change in the EMS are identified. The early period of change is between the realignments of June 1982 and March 1983, when the initially relatively credible pegs between the former 'snake' participants Germany and the Netherlands on the one side and Belgium and Denmark on the other side dissolve. At this time the 'soft currency' bloc with France at its centre and the 'hard currency' bloc linked to Germany are established. The second major period of change in the EMS lies between the realignment of April 1986 and the Basle-Nyborg Agreement of September 1987.

The timing of the first round of policy switches, which established the bipolar operating characteristics of the EMS, is also indicated in the Table 4.9 for a longer sample period, which includes data from the European currency snake period and the EMS period. A striking feature of these estimates is that all policy shifts occurred between the two realignments of June 1982 (gd,gn,nb) and March 1983 (gb,nd,bd). The formerly credible commitments to relatively fixed exchange rates between the three smaller 'snake' participants, in particular the tight Benelux linkages, declines drastically. Furthermore, whilst the Belgian and Danish monetary authorities dissolved their DM pegs, the Dutch central bank after October 1982 moved towards credibly pegging the guilder to the German mark. This fact is also obvious from panel (b) of Figure 4.24. This evidence is consistent with the fact that towards the end of 1981 De Nederlandsche Bank abolished target announcements for the national

Table 4.9.
Switching Regression Estimation Results for the Credibility of Official
Exchange Rate Announcements
(Mar. 1979-July 1993)

Country	Rate	break- point	MC _T t(MC _T)	MC ₁ t(MC ₁)	MC ₂ t(MC ₂)	Chow F -2lnλ	CSF CSB	H _{n,m} H _{1,t-k}
Germany-France	Sep. 1987		0.448 (11.58)	0.556 (11.09)	0.504 (5.104)	14.901*** 32.470***	0.722* 0.128***	3.863*** 39.654***
Germany-Italy	July 1985		0.204 (5.468)	0.252 (4.223)	0.095 (2.222)	1.877 35.454***	0.832*** 0.145***	6.449*** 24.498***
Germany-Netherl.	Oct. 1982		0.414 (7.126)	0.226 (2.254)	0.766 (10.71)	13.564*** 27.293***	0.444*** 0.417***	3.247*** 19.034***
Germany-Belgium	Mar. 1983		0.446 (11.47)	0.575 (9.242)	0.102 (2.457)	30.159*** 51.333***	0.500*** 0.237***	5.510*** 473.03***
Germany-Denmark	Mar. 1982		0.299 (7.530)	0.491 (5.683)	0.132 (3.023)	10.735*** 20.073***	0.398*** 0.489***	3.136*** 55.266***
Germany-Ireland	June 1986		0.516 (11.71)	0.363 (5.943)	0.795 (17.02)	20.598*** 30.164***	0.600 0.204***	2.872*** 80.654***
France-Italy	Jan. 1987		0.221 (5.279)	0.257 (4.508)	0.096 (1.850)	1.589 23.446***	0.847*** 0.133***	4.523*** 22.932***
France-Netherl.	Apr. 1986		0.466 (11.57)	0.655 (17.04)	0.347 (4.200)	15.909*** 24.895***	0.232*** 0.609	2.560*** 12.473***
France-Belgium	Nov. 1986		0.390 (8.955)	0.796 (16.53)	0.109 (1.811)	81.316*** 54.242***	0.315*** 0.195***	1.404* 243.68***
France-Denmark	May 1983		0.579 (12.85)	0.810 (11.94)	0.390 (7.069)	12.148*** 11.297***	0.292 0.583*	1.235 18.031***
France-Ireland	Sep. 1987		0.598 (15.15)	0.734 (13.71)	0.637 (11.15)	19.050*** 21.566***	0.597 0.219***	1.860*** 46.533***
Italy-Netherl.	Apr. 1991		0.182 (5.026)	0.166 (4.555)	0.659 (4.120)	4.744*** 7.852**	0.882 0.062	1.493 6.021**
Italy-Belgium	Oct. 1986		0.222 (5.698)	0.307 (5.656)	0.199 (3.444)	8.146*** 16.092***	0.703** 0.204***	2.641*** 188.23***
Italy-Denmark	July 1986		0.172 (4.490)	0.208 (3.618)	0.122 (2.654)	0.849 6.798**	0.730*** 0.259***	2.333*** 11.872***

Table 4.9 continued

Country	Rate	break -point	MC _T t(MC _T)	MC ₁ t(MC ₁)	MC ₂ t(MC ₂)	Chow F -2lnλ	CSF CSB	H _{n,m} H _{1,t-k}
Italy-Ireland		Sep. 1986	0.236 (5.266)	0.354 (5.06)	0.088 (2.072)	5.591*** 25.143***	0.801*** 0.133***	4.738*** 30.503***
Netherl.-Belgium		May 1982	0.458 (11.29)	0.725 (14.91)	0.164 (3.623)	56.908*** 42.897***	0.170* 0.428***	1.426 327.54***
Netherl.-Denmark		Feb. 1983	0.355 (9.109)	0.566 (11.73)	0.135 (2.537)	17.400*** 16.349***	0.192 0.638	1.234 43.160***
Netherl.-Ireland		June 1986	0.538 (12.82)	0.326 (6.032)	0.806 (16.13)	25.062*** 24.967***	0.471 0.300***	1.531** 129.85***
Belgium-Denmark		Dec. 1985	0.271 (6.280)	0.682 (11.78)	0.171 (3.022)	47.823*** 37.209***	0.310** 0.329***	1.060 219.50***
Belgium-Ireland		Feb. 1990	0.643 (15.16)	0.770 (19.69)	0.663 (8.240)	50.196*** 40.543***	0.456*** 0.172	1.223 115.90***
Denmark-Ireland		Feb. 1988	0.624 (16.88)	0.661 (14.83)	0.689 (9.837)	7.529*** 13.268***	0.598 0.320	1.128 49.185***

Notes: The marginal credibility measures for the overall period (MC_T) and the two sub-periods (MC₁, MC₂) are obtained as the coefficients estimates from the ordinary least-squares regression $(\varepsilon_t - \varepsilon_{t,t-1}^*) = c + (\varepsilon_t^a - \varepsilon_{t,t-1}^*) + v_t$, $v_t \sim N(0, \sigma_v^2)$ with ε_t and ε_t^a as actual and announced exchange rates and $\varepsilon_{t,t-1}^*$ as the optimal multi-process Kalman filter prediction of the exchange rate based on a ARIMA(0,2,2) time series model. Refer to Chapter 3 for details of the estimates. The numbers in parenthesis below the credibility estimates are t-values (5 percent significance level). Estimates above 0.5 indicate credible announcements. The timing of the most likely point of structural break is estimated by switching regression and judged on the basis of the likelihood-ratio test statistic (-2lnλ) of Quandt (1960). A significant structural break is assumed when the majority of six parametric stability tests point towards instability. These stability tests are given by the Chow (1960) F-test, the likelihood-ratio test -2lnλ of Quandt (1960), the forward and backward CUSUM-of-squares tests CSF and CSB of Brown, Durbin and Evans (1975), the test for heteroscedasticity H_{n,m} of Goldfeld and Quandt (1965) and a heteroscedasticity test H_{1,t-k} based on a regression of the squared residuals from the above equation on the squared fitted values. For details of these tests Weber (1990a).

Table 4.10.
Switching Regression Estimation Results for the Credibility of Official
Exchange Rate Announcements (Apr. 1972-July 1993)

Exchange Rate	break -point	MC _T t(MC _T)	MC ₁ t(MC ₁)	MC ₂ t(MC ₂)	Chow F -2lnλ	CSF CSB	H _{n,m} H _{1,t-k}
Germany-Netherl.	Oct. 1982	0.268 (6.886)	0.201 (3.881)	0.766 (10.71)	14.517*** 36.320***	0.636*** 0.247***	3.583*** 8.754***
Germany-Belgium	Mar. 1983	0.332 (9.977)	0.376 (7.656)	0.102 (2.457)	8.646*** 46.457***	0.763*** 0.164***	5.913*** 775.73***
Germany-Denmark	Nov. 1979	0.300 (8.689)	0.339 (4.688)	0.205 (5.249)	2.707* 32.853***	0.626*** 0.350***	5.120*** 19.759***
Netherl.-Belgium	Sep. 1982	0.450 (12.70)	0.598 (13.24)	0.135 (2.894)	31.197*** 32.071***	0.439 0.339***	1.835*** 435.47***
Netherl.-Denmark	Mar. 1983	0.425 (11.60)	0.555 (10.29)	0.144 (2.862)	13.703*** 23.756***	0.596** 0.293***	2.578*** 24.58***
Belgium-Denmark	Mar 1983	0.337 (8.859)	0.572 (10.06)	0.087 (1.961)	25.180*** 30.133***	0.509 0.304***	2.125*** 158.67***

Notes: The marginal credibility measures for the overall period (MC_T) and the two sub-periods (MC₁, MC₂) are obtained as the coefficients estimates from the ordinary least-squares regression $(\varepsilon_t - \varepsilon_{t,t-1}^*) = c + (\varepsilon_t^a - \varepsilon_{t,t-1}^*) + v_t$, $v_t \sim N(0,)$ with ε_t and ε_t^a as actual and announced exchange rates and $\varepsilon_{t,t-1}^*$ as the optimal multi-process Kalman filter prediction of the exchange rate based on a ARIMA(0,2,2) time series model. Refer to Chapter 3 for details of the estimates. The numbers in parenthesis below the credibility estimates are t-values (5 percent significance level). Estimates above 0.5 indicate credible announcements. The timing of the most likely point of structural break is estimated by switching regression and judged on the basis of the likelihood-ratio test statistic (-2lnλ) of Quandt (1960). A significant structural break is assumed when the majority of six parametric stability tests point towards instability. These stability tests are given by the Chow (1960) F-test, the likelihood-ratio test -2lnλ of Quandt (1960), the forward and backward CUSUM-of-squares tests CSF and CSB of Brown, Durbin and Evans (1975), the test for heteroscedasticity H_{n,m} of Goldfeld and Quandt (1965) and a heteroscedasticity test H_{t,t-k} based on a regression of the squared residuals from the above equation on the squared fitted values. For details of these tests Weber (1990a).

liquidity ratio (M2 / net national product) in favour of gearing monetary policy towards a stable German mark exchange rate target.

Evidence on more recent policy shifts and the new tendency of the EMS to converge to a 'hard currency' option is provided in Table 4.9: significant policy shifts towards credible German mark exchange rate policies occurred for Ireland in June 1986, two months prior to the large unilateral devaluation (-8%) of the Irish pound in the EMS. For the French franc a break is detected in September 1987, the month of the Basle-Nyborg Agreement of the EMS.

The Irish policy shift occurred during a period of policy consolidation, as Dornbusch (1989) notes. It was initiated by the weakness of the Irish pound in the EMS, which was largely due to the Irish loss in competitiveness as a result of the sharp depreciation of the British pound, the currency of a major Irish trading partner. The fact that the credibility estimates of the Irish Pound exchange rate relative to both the German mark and the Dutch guilder increased significantly after the policy shift supports the view of Dornbusch (1989) that the Irish pound recently has become one of the hard EMS currencies.

France is also found to have increased its commitment to credibly pegging the exchange rate relative to the German mark. However, this effect is not obvious from Table 4.9 for the most likely break-point, which is highly significant according to all stability tests. A closer look at the switching regression results for France in Figure 4.25, however, clearly reveals the French credibility gains. Panel (b) reports the MC credibility estimate for the French-German exchange rate link when holding fixed the sample endpoint and successively deleting observations from the beginning of the sample. The MC measure initially declines until March 1983, and then remains relatively stable over the disinflation period. During 1987 the French franc exchange rate target *vis-a-vis* the German mark increases, and stabilises at a higher level. Additional credibility gains arise in mid-1990 and in late-1991. The fact that most credibility gains materialise in the aftermath of the Basle-Nyborg Agreement of September 1987, which expanded the role of inframarginal interventions and allowed for a wider use of the fluctuation bands, suggests that the enhanced credibility may partly be attributed to the existence of better control procedures.

Finally, the credibility of the Italian central bank's commitment to fixed exchange rates *vis-a-vis* Germany, France, Belgium, Denmark and Ireland is found to have decreased significantly after the large unilateral devaluation of the Lira in July 1985 and during mid-1986. As noted above, the move to narrower bands in January 1990 did not establish credibility. This suggests that Italy in fact never played by the rules of the EMS.

To summarise, the credibility of the commitment of central banks to targeting the exchange rate varies considerably between EMS countries. Almost perfect exchange rate credibility is found only for the Dutch-German exchange rate link, which is the only exchange rate that survived the recent EMS crisis within the old narrow bands of ± 2.25 percent. In August 1993 all other EMS countries moved to targeting their bilateral exchange rates within much wider bands of ± 15 percent, and Italy suspended its EMS membership in September 1992. The credibility estimates indicate a substantial lack of exchange rate credibility already prior to these events: Italy is found to have possessed almost no credibility, and for many of the remaining EMS countries exchange rate credibility in early 1992 lagged considerably behind that

Figure 4.24.
Switching Regression Estimation Results for the Credibility of Dutch DM
Exchange Rate Targeting Policies Across Exchange Rate Regimes
(Feb. 1957-Aug. 1993)

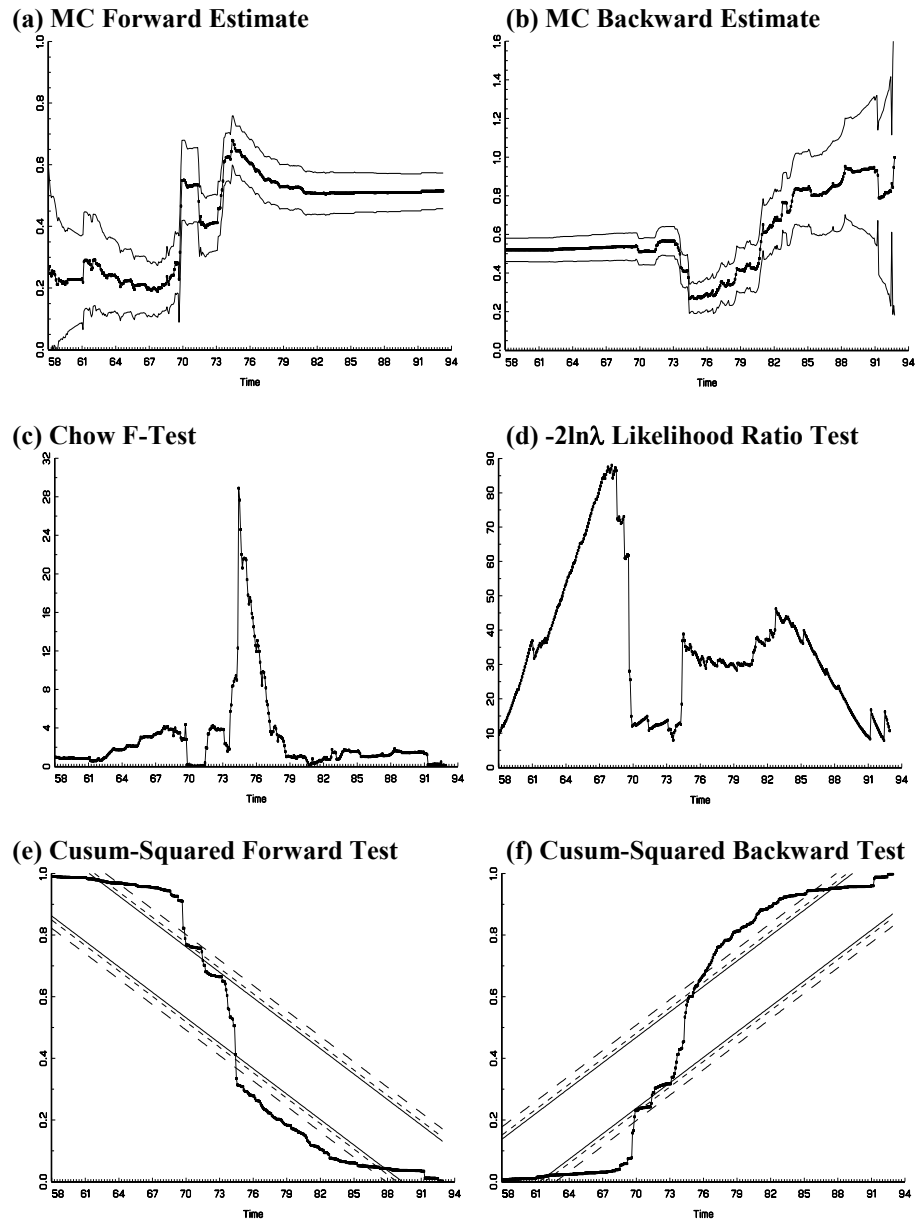
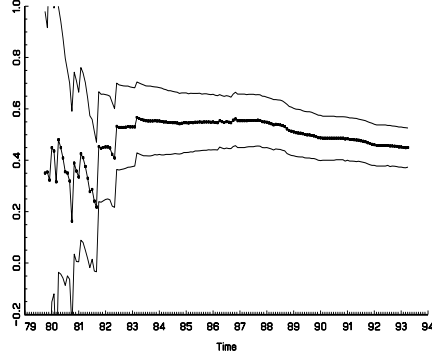
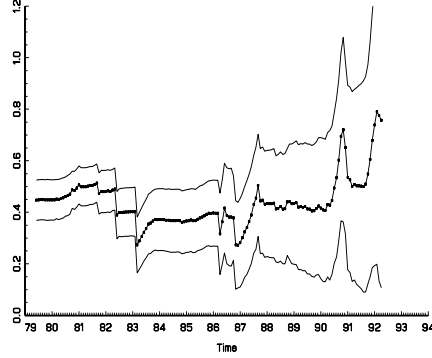


Figure 4.25.
Switching Regression Estimation Results for the Credibility of French DM
Exchange Rate Targeting Policies During the EMS Period
(Mar. 1979-July 1993)

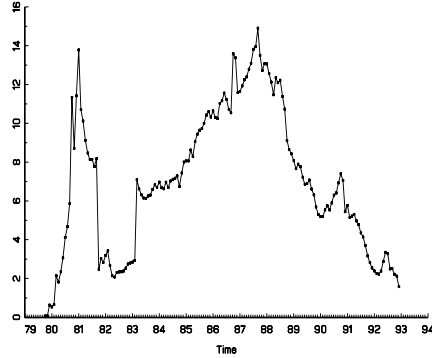
(a) MC Forward Estimate



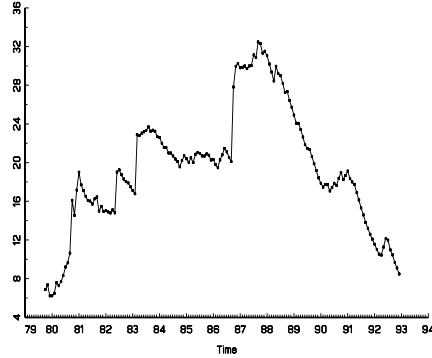
(b) MC Backward Estimate



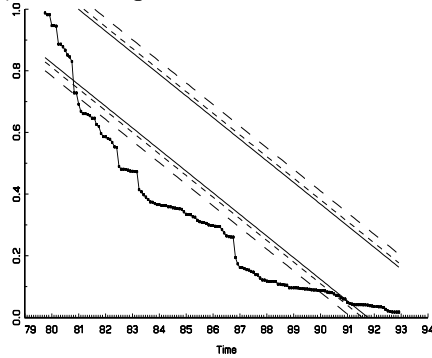
(c) Chow F-Test



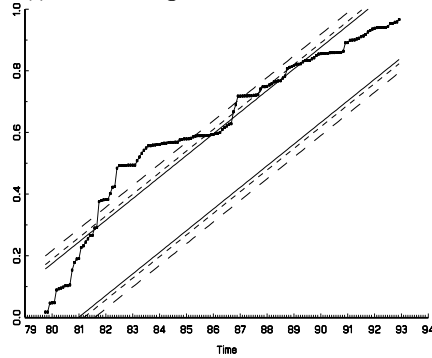
(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test



of the Dutch-German rate. This fact may explain why speculative attacks occurred. In order to analyse this point, it is instructive to study the behaviour of interest rates, in particular their differential movements between EMS countries, which will be discussed in the section below.

4.2.3. The Credibility of Interest Rate Target Announcements

Given that for many countries both monetary quantity targeting and exchange rate targeting appears to have faced serious credibility problems, the other major candidate for implementing credible monetary policies is interest rate targeting. A closer look at monetary policy actions in EMS economies¹⁶ reveals that the central banks of the smaller EMS member states, in particular of the Netherlands, Belgium and Ireland, have predominantly resorted to such interest rate targeting policies, as reflected, for example, by official discount rate changes. It has been argued above that such interest rate targeting policies may have been adopted as an operational procedure to control the exchange rate. This view, formalised in chapter 2, assumes that foreign interest rates combined with projections of potential exchange rate movements within the band can be translated into a target for the domestic interest rate. This type of policy may have taken two forms. First, countries may have targeted domestic market interest rates indirectly by setting official interest rates, such as discount rates or lombard rates, in accordance with official interest rates in the country with which exchange rate stabilisation is desired. Second, central banks may have targeted domestic market interest rates more directly in accordance with market interest rates in the centre-country by open market operations rather than through discount rate policies. Finally, market interest rates may have been targeted by setting official interest rates to be consistent with purely domestic policy objectives. The credibility estimates will not allow us to differentiate between these three forms of interest rate targeting policies, but a closer look at the data will yield some insights with respect to this point.

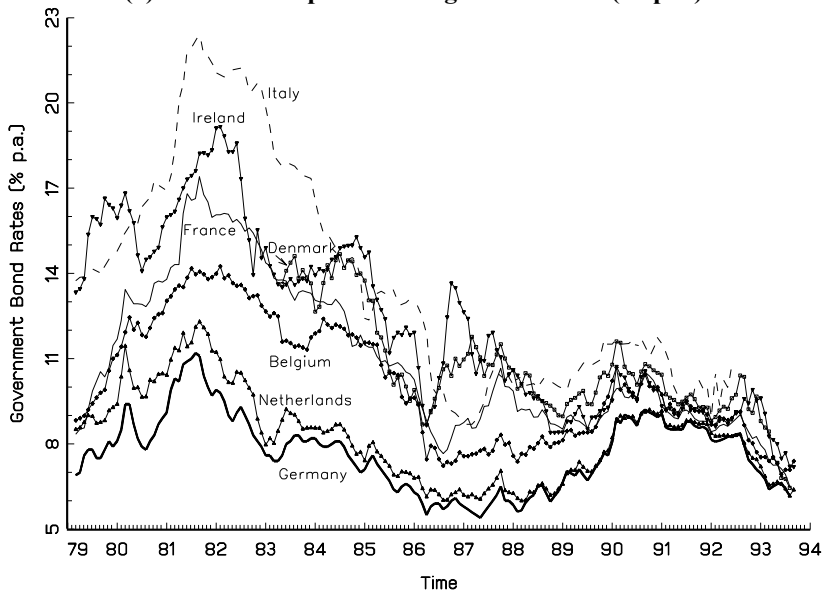
4.2.3.1. The Experience with Interest Rate Targeting

Long-term interest rates in EMS countries have initially risen and diverged considerably in the aftermath of the oil price shock in 1979. Panel (a) of Figure 4.26 further shows that EMS interest rates declined and converged during the disinflation period 1981-86. During 1987-90 almost complete convergence of long-run interest rates occurs due to a substantial increase of German and Dutch rates to the French levels. In the wake of the unification shock German long-term rates decline again after late 1990, along with the rates of all remaining EMS countries. Long-term rates do not show any great response to the EMS crisis of 1992-1993.

In panel (b) of Figure 4.26 the behaviour of long-term interest rates in the G7-countries outside the EMS shows a similar time-pattern. However, non-EMS long-term rates do not converge to a significant extent, and the sizeable interest rate differentials provide room for major exchange rate movements. An interesting feature is the apparent similarity in long-term rates between Germany and Japan, which have both experienced low inflation.

Figure 4.26.
Long-term Government Bond Interest Rates

(a) ERM Participants During EMS Period (% p.a.)



(b) Non-ERM Participants During EMS Period (% p.a.)

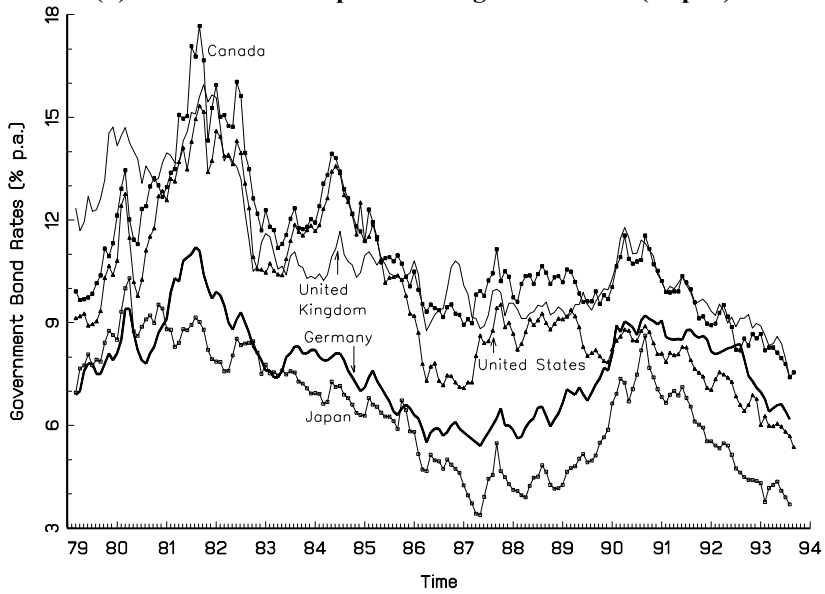
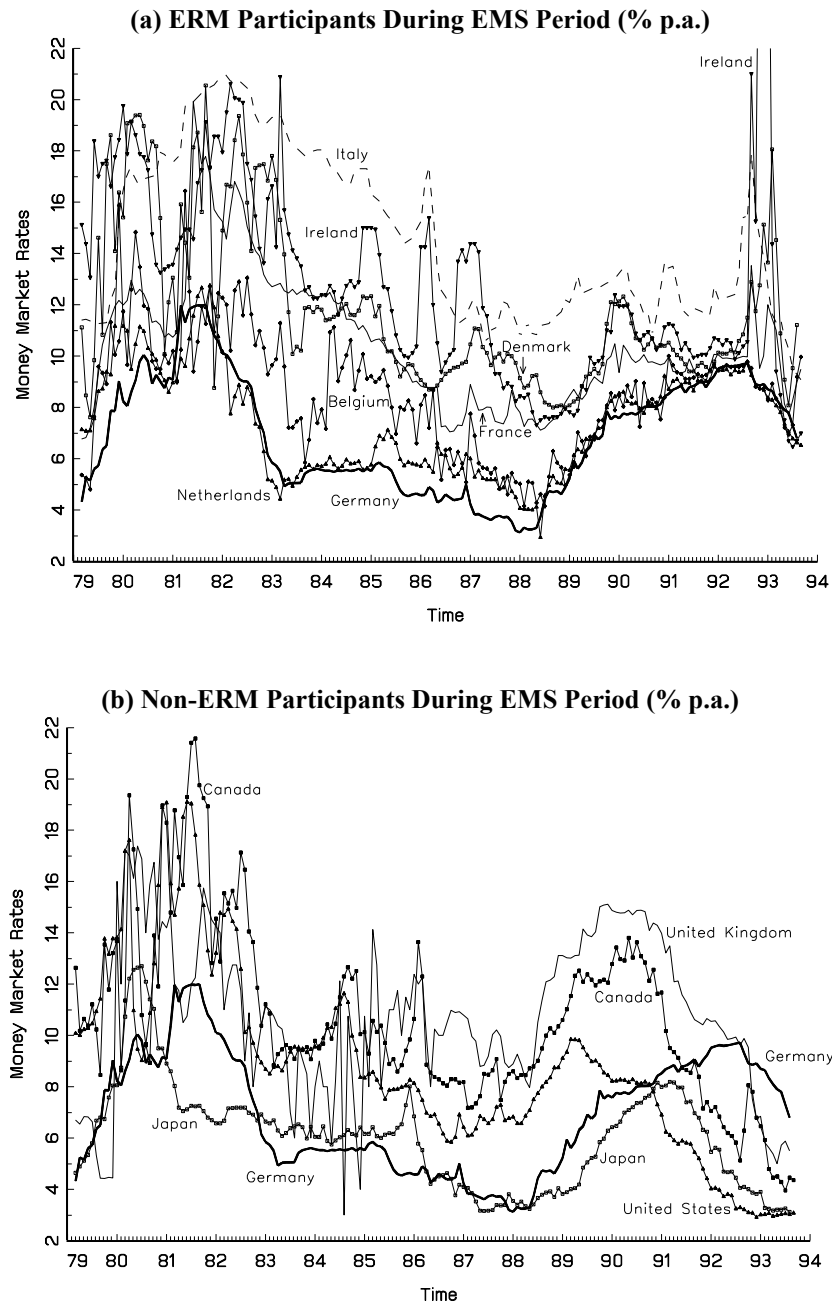


Figure 4.27.
Short-term Interest Rates

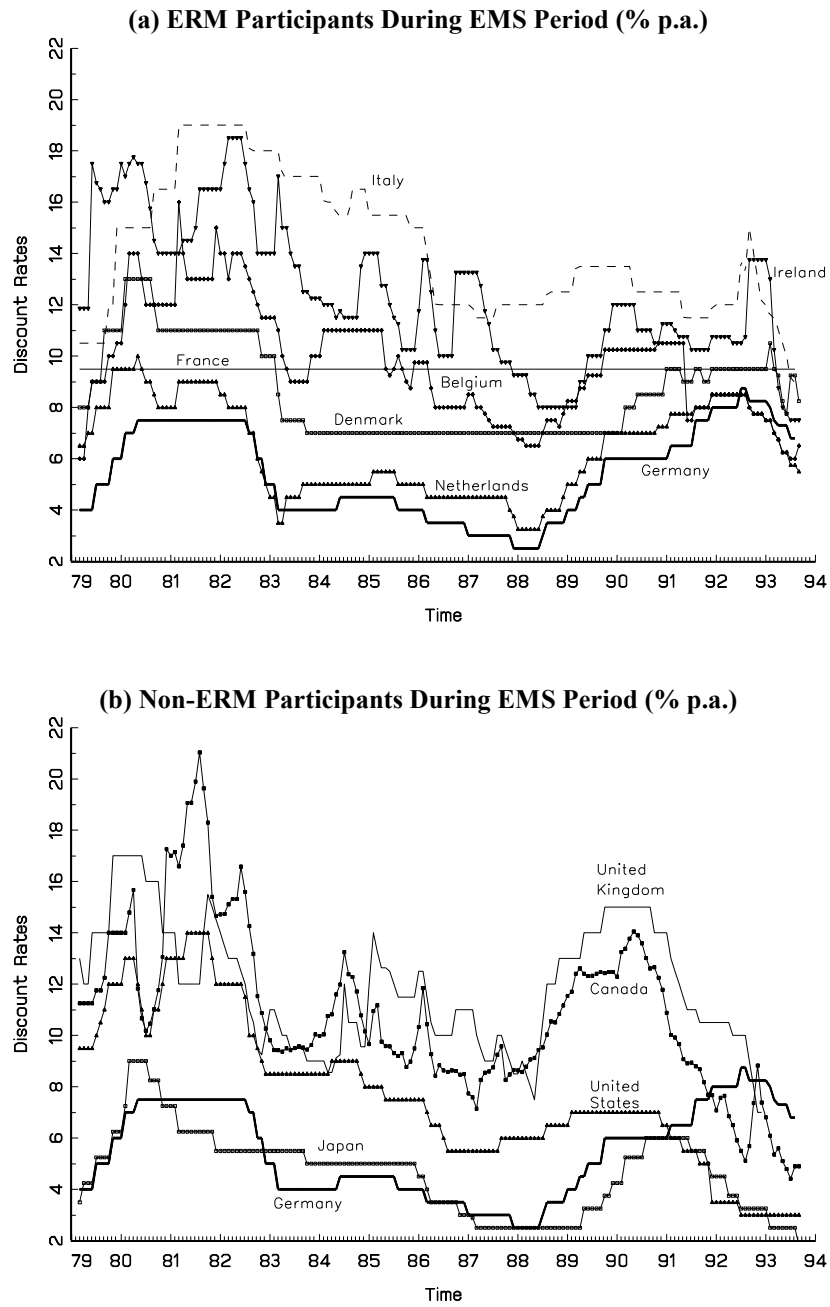


Short-term money market interest rates in panel (a) of Figure 4.27 highlight an additional important aspect of the EMS: four EMS sub-periods can be clearly identified. During the early EMS (1979-83) highly volatile movements at relatively high average levels of interest rates in France, Belgium, Denmark and Ireland reflect speculative attacks, which resulted in frequent unilateral realignments. Disinflation, capital controls and policy adjustments in the following period (1983-87) reduce this volatility drastically and put a downward trend on the average levels of interest rates. The third EMS period (1987-92) is initially characterised by relatively parallel movements of interest rates and a marked increase of all rates between 1988-1990. During 1990-1992 a substantial and almost complete convergence of short-term interest rates occurs. The final EMS period is again characterised by highly volatile interest rate movements in response to the austerity measures pursued by central banks following speculative attacks on their currencies. Belgium and the Netherlands were largely immune to these attacks, but Ireland, Denmark and, to a lesser extent France, came under heavy pressure. This visual impression of an increasing harmonisation of interest rate movements prior to 1990 is also reflected in the average correlation between EMS short-term money market interest rates, which initially rose only slightly from 0.36 (Mar.1979-Feb.1983) to 0.41 (Mar.1983-Dec.1986), but then jumped to 0.63 (Jan.1987-Dec.1989). A similar harmonisation between the non-EMS countries in panel (b) of Figure 4.17 cannot be recognised.

Panel (a) of Figure 4.28 displays EMS discount rates, which exhibit several interesting empirical regularities. First, the Netherlands, and more recently Belgium, have managed to bring their discount rates closely in to line with German rates. In 1991, when the Belgian government publicly announced the exchange rate *vis-a-vis* Germany as the prime objective of its new monetary policy stance, it steeply reduced the discount rate, which thereafter almost exactly followed the German rate. A similar policy shift had been implemented by the Dutch government in late 1981, when it gave up the national liquidity ratio as its monetary target in favour of an exchange rate target relative to the German mark. Throughout the post-1981 period Dutch discount rates very closely kept track of the German rate, and on many occasions both rates were changed at the same date. The small and relatively constant interest rate differential thereby did not vanish until mid-1992, when both Dutch and Belgian discount rates fell below the German discount rate. A second fact from Figure 4.28 is that official discount rate differentials did not converge to a significant extent during the EMS. Finally, and most importantly, Figure 4.18 indicates a parallel evolution of discount rates in Germany, the Netherlands, Belgium and Ireland after mid-1987, joined by Denmark in late 1989. The average correlation between EMS and German discount rates thereby increases by about 35% (from 0.53 to 0.72) between the disinflation and the new inflation period (April 1983 to Dec. 1986 and Jan. 1987 to Dec. 1989). These 'Euro-rounds' of discount rate changes, which signal the growing attention paid to the German mark target in the late 1980's, support the hypothesis of a convergence of the EMS to a 'hard currency' standard. In the post-unification period discount rate changes again appear less co-ordinated, signalling some decay in the Danish and Irish commitment to the German mark target.

To summarise, the interest rate data lend some support to the view that the bipolarity view of the EMS: the striking similarity in the movement of German and Dutch interest rates points towards the existence of a 'small DM-zone', which recently

Figure 4.28.
Official Discount Rates



has been joined by Belgium. The currencies of these 'hard currency' club did not come under huge speculative attacks during 1992-93. Danish and Irish interest rates, and Belgian interest rates during the disinflation period (1983-87), more closely followed French rather than German interest rates. This 'soft currency' club typically experienced higher short-term and long-term interest rates and its exchange rates therefore had a tendency to weaken against the German mark. For Italy this is particularly true. With respect to the recent EMS crisis, an interesting fact can be observed: despite of higher German inflation, German long-term interest rates throughout the post-unification period were below long-term rates in the remaining EMS countries. This suggests that financial markets expected the German inflation surge to be transitory. Indeed, after the German inflation peak in early 1992 German, Dutch and Belgian long-term rates fell by more than the corresponding rates in the remaining EMS countries, re-opening long-term interest rate differentials. At the same time short-term interest rates in Ireland, Italy and Denmark rose steeply in response to speculative attacks. The Netherlands managed to avoid such speculative attacks by more or less completely surrendering monetary sovereignty and pegging to the German mark, for better or for worse.

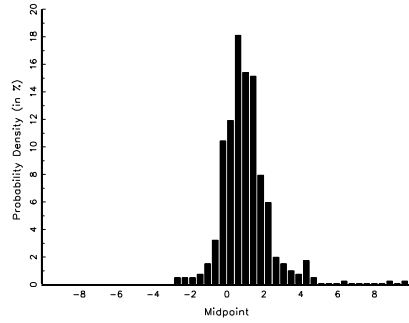
4.2.3.2. Estimates of the Credibility of Interest Rate Target Announcements

Having described some stylised facts about interest rates behaviour in the EMS, the results from the empirical evaluation of the credibility of interest rate targeting policies may now be discussed. Within the context of a modified Cukierman and Meltzer (1986b) model it is important that these interest rate targets are public knowledge. For simplicity, the analysis below assumes that officially announced discount rates reflect the interest rate targets of the central bank. It is not necessary for discount rates to be unbiased measures of the central bank's interest rate target, since the Cukierman and Meltzer (1986b) model explicitly allows for an announcements bias. All that is required is that the discount rate and the interest rate target move together over time.¹⁷

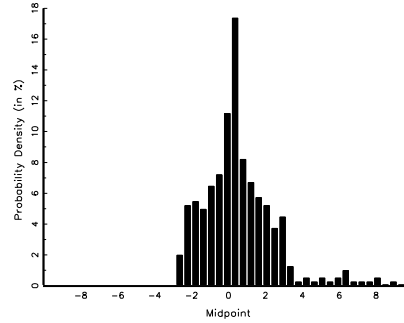
The announcement bias of discount rates with respect to market interest rates is visualised in Figure 4.29. For Germany, shown in panel (a), discount rates on average lie below market interest rates. This negative announcement bias is due to the fact that the Bundesbank targets short-term money market rates between the discount and the lombard rate, which typically is between 1 and 2 percentage points above the discount rate. Most of the probability distribution therefore falls into this interval. In Figure 4.29 a similar negative announcement bias exists in France, Italy, the Netherlands, the United States and Canada. A positive announcement bias, with discount rates typically above market rates, is found for Belgium, Denmark, Ireland and the United Kingdom. The result for Ireland indicates a serious problem: both the official discount rate and the interbank rate are administered interest rates, which are changed only occasionally and frequently at the same time. A high credibility estimate for Ireland should therefore be interpreted with caution.

Figure 4.29.
Probability Distributions of Short-term Interest Rates Around
Discount Rate Targets (in %)

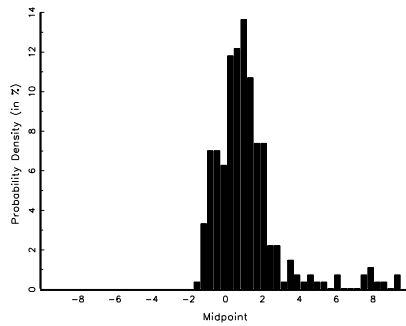
(a) Germany, Jan. 1960- Aug. 1993



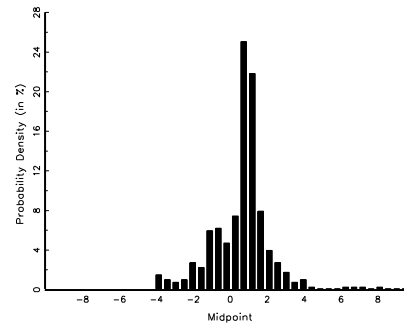
(b) France, Jan. 1960- Aug. 1993



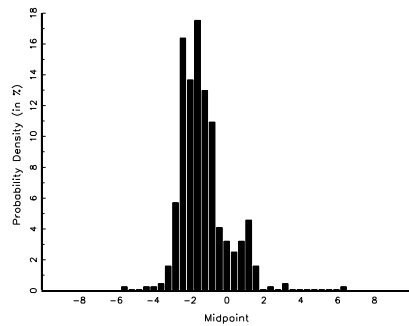
(c) Italy, Jan. 1971- Aug. 1993



(d) Netherlands, Jan. 1960-Aug. 1993



(e) Belgium, Jan. 1960- Aug. 1993



(f) Denmark, Jan. 1960- Aug. 1993

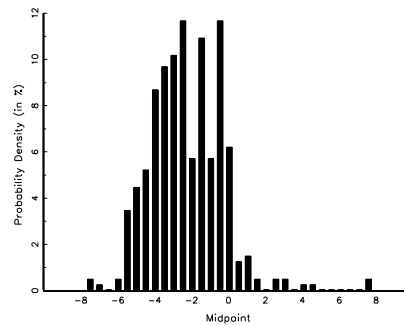
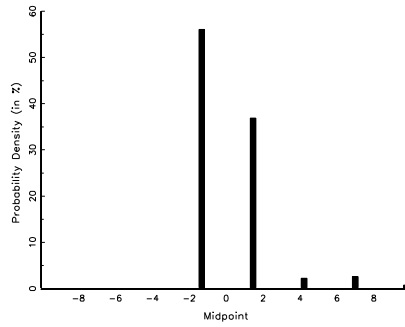
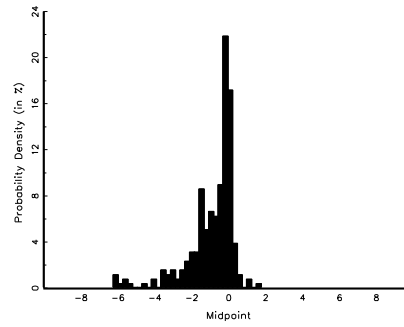


Figure 4.29 continued

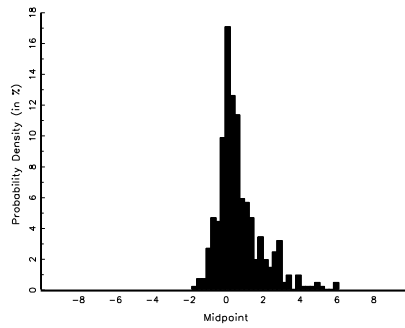
(g) Ireland, Jan. 1971 - Aug. 1993



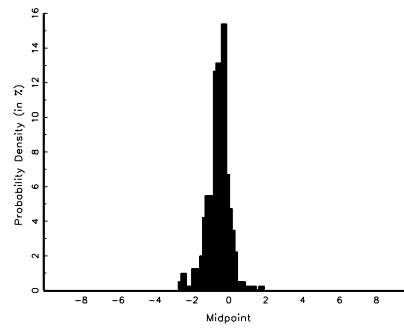
(h) U.K., Jan.1972-Sep.1992



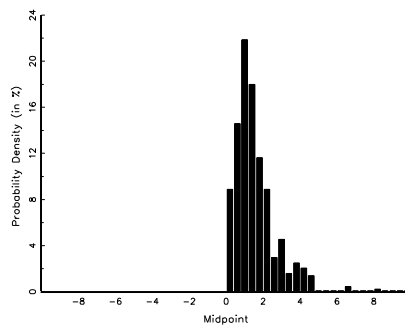
(i) U.S.A., Jan. 1960-Aug.1993



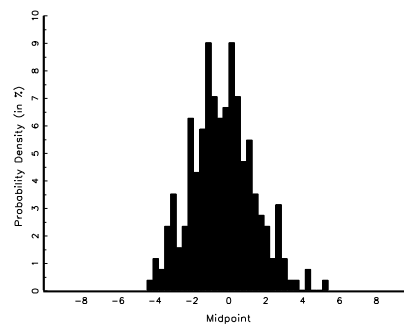
(j) Canada, Jan. 1960- Aug. 1993



(k) Japan, Jan 1960- Aug. 1993



(l) Switzerland, Jan. 1972- Aug. 1993



4.2.3.2.1. The Credibility of Interest Rate Target Announcements Across Exchange Rate Regimes

Panel (a) of Figure 4.30 displays the MC credibility estimate for both short-term money market rates and long-term government bond rates of EMS countries when compared between the Bretton Woods, the European snake and the EMS countries. Panel (b) displays the corresponding results for non-EMS countries. The results may be summarised as follows: First, interest rate targeting policies of both EMS and non-EMS countries possessed some short-term credibility, but lacked long-term credibility. The remainder of this section will therefore focus on the short-term rates. Second, amongst the initial EMS member countries only Belgium and the Netherlands made relatively credible interest rates announcements, whilst for France, Italy and Denmark low MC estimates are found. The high estimate for Ireland is a statistical artefact, as indicated above, and will be ignored throughout this section. A third finding from Figure 4.30 is that the German credibility estimate falls sharply in the EMS period relative to the Bretton Woods or snake period. This may be explained by the move to monetary quantity targeting in the late 1970's, as described in section 4.2.1 above. For the Netherlands, on the other hand, the MC credibility estimate increases continuously.

Panels (a) and (b) of Figure 4.30 further reveal that for the United Kingdom, the United States and Canada interest rate target announcements have gained credibility during the EMS period. This result is not surprising, given the limited success of these countries in establishing credibility with monetary target announcements.

Figure 4.31 presents similar evidence for the various EMS sub-periods. The key point from panel (a) of Figure 4.31 is that in the most recent EMS period (Jan. 1990-July 1993) all EMS countries except Germany and Denmark have been able to rely on credible interest rate target announcements in the sense that discount rates could effectively be used by the public to forecast movements in short-term money market rates. But, as above, these signals had little relevance for predicting the behaviour of long-term government bond rates. This result may be interpreted as evidence of a lack of credibility of anti-inflation policies in the long-run, since under zero expected inflation short-term and long-term rates should move closely together and hence be equally responsive to the policy signal. For Germany the credibility of discount rate announcements fall to almost zero during the EMS. This finding is consistent with the view expressed in Neumann (1988) that the Bundesbank during the 1980s has targeted money market interest rates not through discount operations but rather more directly by influencing interest rates on short-term treasury bills. The evidence from panel (b) of Figure 4.31 suggests that credible interest rate target announcements have been the exception rather than the rule in countries outside the EMS. Interestingly, the only countries with credible interest rate announcements (in the sense $MC > 0.5$) are Canada, Sweden and Norway. In all three countries exchange rate targeting has officially played an important role in the implementation of monetary policy. The potential link between exchange rate targeting and interest rate targeting is explored in some more depth below.

Figure 4.30.
Credibility Estimates for Interest Rates Targeting Across Regimes

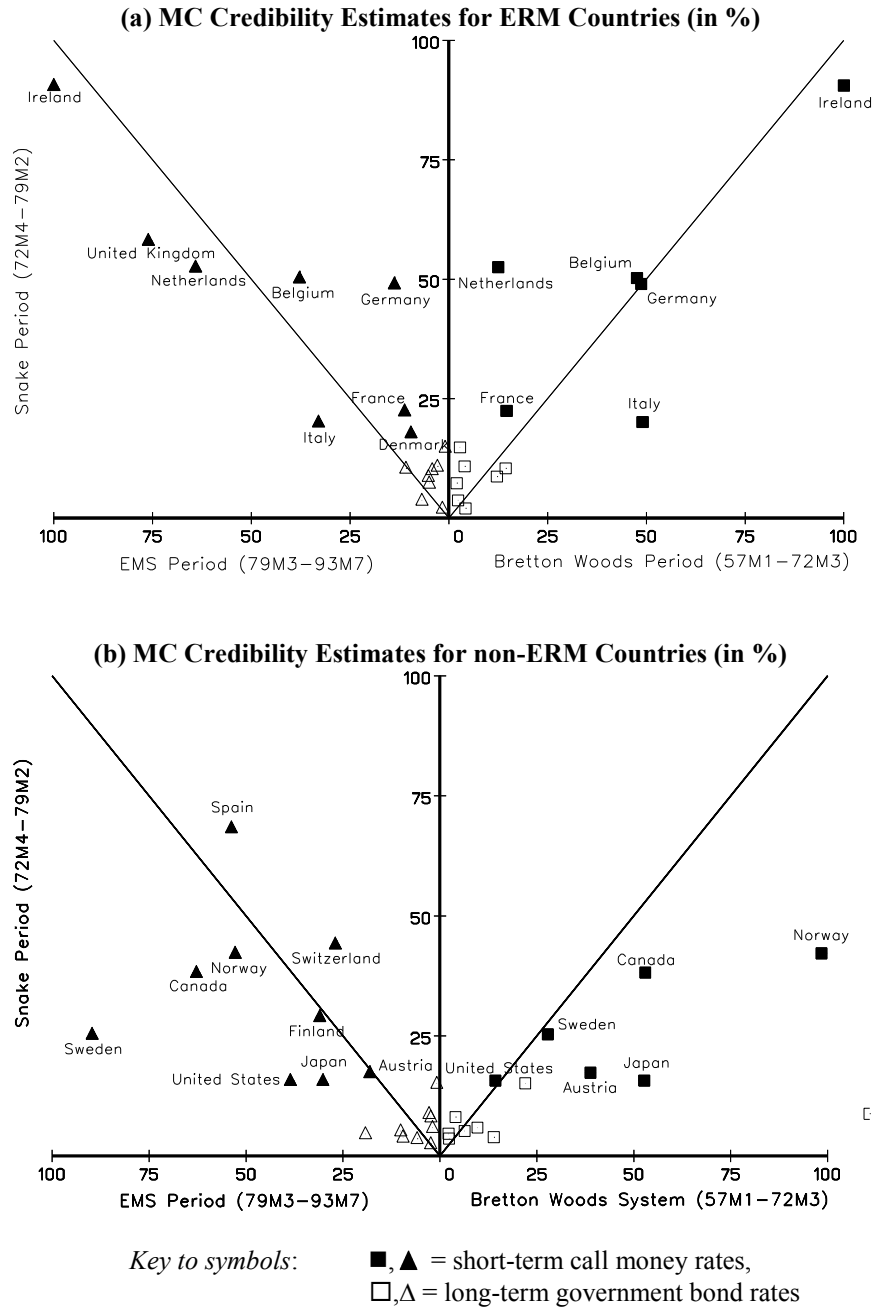
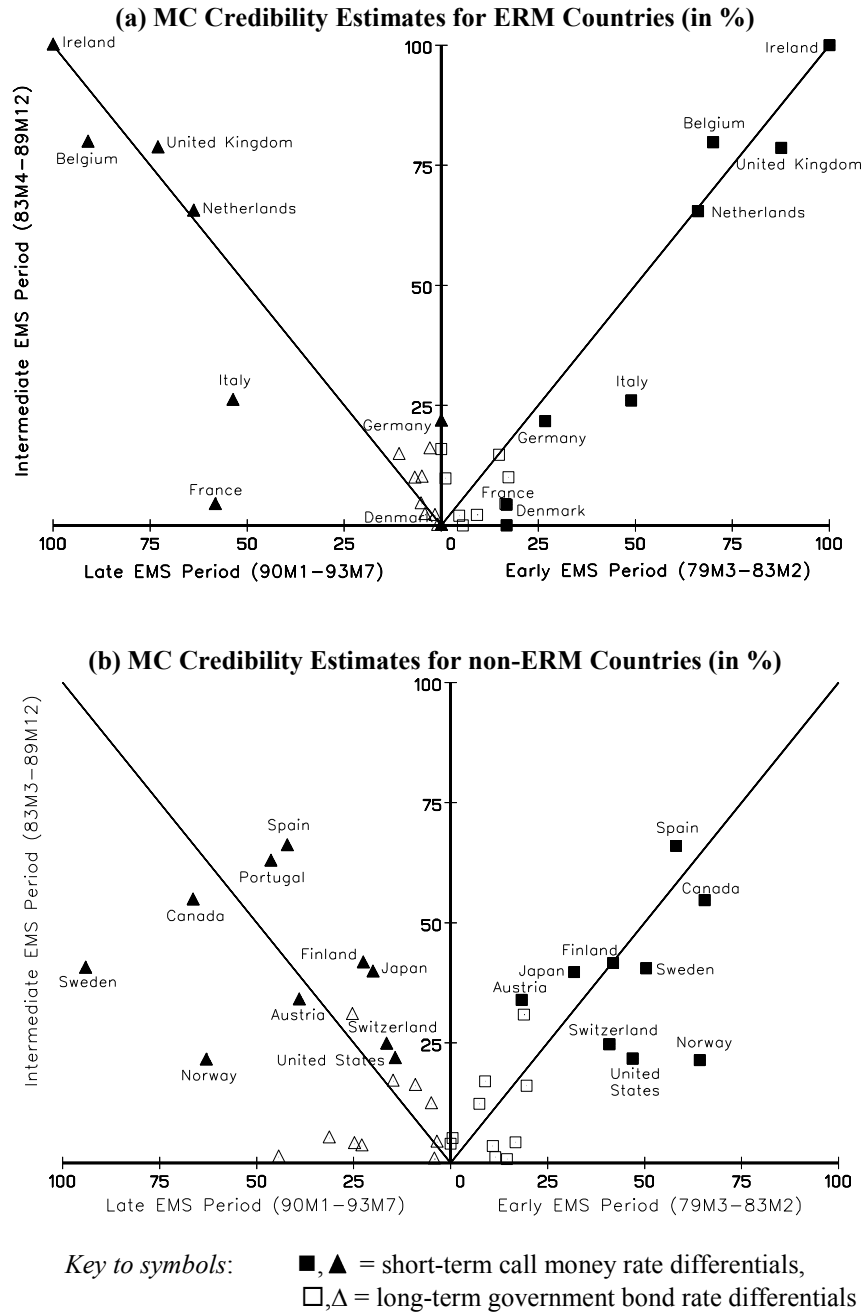


Figure 4.31.
Credibility Estimates for Interest Rates Targeting Across EMS Periods



In the theoretical model of chapter 2 it was mentioned that instead of targeting interest rates under purely domestic policy considerations, central banks of smaller countries may target interest rates as a short-run operational procedure for targeting the exchange rate. In order to control exchange rate movements central banks aim at controlling interest rate differentials. They do this by setting domestic interest rate targets to be consistent with those of the foreign country. The credibility of targeting interest rate differentials (and ultimately exchange rates) may then be analysed by estimating the signalling effect of discount rate differentials. Figure 4.32 reports the estimates, which correspond to those in Figure 4.31 except that interest rates and discount rates have been replaced by interest rate differentials and discount rate differentials *vis-a-vis* Germany. The key result from panel (a) of Figure 4.32 is as follows: those countries which issued credible interest rate announcements in a purely domestic context during 1990-93 have not been able to achieve similar credibility with respect to interest rate differentials *vis-a-vis* Germany. This is so because the credibility of German interest rate targeting declined substantially in the aftermath of German unification, as indicated in Figure 4.31. German unification thus made it more difficult for EMS countries to control exchange rates by targeting interest rate differentials *vis-a-vis* Germany.

4.2.3.2.2. Time-paths of the Credibility Estimates

As in the case of exchange rate targeting above, the relevance of the 'Lucas-critique' is evaluated by searching for potential structural breaks in central banks' commitment to interest rate targeting. The results are reported in Table 4.11 for the post-1975 period. The main findings are as follows: First, the majority of stability test statistics indicate significant structural breaks in the estimated relationship for each country. For Germany, the Netherlands, Denmark and the United Kingdom significant instability occurred during the 1981-83 period. The Netherlands and the United Kingdom have shifted to more credible interest rate announcements, whilst the Danish targets lost credibility. A second very interesting result of Table 4.11 is that for Ireland and France significant structural breaks are detected in August 1992, the month prior to the EMS crisis which drove Italy and the United Kingdom out of the system.

The apparent instability of interest rate targeting policies in EMS countries is somewhat surprising in view of the various policy U-turns, which have been described above in the context of monetary and exchange rate targeting. In particular, central banks quite frequently seem to shift between these objectives. The clearest example of such a policy switch in the context of interest rate targeting policies is given by the Dutch-German link. The Dutch central bank clearly established credible interest rate targeting as a means for stabilising the exchange rate with Germany. This becomes obvious when considering the timing of the Dutch policy U-turn. Figure 4.33 reports the switching regression results for the post-1960 period. The likelihood ratio test in panel (d), as well as the two Cusum-of-squares tests in panels (e) and (f) indicate that a significant break occurred in March 1982. The data discussed above pointed out that only after 1982 did all Dutch interest rates moved closely in line with the corresponding German rates, and exchange rates were largely stabilised within a much narrower target zone inside. Panel (a) of Figure 4.33 displays the time-path of the derived credibility measure. The credibility of discount rate announcements falls

Figure 4.32.
Credibility Estimates for Interest Rates Differentials Targeting
Across ERM Periods

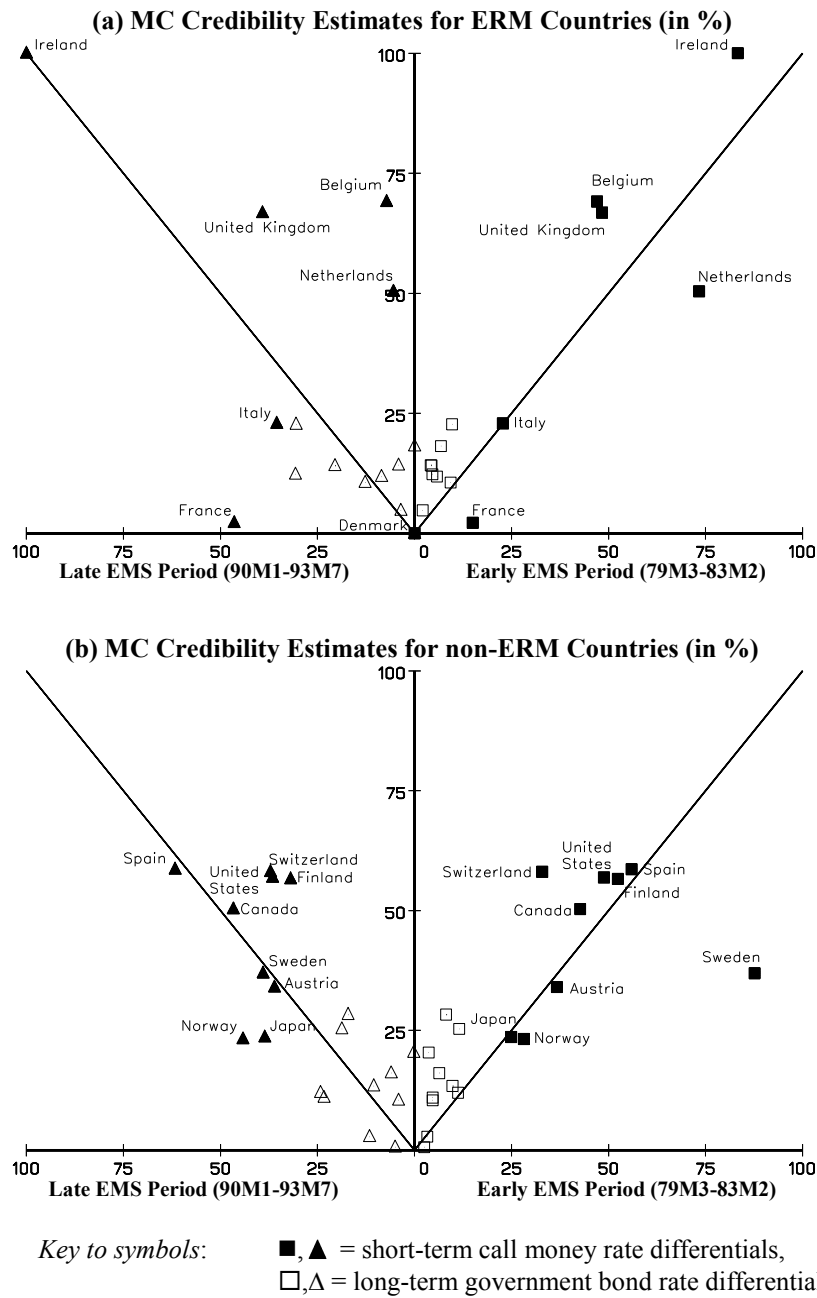


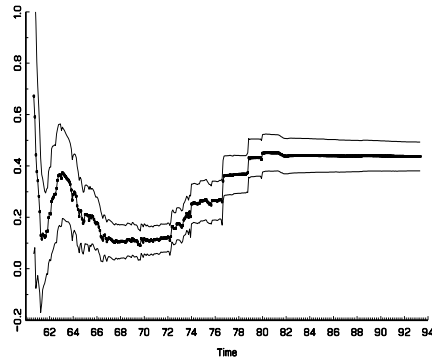
Table 4.11.
Switching Regression Estimation Results for the Credibility of Official
Interest Rate Announcements for Call Money Rates (Jan. 1975-July 1993)

Country	Rate	break- point	MC _T t(MC _T)	MC ₁ t(MC ₁)	MC ₂ t(MC ₂)	Chow F -2lnλ	CSF CSB	H _{n,m} H _{1,t-k}
Germany	call money	Sep. 1981	0.171 (4.113)	0.143 (1.781)	0.168 (4.673)	1.943 60.342***	0.828*** 0.155***	9.600*** 0.348
France	call money	Aug. 1992	0.101 (5.274)	0.077 (4.686)	0.602 (3.314)	19.559*** 26.302***	0.664*** 0.185	5.311*** 66.506***
Italy	call money	Oct. 1976	0.279 (11.06)	0.510 (7.350)	0.336 (11.16)	43.322*** 41.289***	0.186 0.532***	3.515*** 7.349***
Nether- lands	call money	Mar. 1982	0.578 (15.59)	0.574 (9.600)	0.661 (13.74)	0.260 126.39***	0.955*** 0.042***	36.123*** 1.719***
Belgium	call money	Jan. 1987	0.429 (9.077)	0.633 (9.461)	0.123 (3.150)	16.289*** 35.638***	0.780** 0.091***	4.676*** 49.931***
Denmark	call money	Apr. 1983	0.074 (3.618)	0.134 (3.355)	0.006 (0.317)	4.607*** 62.437***	0.854*** 0.106***	10.094*** 0.012
Ireland	call money	Aug. 1992	1.138 (15.02)	0.995 (14.26)	1.405 (4.028)	29.492*** 211.79***	0.080*** 0.709***	169.20*** 0.016***
U.K.	call money	Mar. 1982	0.701 (14.04)	0.890 (9.566)	0.796 (17.47)	25.504*** 49.886***	0.619*** 0.187***	4.989*** 1.818

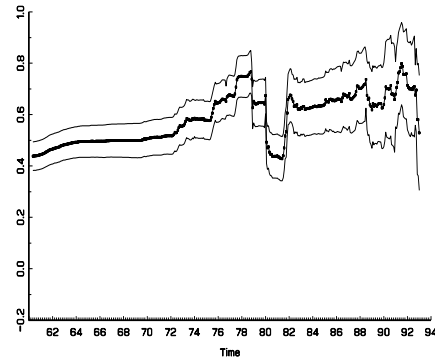
Notes: The marginal credibility measures for the overall period (MC_T) and the two sub-periods (MC₁, MC₂) are obtained as the coefficients estimates from the ordinary least-squares regression $(i_t - i_{t,t-1}^*) = c + (i_t^a - i_{t,t-1}^*) + v_t$, $v_t \sim N(0, \sigma_v^2)$ with i_t and i_t^a as actual and announced interest rates and $i_{t,t-1}^*$ as the optimal multi-process Kalman filter prediction of call money interest rates based on a ARIMA(0,2,2) time series model. Refer to Chapter 3 for details of the estimates. The numbers in parenthesis below the credibility estimates are t-values (5 percent significance level). Estimates above 0.5 indicate credible announcements. The timing of the most likely point of structural break is estimated by switching regression and judged on the basis of the likelihood-ratio test statistic (-2lnλ) of Quandt (1960). A significant structural break is assumed when the majority of six parametric stability tests point towards instability. These stability tests are given by the Chow (1960) F-test, the likelihood-ratio test -2lnλ of Quandt (1960), the forward and backward CUSUM-of-squares tests CSF and CSB of Brown, Durbin and Evans (1975), the test for heteroscedasticity H_{n,m} of Goldfeld and Quandt (1965) and a heteroscedasticity test H_{t,t-k} based on a regression of the squared residuals from the above equation on the squared fitted values. For details of these tests Weber (1990a).

Figure 4.33.
Switching Regression Estimation Results for the Credibility of Dutch Interest Rate Targeting Policies Across Exchange Rate Regimes (Feb. 1960-July 1993)

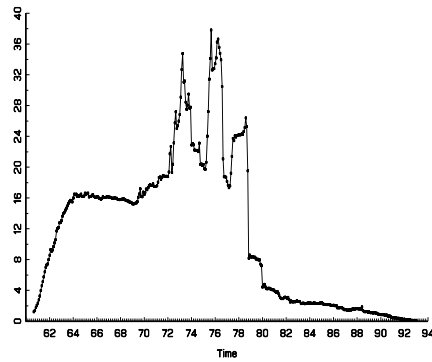
(a) MC Forward Estimate



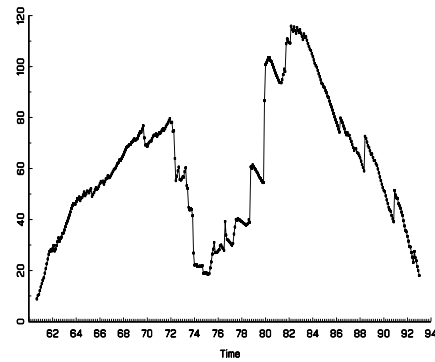
(b) MC Backward Estimate



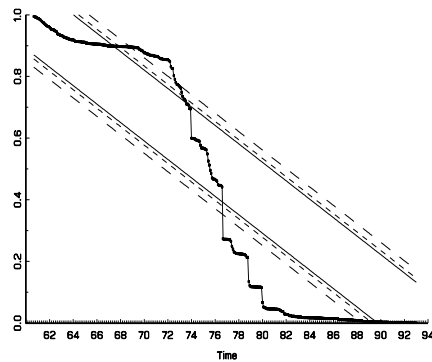
(c) Chow F-Test



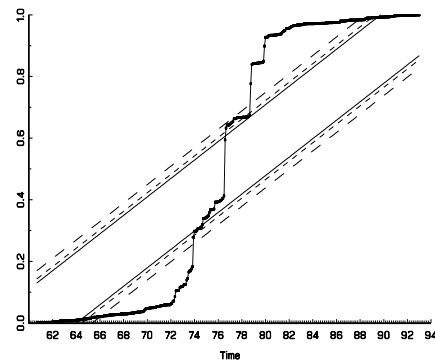
(d) $-2\ln\lambda$ Likelihood Ratio Test



(e) Cusum-Squared Forward Test



(f) Cusum-Squared Backward Test



substantially towards the end of the Bretton Woods period, and stabilises at a lower level during 1970-72. The MC measure increases again after the onset of the European snake arrangement, which pinned the Dutch-German exchange rate down to a fluctuation band of ± 1.5 percent. In the post-1982 period the credibility measure is fairly high, as is indicated in panel (b).

4.2.4. Country by Country Summary

In the previous sections an extensive discussion of policy credibility, both within the policy game and the target zone context, has been presented. The main results are summarised briefly below for the various EMS countries.

In general the results reported in this study raise some doubt about the hypothesis that the EMS may be viewed as a disinflation device for all non-German EMS members. In particular the early bipolar nature of the EMS - the joint existence of a hard and a soft currency option, seriously undermines the borrowing reputation hypothesis since the EMS can no longer automatically be taken as exhibiting a disinflationary bias. Depending on whether they pegged to a hard or a soft centre country, policymakers in EMS economies may have borrowed a good or a bad counterinflation reputation. The bipolarity hypothesis, furthermore, pretty well accounts for the fact that disinflation in the EMS has been slower and less than complete initially. But after 1986, and in particular in the period after German unification an increased commitment of EMS member countries to targeting the German mark have been found in the data. It has been argued that this was due to the fact that the German hard stance has mellowed in the aftermath of German unification, which has rendered the fixed parities more credible.

Germany was found to have established and maintained a high counterinflation reputation through a consistent low inflation performances prior to 1987. In particular, the inflationary impact of the 1979 oil price shock in Germany was relatively small. Disinflation therefore was not a major problem. Recently German unification has pushed up inflation to about 5 percent and counterinflation reputation has eroded somewhat. The German success in controlling and containing inflation in the early 1990's could thereby not be attributed to the use of any particularly credible monetary policy instrument. This may be due to the publicly acknowledged policy stance of the German Bundesbank of not strictly adhering to any particular policy rule, but to adopt whatever policy measures appear adequate at the time in order to achieve the prime policy target of a low inflation rates. Low inflation still is the prime policy objective in post-unification Germany, but the strong wage-push component of inflation, as well as the inflationary consequences of the growing budget deficits, have recently made inflation more difficult to contain.

French anti-inflation reputation is found to have been low and remained relatively low throughout the EMS due to higher French inflation. Double-digit inflation rates persisted throughout 1979 to early 1983, and the stringent austerity programme adopted after the March 1983 realignment succeeded in bringing inflation down to 3% in late 1987. Since then inflation roughly stayed at that level. The widespread adoption of foreign exchange controls thereby allowed France to circumvent many of the disciplinary effects of fixed exchange rates and enabled policymakers to effectively pursue an independent monetary policy. Deflation in

France was therefore largely home-made. After 1987 the convergence of inflation rates between Germany and France has been achieved by constant French inflation and a rise of German inflation. This suggests that the recent convergence of the EMS has involved two elements: France has belatedly embraced the hard option, whilst Germany has slightly mellowed its hard stance. Initially this resulted in a more stable system, but since the complete abolition of foreign exchange controls the tensions within the system grew again as countries contemplated the transition to economic and monetary union (EMU). Disputes over these issues have greatly destabilised the system despite a substantial degree of economic convergence.

Given the reputation of both major EMS countries for initially being hard or soft about inflation, the smaller EMS members were in principle free to choose amongst these alternative deflation scenarios offered by EMS membership.

The Netherlands entered the EMS with inflation rates only slightly above the levels of Germany. By late 1982 the Dutch central bank increases the credibility of its commitment to the German mark exchange rate and the positive inflation differential had disappeared. Throughout the remaining EMS period Dutch inflation closely follows that of Germany and counterinflation reputation in both countries was found to have been equally high. The Dutch disinflation process during the EMS period may therefore be explained by the hypothesis of borrowing reputation from the German Bundesbank via credible exchange rate policies. This is indicated by the credibility estimates from both the policy game and the target zone literature. In fact the closeness of discount rate announcements by the Nederlandsche Bank and the Bundesbank largely enhances the credibility of the Dutch exchange rate commitment.

Belgium, which maintained a very close bilateral exchange rate linkage with the Netherlands during the European currency snake system, also entered the EMS with inflation rates only slightly above those of Germany. However, in June 1982 the Belgian policy shift from credibly pegging to the Dutch guilder (and hence indirectly to the German mark) to adopting the soft currency option of credibly pegging to the French franc results in a rise of inflation to French levels. Thereafter Belgium and France experienced similar inflation performances and macroeconomic policies, which were dominated by direct price and wage controls and attempts to reduce the inflationary impacts of automatic wage indexation schemes. However, despite the decline in Belgium inflation during 1983-86, there was almost no convergence to the also declining German and Dutch inflation rates. The soft currency option of credibly pegging to the French franc in connection with the higher French inflation rates explains why Belgium despite its gain in counterinflation reputation could not disinflate more quickly. The more recent commitment to level pegging the German mark exchange rate, confirmed by Belgian participation in the so-called 'Euro-rounds' of discount rate changes, is associated with a gradual convergence of its inflation rate to German levels in the post-1987 period. Whilst some degree of exchange rate credibility has materialised, it is still far from being as credible as the Dutch-German link, as the speculative attacks during 1992-92 point out.

Denmark also entered the EMS with inflation rates lower than those in France. Inflation then jumped to French levels as a result of the second oil price shock just after the onset of the EMS and remained there for some time. During the deflation period 1982-1986 the inflation performances of Denmark and Belgium are almost identical, with an emphasis on wage de-indexation. Thus, the slow Danish disinflation

is in accord with its embracing of the soft currency option. There is less evidence of any possible recent shift towards the hard option. Denmark has only recently taken part in co-ordinated discount rate changes, and no particularly credible policy instrument was found.

The Irish disinflation experience was different from that of Belgium and Denmark. First the inflationary impact of the oil price increase in Ireland was massive. After a slight decline in 1980-81 Irish disinflation started in 1982 with the adoption of an austerity and fiscal consolidation programme. Tight fiscal policies and not taking advantage of the two EMS realignments in 1982 helped Ireland to reduce inflation from substantially by mid 1983. Between 1983 and early 1986 fiscal consolidation largely eliminated budget deficits and Irish inflation declined slowly along with the French rate. Throughout this time, credibly pegged exchange rates relative to the soft currency bloc in the EMS were maintained. After a period of weakness in mid-1986 and a drastic devaluation (-8%) in August 1986, the Irish pound switched to the hard currency bloc. Despite the reflationary impact of this drastic devaluation, inflation had declined to the low levels of Germany and the Netherlands by late 1989. The recent Irish participation in the co-ordinated discount rate changes has provided support for the new policy stance of containing inflation.

No credible form of intermediate monetary targeting has been detected for Italy. Whilst the Giavazzi and Spaventa (1989) hypothesis that exchange rate targets are more credible than monetary targets is verified, it does not follow that exchange rate targets have been credible. In fact, all Italian EMS exchange rate commitments have been non-credible, a finding is consistent with the trend movements of most Italian bilateral exchange rates throughout the EMS period. The most credible form of intermediate monetary targeting in Italy is interest rate targeting. Yet, even this strategy has not been implemented in a way consistent with fixed exchange rates, as indicated by the still prevailing interest rate and inflation differentials with the remaining EMS countries. In view of these findings it is not surprising that amongst all EMS countries Italy faced most problems during the 1992 EMS crisis, and was forced to leave the system.

4.3. Evidence about Target Zone Credibility

The various propositions about the distributions, variability and correlation between exchange rates and interest rate differentials in systems of fixed but adjustable exchange rate bands have been at the heart of a vastly growing empirical literature, which is briefly summarised below.

Empirical evidence regarding the relationship between interest rate differentials and exchange rates in the unilateral Swedish exchange rate target zone is provided in Svensson (1991b) for monthly data and in Lindberg and Söderlind (1991) for daily data. Svensson (1991b) estimates a linearized version of his model by regressing interest rate differentials of various maturity on the parity deviation of the exchange rate. The estimated slope coefficients exhibit the expected pattern of being negative and smaller for longer maturities. However, the fit between theory and data is far from perfect, and a strongly serially correlated component is left unexplained., as Bertola and Svensson (1991) note. Serious doubts about the empirical validity of

the standard target zone model for the Swedish data are raised in Lindberg and Söderlind (1991), who apply calibration methods to daily data and show that their results in most cases refute the standard target zone model.

For the EMS empirical evidence on the relationship between interest rate differentials and exchange rates is provided in Flood, Rose and Mathieson (1990), albeit without Svensson's theoretical framework. Flood, Rose and Mathieson (1990) find no compelling evidence of the type of non-linearities implied by standard target zone models.

Recent research has focused on second generation target zone models which incorporate realignment risks and devaluation expectations. Some empirical evidence based on this type of augmented target zone model is provided in Rose and Svensson (1991) and Svensson (1991d) for EMS exchange rates and interest rate differentials relative to Germany. Rose and Svensson (1991) show that adding fluctuating devaluation risk can reconcile some of the problems associated with early target zone models, which have only a single forcing variable, the fundamentals process. For more recent applications see Lindberg, Svensson and Söderlind (1991), Koen (1991), Weber (1991b, 1992a), Chen and Giovannini (1993) and Caramazza (1993). Svensson and Rose (1993) use the target zone framework to analyse the exchange rate crisis of September 1992. Before turning to the empirical evidence on the credibility of real world exchange rate target zone arrangements, it is instructive to take a closer look at the data.

4.3.1. Experiences with Target Zones

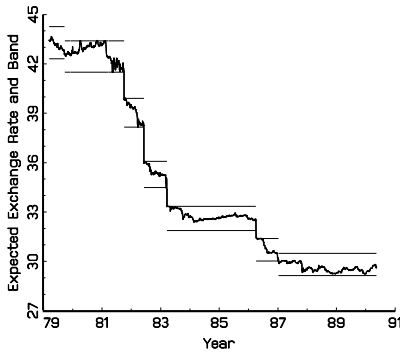
This present study will deal exclusively with the European Monetary System. Section 4.2.2.1 above already discussed the evolution of exchange rates of EMS and non-EMS countries between the Bretton Woods, the snake and the EMS period. The fluctuation bands played no role here. However, in the target zone framework the existence of currency bands has an important effect on the movements of exchange rates between these boundaries. Bands also have far-reaching implications for the relationship between interest rate differentials and the exchange rate's band position, and this should be reflected in the data.

The data used in this section are daily exchange rate and interest rate data for the period 13 March 1979 to 28 August 1990. The choice of the sample period deliberately excludes the more recent post-unification period, in order to avoid a sample selection bias. Such a bias would be implied if credibility effects were tested for in a sample containing the collapse of the exchange rate system. For a recent target zone study of the period prior to October 1992 see Rose and Svensson (1993).

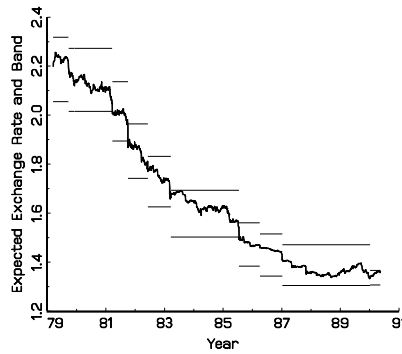
Figure 4.34 displays the German mark exchange rates of the initial EMS member countries. Several aspects about EMS realignment strategies can be seen from these six panels. The Dutch guilder exchange rate underwent only two realignments and is extremely stable by comparison with the remaining EMS currencies, in particular in the post-1983 period. At each realignment the guilder rate was set more or less at the centre of the band. The remaining EMS exchange rates were typically re-set to a position at the upper boundary of the band. This is a clear indication of the fact that policymakers did not expect these exchange rates to turn

Figure 4.34.
EMS Exchange Rates and Official Exchange Rate Bands
during the EMS Period

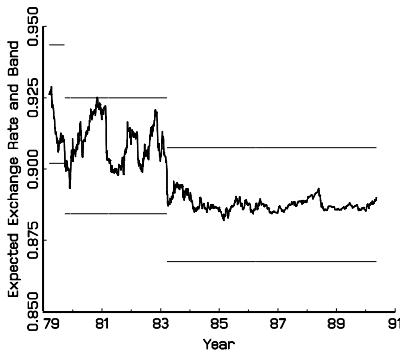
(a) FF/DM Rate, 13/03/79-16/05/90



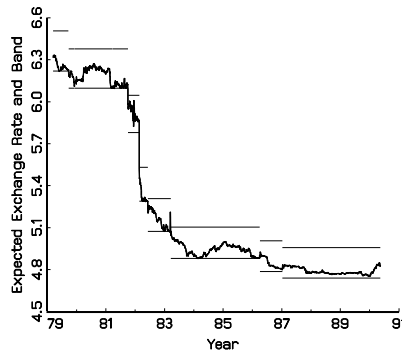
(b) Lit/DM Rate, 13/03/79-16/05/90



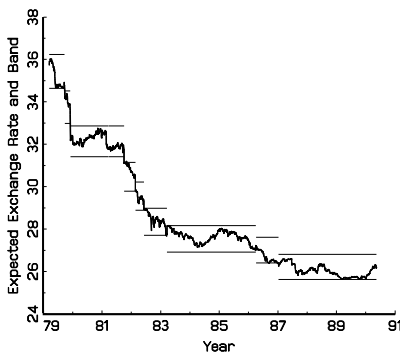
(c) Hfl/DM Rate, 13/03/79-16/05/90



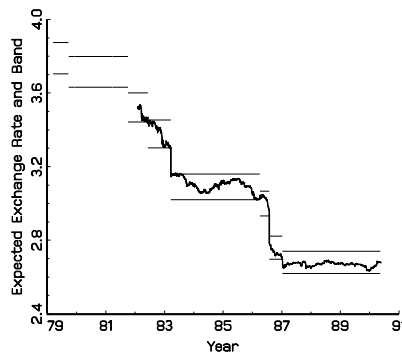
(d) Bfr/DM Rate, 13/03/79-16/05/90



(e) Dkr/DM Rate, 13/03/79-16/05/90



(f) IrL/DM Rate, 13/03/79-16/05/90



more stable after the realignment, as no room was allowed for these currencies to appreciate against the mark. This may signal a serious lack of target zone credibility.

Figure 4.35 displays the exchange rate's band position against one-month Euro interest rate differentials. These off-shore interest rates are much more volatile than the domestic interest rates analysed above, because in the early EMS period central banks heavily relied on foreign exchange controls in order to insulate domestic rates from speculative attacks. However, these speculative runs clearly show up in the off-shore interest rate differentials. The French and Italian Euro rate differentials with respect to Germany were frequently above ten percent, and in some cases rose as high as 35 percent per year. With the exception of the Netherlands, interest rate differentials thereby typically were one-sided, with German rates being lower. The same pattern has been established above for the interest rate differentials between domestic short-term and long-term rates.

At a purely descriptive level, the postulated deterministic inverse relationship between interest rate differentials and the exchange rate's band position appears not to be supported by the data. Rather, the first visual impression is that interest rate differentials and exchange rates are positively correlated. This again points towards a lack of target zone credibility.

Another obvious fact from Figure 4.35 is that EMS realignments, that is, changes of the central parity, typically coincide with over proportional jumps in the relative band position of the exchange rate. But these jumps in exchange rates are only occasionally mirrored by corresponding jumps in the interest rate differentials, indicating that some realignments came as a surprise. Furthermore, most of the large interest rate differentials occur in the first half of the EMS period. Typically currencies were then weak against the mark and high interest rate differentials signal high devaluation expectations. This fact is in sharp contrast to the assumptions of the simple, fully credible target zone model, which predicts an inherent stabilisation effect.

4.3.2. Estimates of the Credibility of Exchange Rate Target Zones

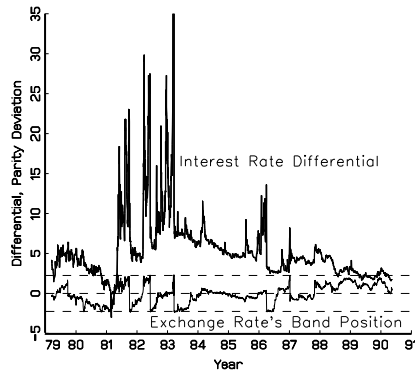
First generation standard target zone model assume perfect credibility, whilst augmented target zone models allow for imperfect credibility and devaluation risks. Second generation target zone models explicitly introduce devaluation expectations as a second state variable. Before turning to these more recent models, the issue of target zone credibility is discussed by confronting the predictions of the more simple fully credible target zone model with those models which assume imperfect credibility. These models only allow indirect inference about target zone credibility by evaluating the relevance of propositions 3.1 to 3.7 (4.1 to 4.7) for the model with perfect (imperfect) target zone credibility.

4.3.2.1. Indirect Evidence on Target Zone Credibility

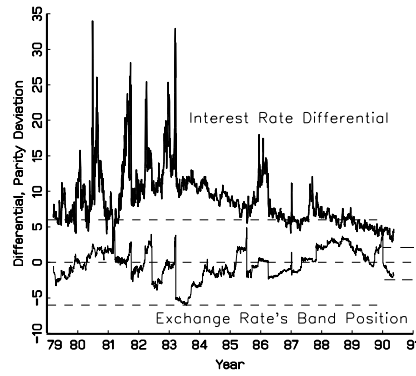
This section presents a number of non-parametric test statistics on the probability distributions, the variability and the correlation between the exchange rate's band position and interest rate differentials. I view this analysis as a systematic way of

Figure 4.35.
EMS Parity Deviations of DM Exchange Rates and Corresponding
One Month Interest Rate Differentials

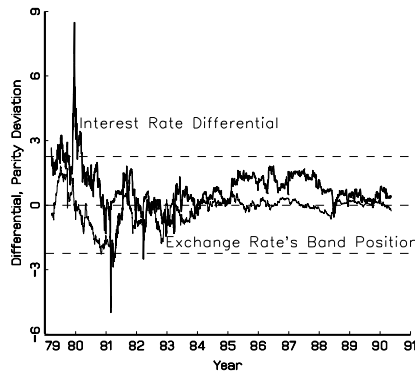
(a) France-Germany



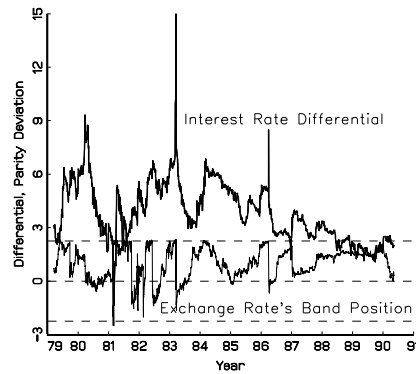
(b) Italy-Germany



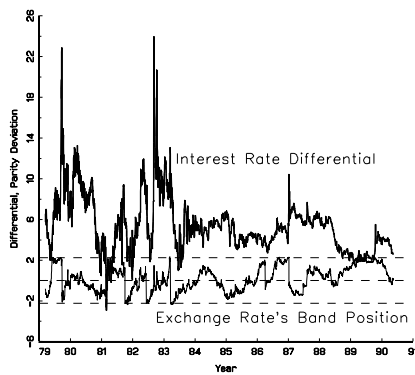
(c) Netherlands-Germany



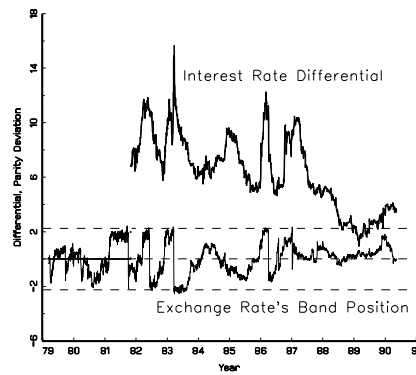
(d) Belgium-Germany



(e) Denmark-Germany



(f) Ireland-Germany



comparing the characteristics of the exchange rate and interest rate data across EMS countries, and not as some formal test.

Figure 4.36 displays the probability density distributions of exchange rates within the band. The fully credible target zone model predicts a U-shaped distribution with exchange rates being more frequently at the edges of the band (proposition 3.2). All six panels of Figure 4.36 reject this proposition. EMS exchange rates tended to be more frequently in the middle of the band. The Dutch guilder exchange rate is an extreme example for this. On the other hand, the Danish krona exchange rate was quite uniformly distributed over the band.

Figure 4.37 describes the variability of exchange rates within the band. Perfectly credible target zone models predict an inherent stabilisation effect, with most variability in the middle of the band and low variability at the boundaries (proposition 3.3). All six panels of Figure 4.37 reject this conjecture. As suggested in the model of imperfect target zone credibility exchange rate variability is typically high at the edges of the band. This is particularly obvious for France, Italy and Belgium. Except for the extreme variability at the edges, exchange rate variability otherwise is relatively uniform across the band, as predicted by the random walk hypothesis of exchange rates under a free float. EMS exchange rate bands thus do not seem to have any great stabilising effects. Rather, the extreme variability at the edges of the bands points towards some degree of destabilising speculation as exchange rates approach the boundaries of the bands.

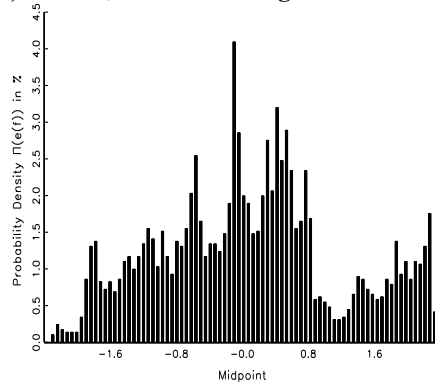
Figure 4.38 displays the probability distributions of 12-month Euro interest rate differentials between EMS countries and Germany. The fully credible target zone model predicts bimodal U-shaped distributions (proposition 3.6). All six panels of Figure 4.38 point more towards unimodal distributions, with more mass concentration around intermediate levels of interest rate differentials. The only minor exception is the Netherlands where some weak indication of bimodality can be found. In most cases, however, the data appear to reject the predictions of the fully credible target zone model.

Figure 4.39 shows the variability of interest rate differentials in EMS countries. The fully credible target zone model predicts that most variability should occur for intermediate levels of interest rate differentials (proposition 3.7). Such a unimodal relationship with high variability at intermediate levels of interest rate differentials is clearly rejected by all six panels of Figure 4.39. For the Netherlands the relationship is obviously U shaped, with high variability occurring at both high and low levels of interest rate differentials. For the remaining EMS countries high variability coincided with high levels of interest rate differentials. The data therefore largely refute the fully credible target zone model.

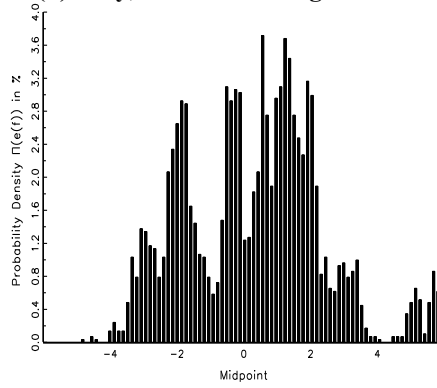
Figure 4.40 indicated the relationship between interest rate differentials and the exchange rate's band position. Fully credible target zone models derive a negative relationship (proposition 3.5). The six panels of Figure 4.40 display no clear pattern. For France, Denmark and Ireland no obvious relationship exists. For Italy and Belgium there is some weak indication of a negative correlation on average, whilst for the Netherlands a slightly positive relationship is suggested. The pattern in the data is, however, not very systematic, and it is difficult to say anything about the relevance of the standard target zone model based on this diffuse evidence.

Figure 4.36.
Probability Distributions of EMS Exchange Rates within the
Fluctuation Band (in %)

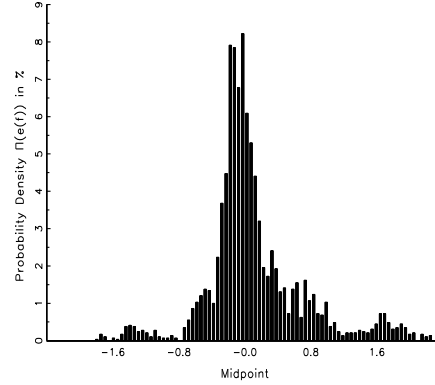
(a) France, Jan. 1979- Aug. 1990



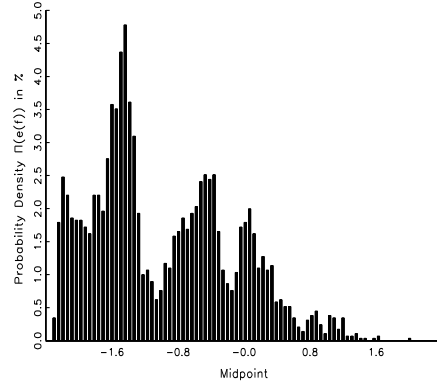
(b) Italy, Mar. 1979- Aug. 1990



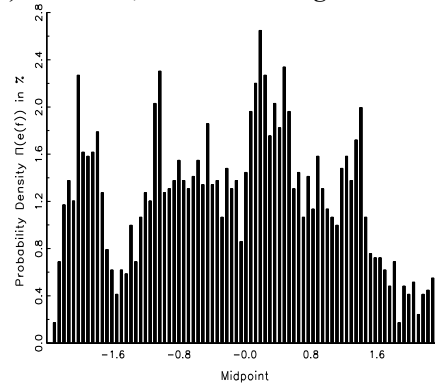
(c) Netherlands, Mar. 1979- Aug. 1990



(d) Belgium, Mar. 1979- Aug. 1990



(e) Denmark, Mar. 1979- Aug. 1990



(f) Ireland, Jan. 1982- Aug. 1990

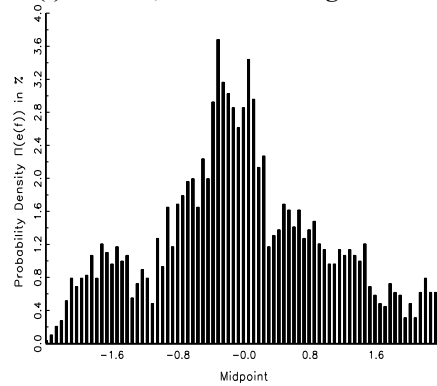
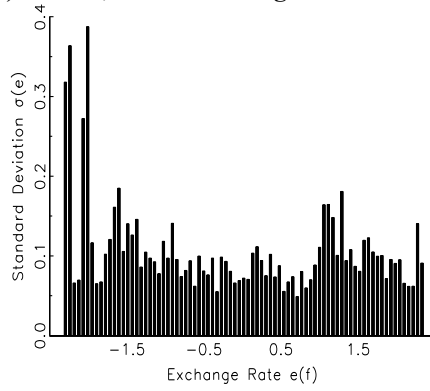
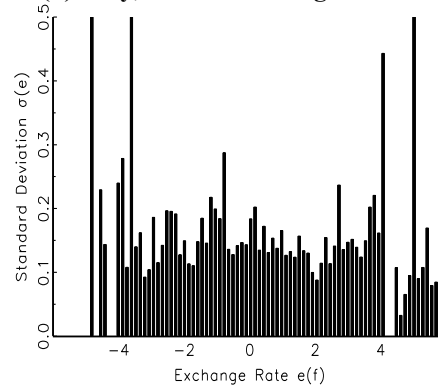


Figure 4.37.
Variability of EMS Exchange Rates within the Fluctuation Band
(Standard Deviation)

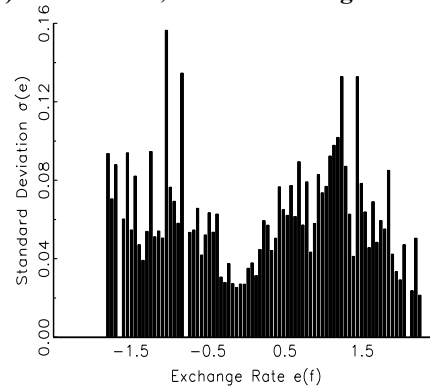
(a) France, Jan. 1979- Aug. 1990



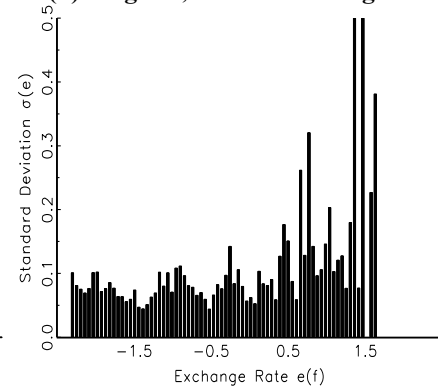
(b) Italy, Mar. 1979- Aug. 1990



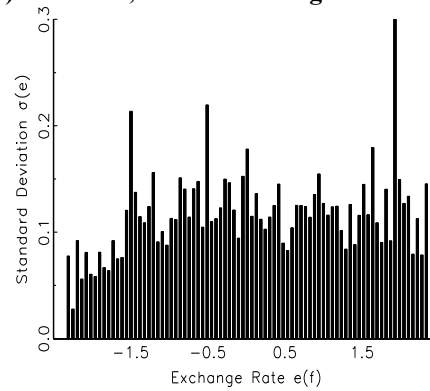
(c) Netherlands, Mar. 1979- Aug. 1990



(d) Belgium, Mar. 1979- Aug. 1990



(e) Denmark, Mar. 1979- Aug. 1990



(f) Ireland, Jan. 1982- Aug. 1990

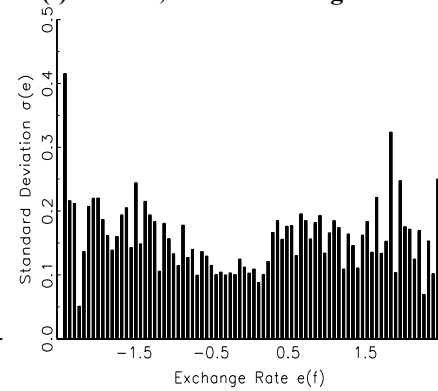
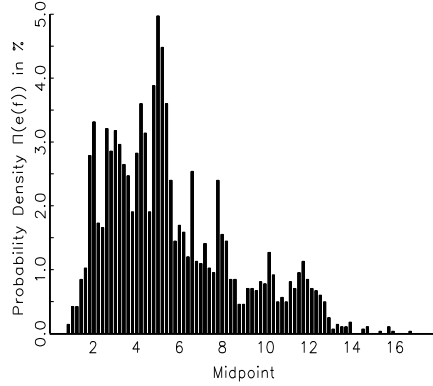
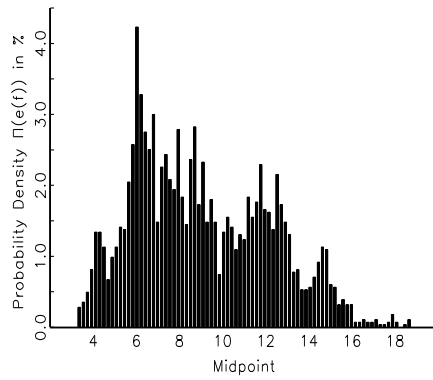


Figure 4.38.
Probability Density Distribution of 12-Month
Interest Rate Differentials (in %)

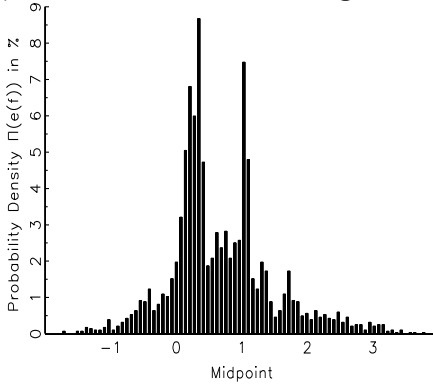
(a) France, Jan. 1979- Aug. 1990



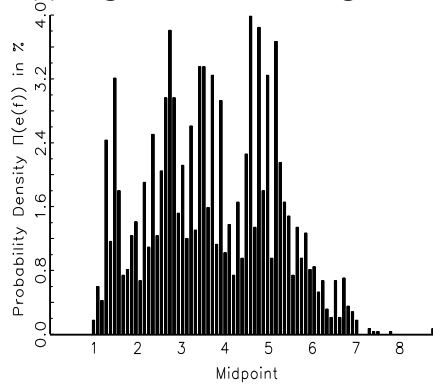
(b) Italy, Mar. 1979- Aug. 1990



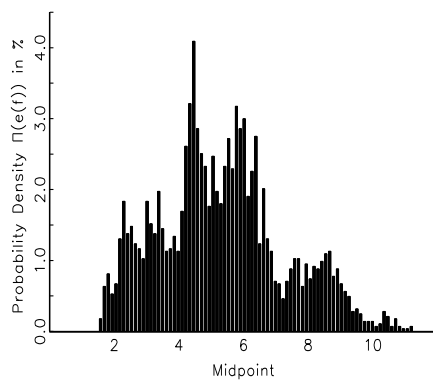
(c) Netherlands, Mar. 1979- Aug. 1990



(d) Belgium, Mar. 1979- Aug. 1990



(e) Denmark, Mar. 1979- Aug. 1990



(f) Ireland, Jan. 1982- Aug. 1990

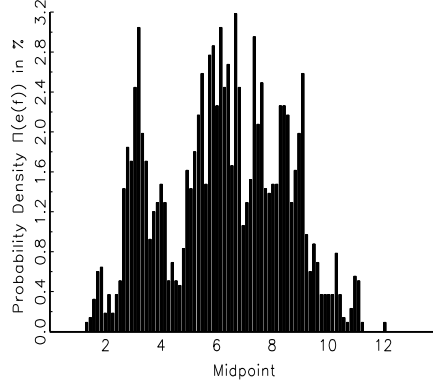
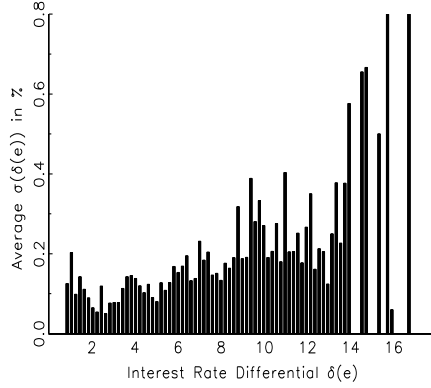
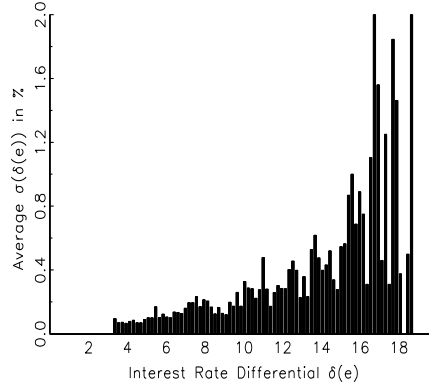


Figure 4.39.
Variability of 12-Month Interest Rate Differentials
(Standard Deviation)

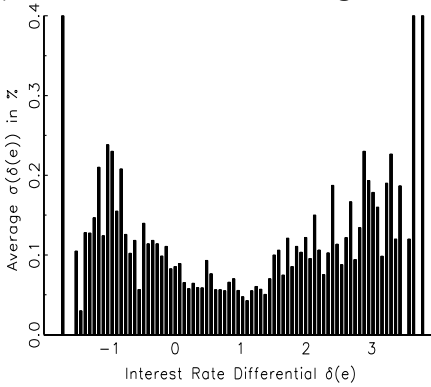
(a) France, Jan. 1979- Aug. 1990



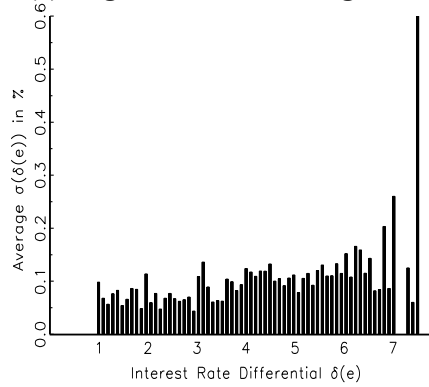
(b) Italy, Mar. 1979- Aug. 1990



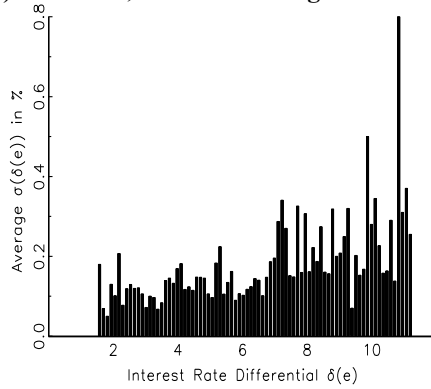
(c) Netherlands, Mar. 1979- Aug. 1990



(d) Belgium, Mar. 1979- Aug. 1990



(e) Denmark, Mar. 1979- Aug. 1990



(f) Ireland, Jan. 1982- Aug. 1990

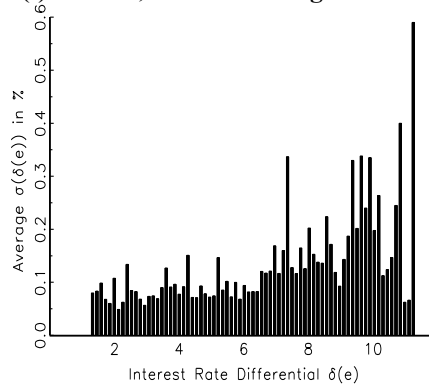
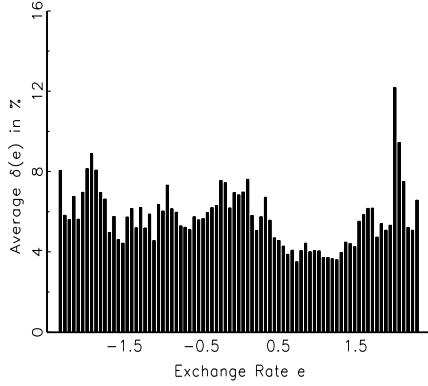
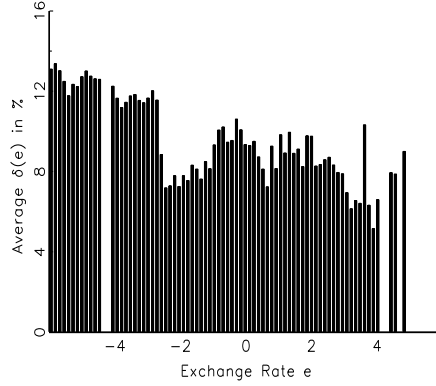


Figure 4.40
Relationship Between 12-Month Interest Rate Differentials
and the Exchange Rate's Position in the Band

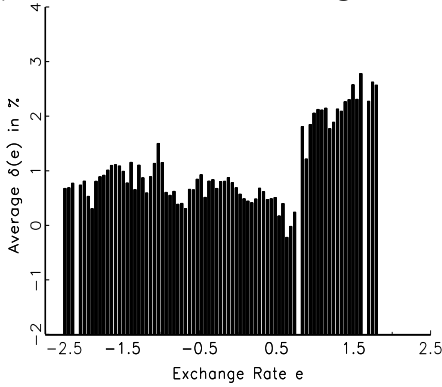
(a) France, Jan. 1979- Aug. 1990



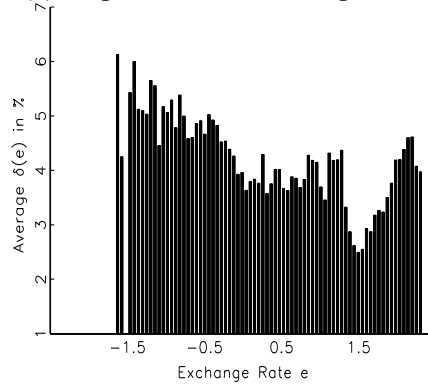
(b) Italy, Mar. 1979- Aug. 1990



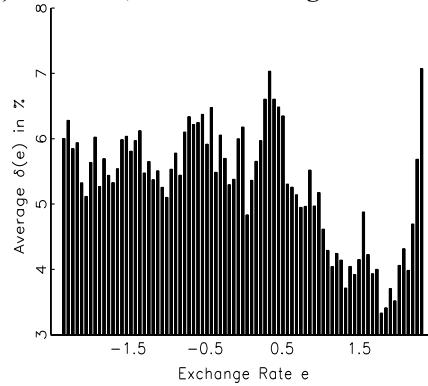
(c) Netherlands, Mar. 1979- Aug. 1990



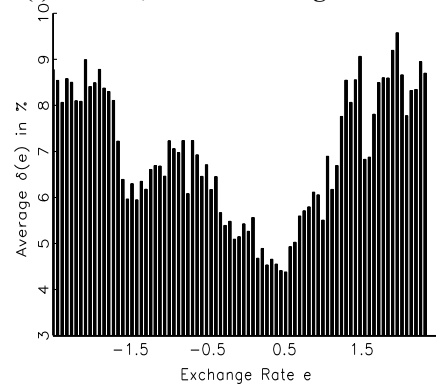
(d) Belgium, Mar. 1979- Aug. 1990



(e) Denmark, Mar. 1979- Aug. 1990



(f) Ireland, Jan. 1982- Aug. 1990



To summarise, the informal evidence discussed above raises serious doubts about the ability of the standard target zone model to resemble the stylised facts of the evolution of exchange rates and interest rate differentials in the EMS.

4.3.2.2. Direct Evidence on Target Zone Credibility

Augmented target zone models focus on time-varying expected devaluation rates as the major factor in explaining the time-varying wedge between interest rate differentials and the exchange rate's band position in Figure 4.35. Svensson (1991a) proposes a 'simple test' of target zone credibility by assuming that expected devaluation rates are identical to interest rate differentials. In this case a 'simple credibility test' can be constructed by calculating the expected exchange rate implied by interest rate differentials of a given maturity, and plotting that rate against the prevailing exchange rate bands. The problem with this test is that it makes no distinction between expected parity changes and expected exchange rate changes. Svensson (1991d), Svensson and Rose (1991, 1993) and Lindberg, Svensson and Söderlind (1991), amongst others, apply the so-called 'drift adjustment' method for obtaining estimates of expected parity changes and devaluation rates. In Weber (1991a,c) an alternative approach to estimating devaluation expectations based on time-varying parameter regression is explored. As in the 'drift adjustment' method, the derivation of devaluation expectations in Weber (1992a) accounts for the possibility of infra-band exchange rate movements. Since both methods yield very similar results, the analysis below will focus on Svensson's (1991a) 'simple' test and on the time varying parameter approach proposed in Weber (1992b).

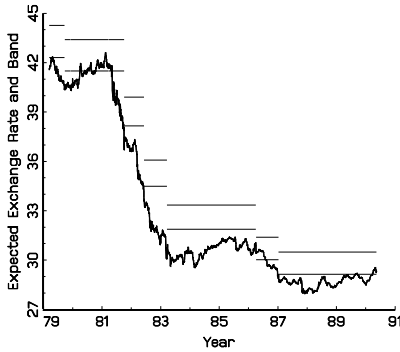
4.3.2.2.1. Svensson's 'Simple' Credibility Test

Before turning to the details of these devaluation expectation estimates, some less formal evidence on target zone credibility will be provided by computing Svensson's (1991a) 'simple test'. Figures 4.41 and 4.42 display the 'simple test' for twelve-month and one-month interest rate differentials respectively. These tests, which are reported in Flood, Rose and Mathieson (1990) clearly indicate that, with the exception of the Dutch guilder rate, EMS exchange rate target zones have completely lacked credibility at the twelve months horizon, as almost none of the expected exchange rates one year ahead lies within the boundaries of the exchange rate bands. Only as late as 1990 is an increase in target zone credibility noticeable. The analysis of policy credibility in the sections above strongly suggests that this is due to rising German inflation and interest rates in the aftermath of unification. The Dutch guilder exchange rate target zone, on the other hand, possesses credibility well beyond the one year horizon. This finding again strongly suggests that only Germany and the Netherlands may be viewed as members of a credible DM-zone in the EMS.

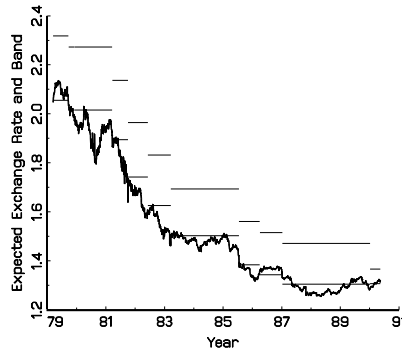
In Figure 4.42 the credibility of the expected exchange rates at the one month horizon point towards another interesting EMS phenomenon. Many of the early EMS realignments were preceded by short periods of sizeable devaluation expectations which indicate substantial speculation over a realignment within the next month. This feature of the data vanishes in the more recent EMS realignment periods, indicating an increase in short-term target zone credibility.

Figure 4.41
Expected Twelve Month Ahead EMS Exchange Rates
and Official Exchange Rate Bands during the EMS Period

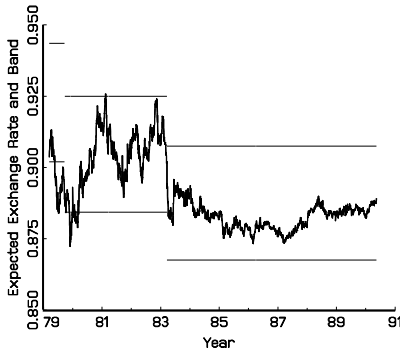
(a) FF/DM Rate, 13/03/79-16/05/90



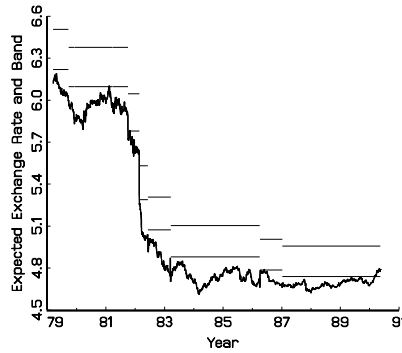
(b) Lit/DM Rate, 13/03/79-16/05/90



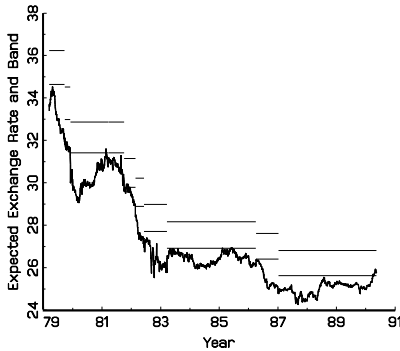
(c) Hfl/DM Rate, 13/03/79-16/05/90



(d) Bfr/DM Rate, 13/03/79-16/05/90



(e) Dkr/DM Rate, 13/03/79-16/05/90



(f) IrL/DM Rate, 13/03/79-16/05/90

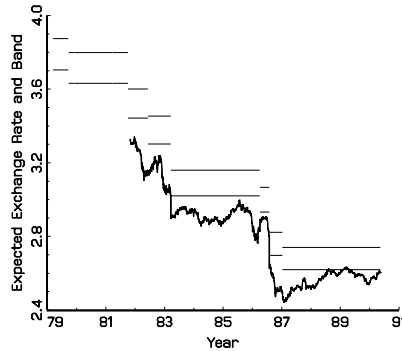
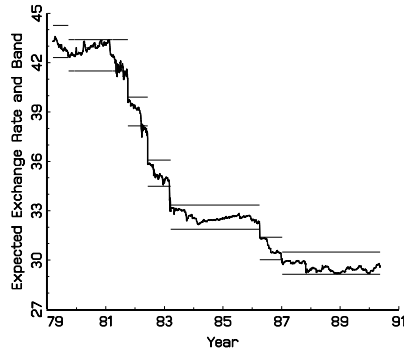
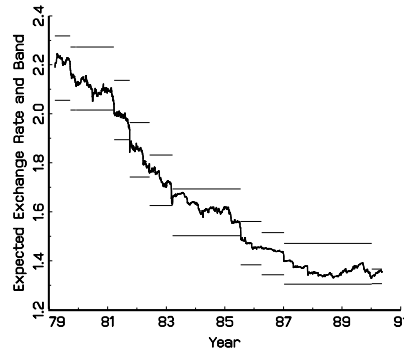


Figure 4.42.
Expected One Month Ahead EMS Exchange Rates
and Official Exchange Rate Bands during the EMS Period

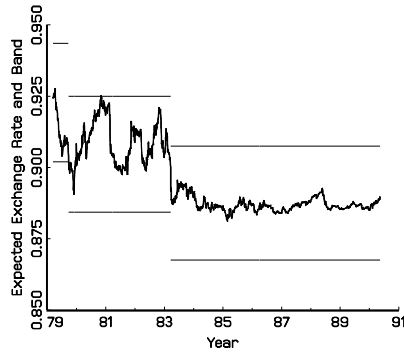
(a) FF/DM Rate, 13/03/79-16/05/90



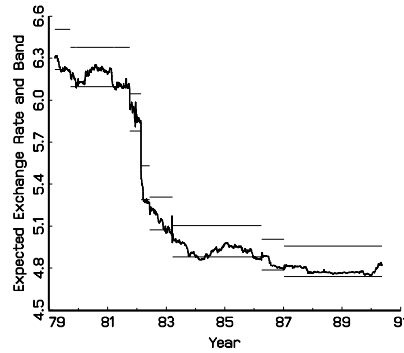
(b) Lit/DM Rate, 13/03/79-16/05/90



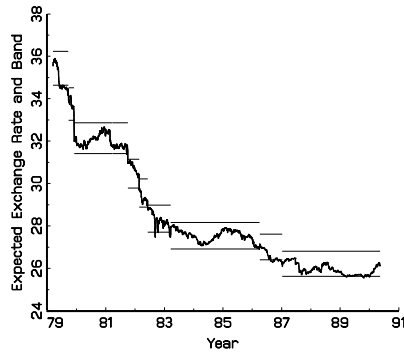
(c) Hfl/DM Rate, 13/03/79-16/05/90



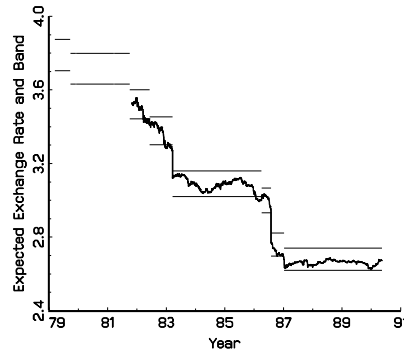
(d) Bfr/DM Rate, 13/03/79-16/05/90



(e) Dkr/DM Rate, 13/03/79-16/05/90



(f) IrL/DM Rate, 13/03/79-16/05/90



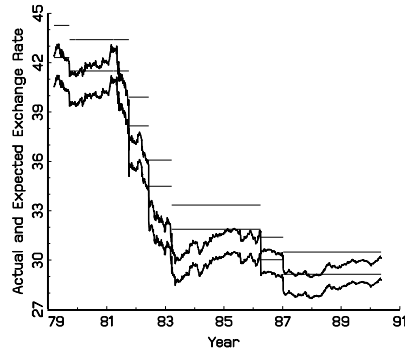
The problem with the 'simple test' of Svensson (1991a) is that it implicitly assumes that the band position of the exchange rate will not change over the maturity horizon for which exchange rate expectations are calculated. In Weber (1992c) I have proposed an alternative test, which accounts for the possibility of favourable within-band exchange rate changes. This produces a more conservative test. The 'modified simple test' consists of plotting the expected boundaries of the exchange rate band against the officially prevailing ones and then judging credibility by the percentage area of overlap. Figures 4.43 and 4.44 display the official and expected bands implied by twelve-month and one-month interest rate differentials respectively. Figure 4.45 displays the corresponding credibility estimates in terms of the percentage overlap of both bands for the two-day, one-month and twelve-month time horizon. Several interesting aspects should be mentioned. First, credibility no longer must be viewed as a (0,1)-variable. For example, Figure 4.43 indicates that the EMS exchange rate target zone no longer have completely lacked credibility at the twelve month horizon. Rather, a limited degree of credibility has been present during the period of weakness of the German mark in 1981 and during the post 1986 German reflation period. After German unification EMS target zone credibility is relatively high in all EMS countries, and almost perfect in the case of the Netherlands. This result is consistent with the findings of Rose and Svensson (1993). Figure 4.43 also indicates that the credibility of the Dutch-German exchange rate target zone has been high but until recently far from being perfect. This was impossible to detect by using the 'simple test' of Svensson (1991a). Another advantage of the modified test proposed here is obvious from Figure 4.44, as it is now relatively easy to see that most of the early EMS realignments, in particular with respect to the French franc, did not come unexpectedly. Finally, Figure 4.45 provides a convenient normalisation of the modified tests for target zone credibility by calculating the percentage overlap of expected and actual fluctuation bands. A clear rating of target zone credibility with respect to the one-year time horizon emerges: German mark exchange rate target zones were predominantly credible for the Netherlands, followed by Belgium. Much less credibility is found for Denmark and France, and Ireland and Italy almost completely lacked credibility until recently. This informal evidence about the credibility of the DM target zones suggest that whilst recently some gains in credibility have been materialised, the EMS by mid-1990 was still far from being a system of credible exchange rate target zones.

4.3.2.2.2. Target Zone Credibility and Estimates of Devaluation Expectations

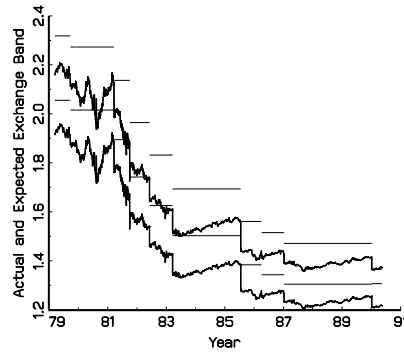
Having described the less formal evidence provided by a variety of 'simple' credibility tests, I now turn to the more formal evidence about expected devaluation rates. The procedure used in the present study is based on the time-varying parameter regression approach outlined in section 3. Time-varying parameter regression extracts a measure of the unobservable expected devaluation rates from data on interest rate differentials and exchange rate parity deviations in the EMS. This measure corresponds to the intercept estimate in a regression of interest rate differentials on a constant and the exchange rate's band position. The important point here is that the coefficient of the intercept term is allowed to be time-varying, rather than being constant. Postulating that the evolution of the intercept coefficient and hence devaluation expectations are

Figure 4.43.
Actual and Expected Twelve Month Ahead EMS Exchange Rate Bands
during the EMS Period

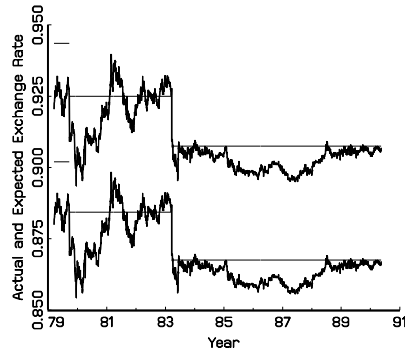
(a) FF/DM Rate, 13/03/79-16/05/90



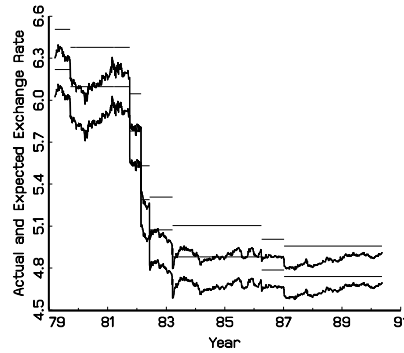
(b) Lit/DM Rate, 13/03/79-16/05/90



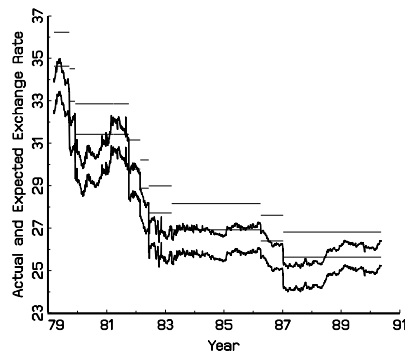
(c) Hfl/DM Rate, 13/03/79-16/05/90



(d) Bfr/DM Rate, 13/03/79-16/05/90



(e) Dkr/DM Rate, 13/03/79-16/05/90



(f) IrL/DM Rate, 13/03/79-16/05/90

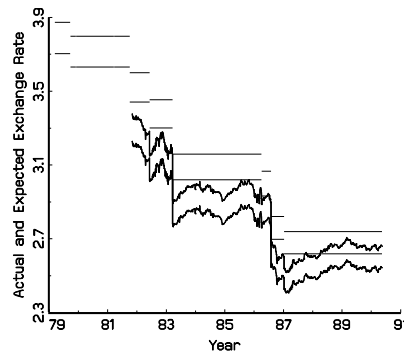
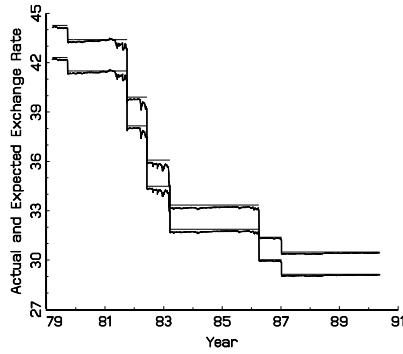
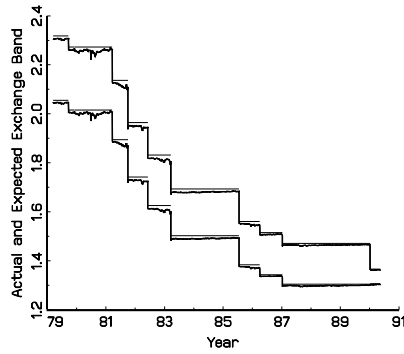


Figure 4.44.
Actual and Expected One Month Ahead EMS Exchange Bands
during the EMS Period

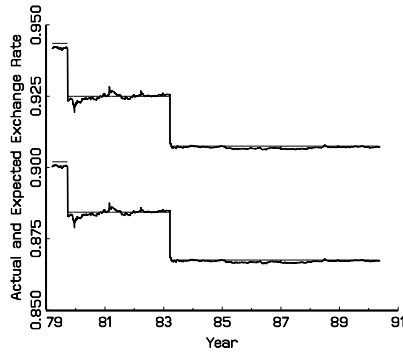
(a) FF/DM Rate, 13/03/79-16/05/90



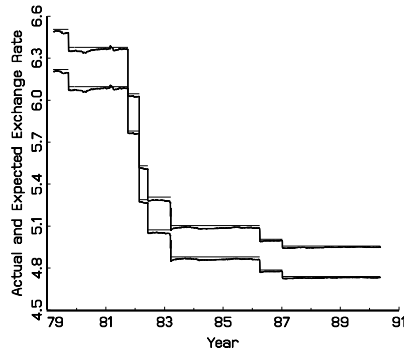
(b) Lit/DM Rate, 13/03/79-16/05/90



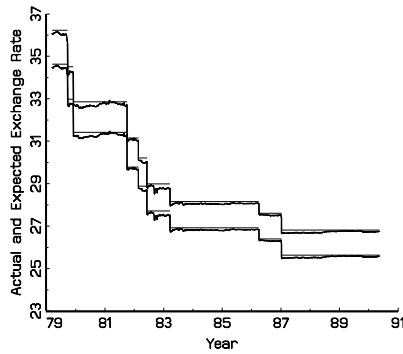
(c) Hfl/DM Rate, 13/03/79-16/05/90



(d) Bfr/DM Rate, 13/03/79-16/05/90



(e) Dkr/DM Rate, 13/03/79-16/05/90



(f) IrL/DM Rate, 13/03/79-16/05/90

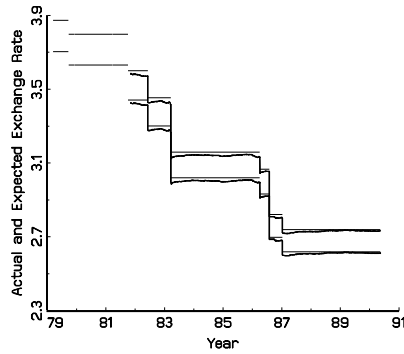
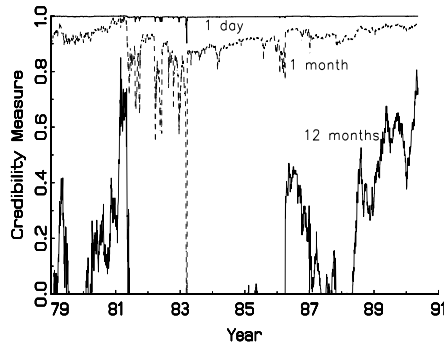
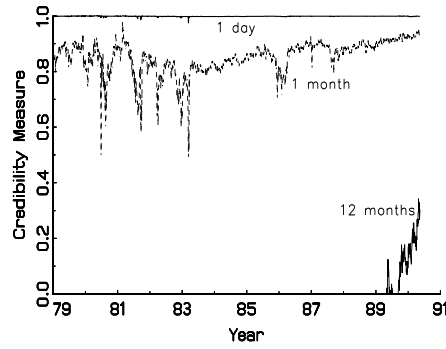


Figure 4.45
'Simple Estimates' of EMS Target Zone Credibility
for Various Time-Horizons

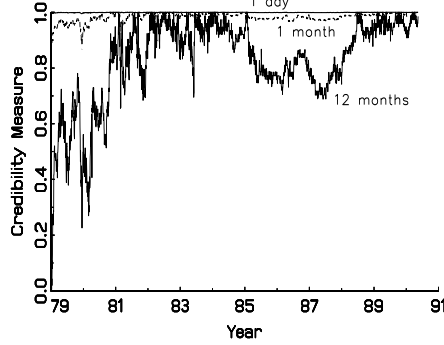
(a) France-Germany



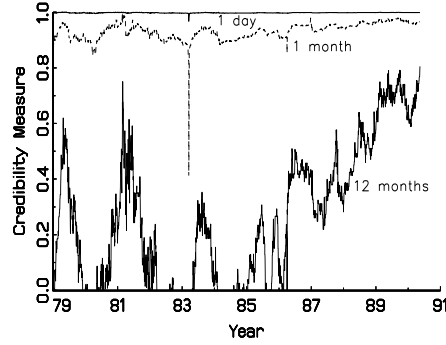
(b) Italy-Germany



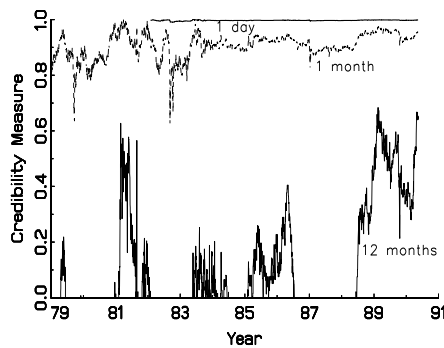
(c) Netherlands-Germany



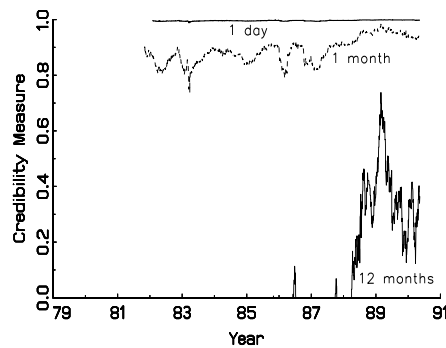
(d) Belgium-Germany



(e) Denmark-Germany



(f) Ireland-Germany



driven by a mixture of transitory and permanent shocks then results in a time-varying estimate of expected devaluation rates, which corresponds to that part of interest rate differentials not explained by infra-band movements of exchange rates.

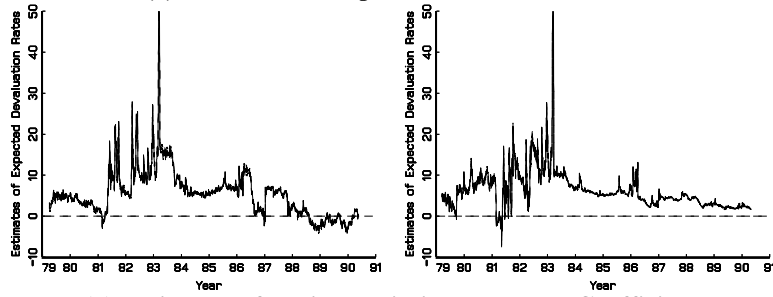
The evidence obtained from this analysis, to be discussed in detail below, shows that whilst no apparent relationship exists between actual interest rate differentials and the exchange rate's band position, as is commonly found in the literature, a clear and relatively noise-free empirical relationship can be derived after adjusting interest rate differentials for time-varying expected devaluation rates. In the fully credible target zone model these expected devaluations are assumed to be zero. The finding that devaluation expectations have declined significantly over the EMS period may thus be interpreted as evidence of an increase in the credibility of EMS exchange rate target zones. This increase in credibility does not, however, imply that target zone credibility have achieved sufficient credibility for the predictions of the fully credible target zone model to be true, as will be discussed below.

The estimates of expected devaluation rates are displayed in Figures 4.46 to 4.48, together with the estimates of the slope estimate of the correlation between interest rate differentials and parity deviations, the probability of transitory parameter variation and the standardised prediction errors, both for forward and backward regressions.¹⁸

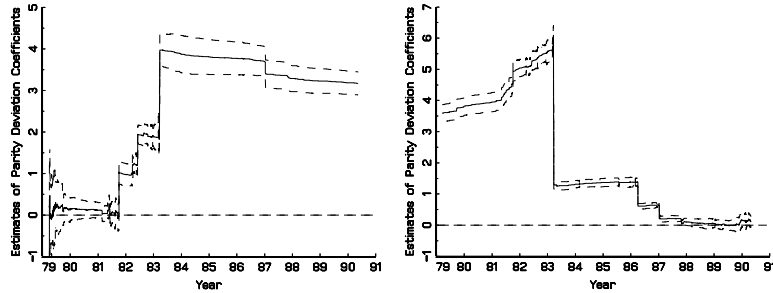
As in the paper by Rose and Svensson (1991), the expected rate of devaluation implied by the French-German one month interest rate differentials is displayed in Figure 4.46. The forward estimates in the upper left panel of Figures 4.46 are highly correlated with the interest rate differential, especially when the interest rate differential takes extreme values in the first half of the EMS period. The estimates of expected devaluation rates are almost indistinguishable from the corresponding estimates in Rose and Svensson (1991), despite being derived by using a completely different approach: as in the Rose and Svensson (1991) paper, zero or even negative expected rates of devaluation are found for the second half of the EMS period, and towards the end of the sample the expected devaluation rates are generally more variable than the relatively stable interest rate differentials. The backward estimates, on the other hand, are consistently positive and much less variable in the late EMS period, and track interest rate differentials quite closely. In both cases the estimates of expected devaluation rates decline substantially after 1983, indicating a move to more credible target zones. The coefficients of the exchange rate's parity deviations, shown in the second panel of Figure 4.46, have positive signs throughout the sample period and are significantly different from zero for the post-1982 period, as indicated by the confidence intervals. These positive coefficients point towards a non-credible target zone. The evolution of these coefficients further appears to be correlated with the exchange rate, since permanent jumps occur at each of the devaluation dates. The increasing positive correlation between the interest rate differential (for a given maturity) and the band position of the exchange rate may thereby be taken as an indication of a stepwise erosion of credibility, which diminishes with each realignment. Justification for this interpretation may be found by referring to the simulation results of Bertola and Svensson (1991), who show that increased devaluation risk *ceteris paribus* implies steeper slope coefficients. Another finding is that the probability of transitory parameter variation, as shown in the third panel of Figures 4.46, has frequently taken non-zero values in the pre-1983 EMS period, and

Figure 4.46.
Forward (Left) and Backward (Right) Estimation Results for
French-German Interest Rate Differentials

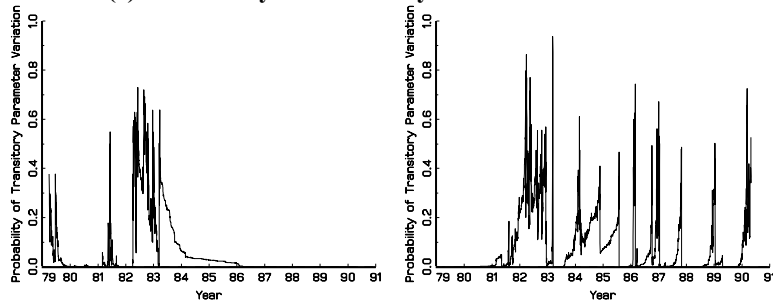
(a) Estimates of Expected Devaluation Rate



(b) Estimates of Parity Deviation Response Coefficient



(c) Probability of Transitory Parameter Variation



(d) Standardized Regression Residuals

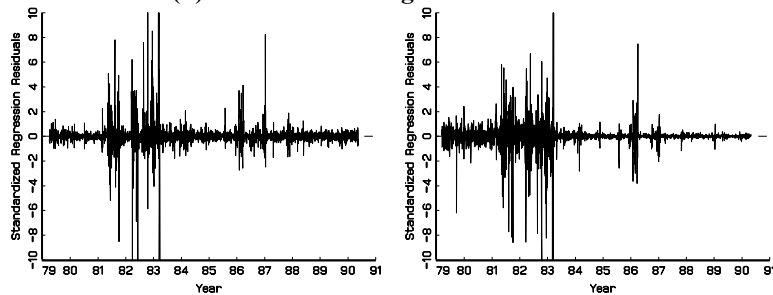


Figure 4.47.
Forward (Left) and Backward (Right) Estimation Results
for Italian-German Interest Rate Differentials

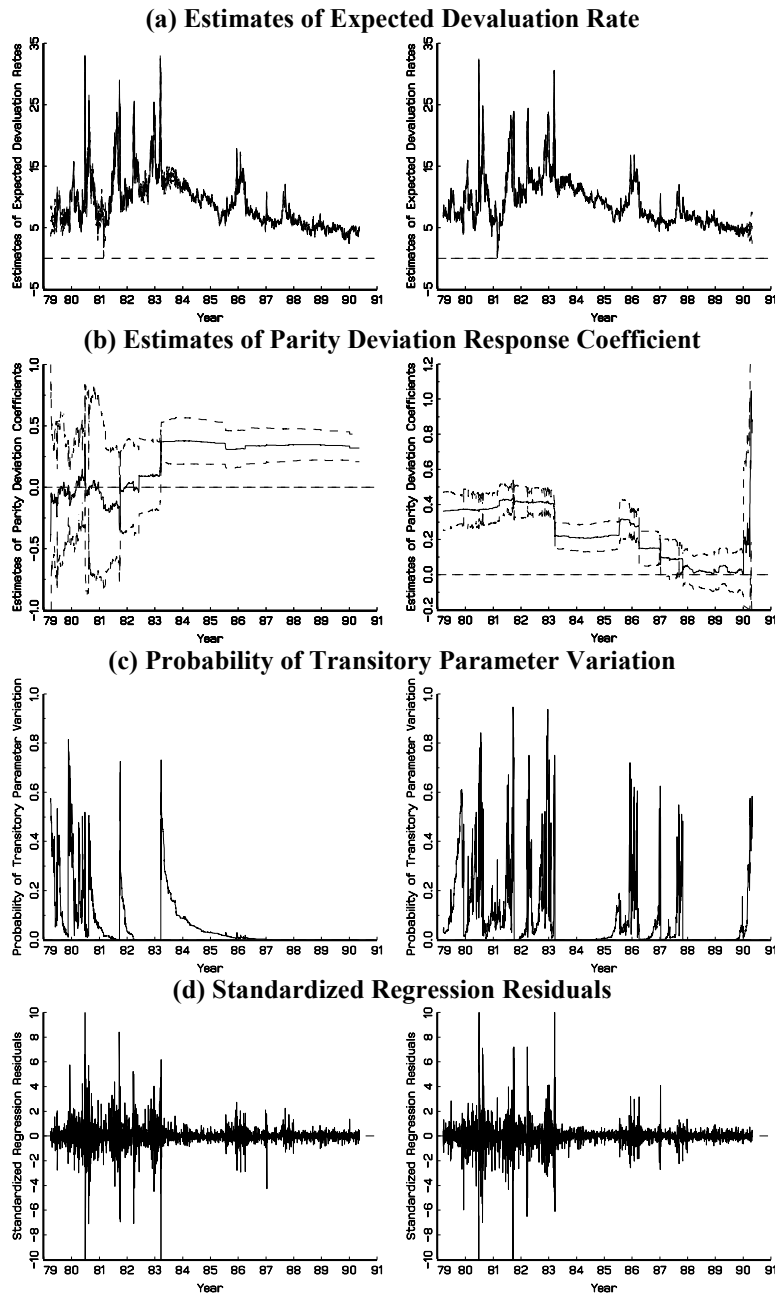
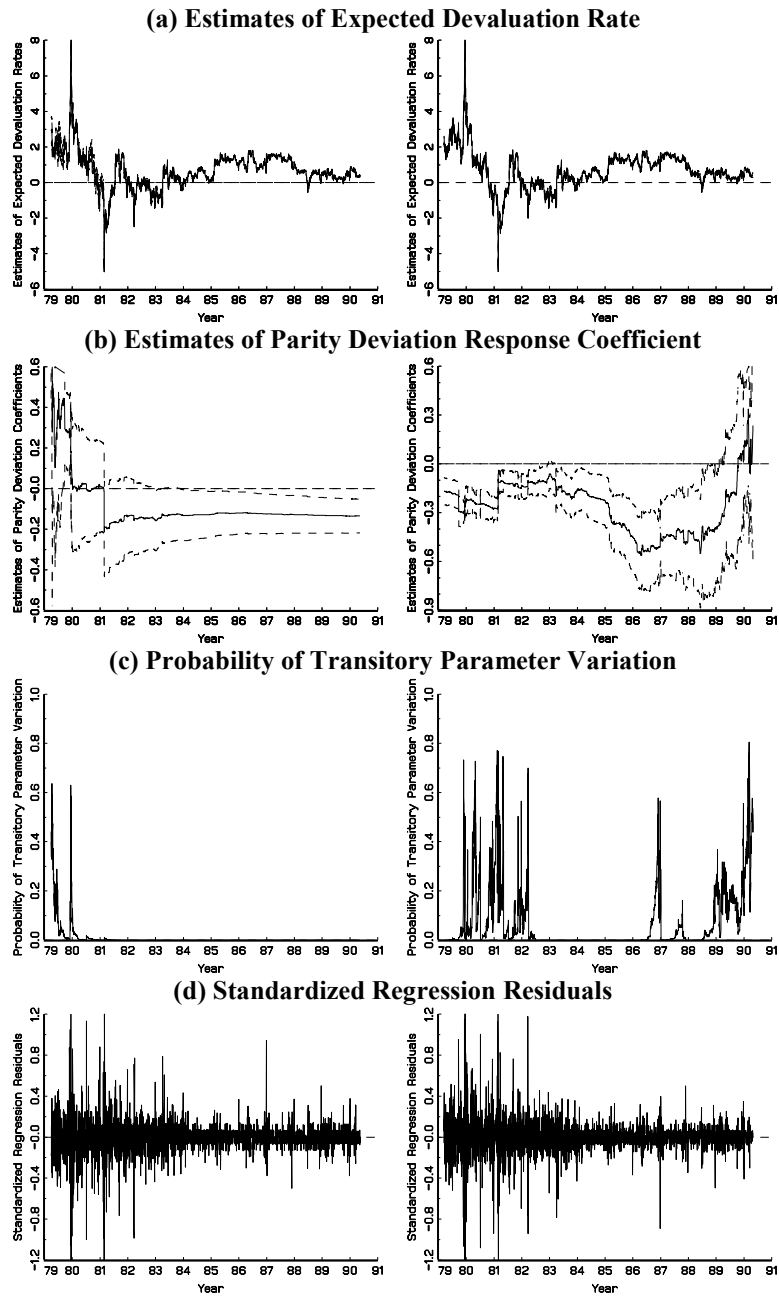


Figure 4.48.
Forward (Left) and Backward (Right) Estimation Results
for Dutch-German Interest Rate Differentials



that this feature has vanished recently. This points towards less speculative attacks and increased target zone credibility. For the post-1990 sample period Svensson and Rose (1993) show that few changes in these conclusions occur until immediately before the ERM crisis of September 1992. They interpret this as evidence that the credibility crisis in the EMS appears to have been largely unexpected.

The results for Italy and the Netherlands in Figures 4.47 and 4.48 are close in spirit to those of France. In each case significant positive slope estimates are obtained in the forward regressions for the post-1983 EMS period, whilst in the backward regressions the slope estimates typically decline towards the late EMS period and are frequently not significantly different from zero towards the end of the sample. This finding is in keeping with the view that the DM exchange rate target zones in the EMS have recently become more credible, and that the speculative attacks on the non-credible target zones from the early EMS period have mostly vanished. This is largely consistent with the results from the 'simple' target zone credibility tests above and the evidence reported in Svensson and Rose (1993).

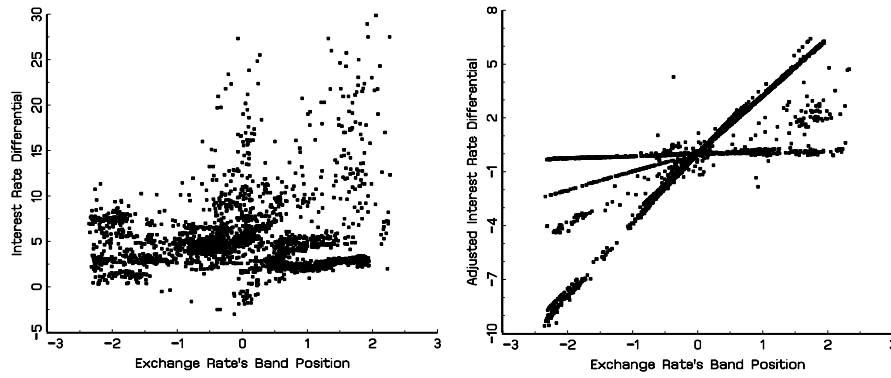
The Dutch-German exchange rate represents the only exception from the above pattern, as is pointed out in Figure 4.48. In both forward and backward regressions a significantly negative estimate of the slope coefficient is obtained for most of the sample period, pointing towards a credible target zone. At the same time the estimates of expected devaluation rates are the lowest of all countries considered, which conforms with the existence of a relatively credible target zone. The striking difference between the Dutch-German and the remaining DM exchange rate target zones within the EMS strongly supports the evidence reported above in the policy game context. Weber (1991a) points out that owing to the bipolar functioning of the EMS, only Germany and the Netherlands appear to have formed a credibly pegged *hard currency bloc* or *small DM exchange rate target zone*.

The final point to be considered here regards the "value added" of augmented as compared to standard target zone models. The above empirical estimates, and the results derived in Rose and Svensson (1991, 1993), Svensson (1991d), and Lindberg, Svensson and Söderlind (1991) suggest that allowing for time-varying devaluation risk in target zone models is an essential and non-trivial extension. This extension is vital if the predictions of the target zone theory are to be confronted with real world data. The advantage of the Bertola and Svensson (1991) model over standard target zone models may be demonstrated by referring to Figure 4.49, which compares scatterplots of the standard (left hand side) and the devaluation expectations augmented relationships between the exchange rate's band position and one-month Euro interest rate differentials. Scatterplots similar to those on the left hand side of Figures 4.49 are examined in Bertola and Caballero (1990), Flood, Rose and Mathieson (1990) and Bartolini and Bodnar (1991) for the EMS in search of a stable downward sloping, non-linear (s-shaped) relationship. Needless to say, most authors find no clear patterns in the data.

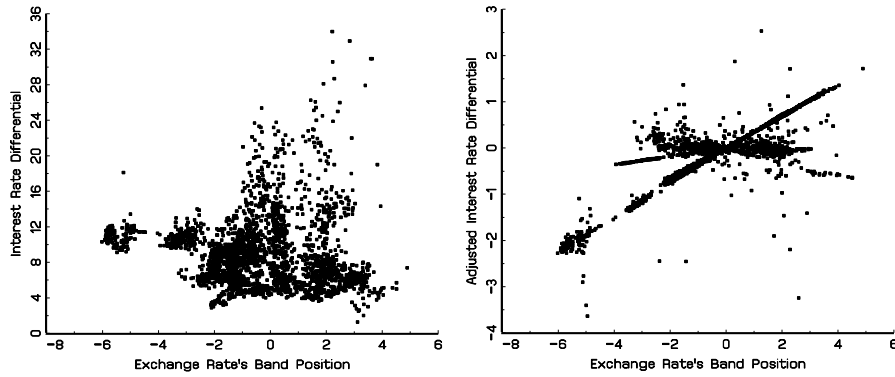
Augmented target zone models of the Bertola and Svensson (1991) type, displayed on the right hand side of Figure 4.49, predict a negatively sloped non-linear relationship only between exchange rates and devaluation expectations adjusted interest rate differentials, that is the actual differentials minus the expected rates of devaluation. However, with the exception of the Dutch-German case these scatterplots strongly refute the hypothesis that devaluation expectation adjusted EMS exchange

Figure 4.49
Relationship Between Interest Rate Differentials and Exchange Rates in
Standard and Augmented Target Zone Models

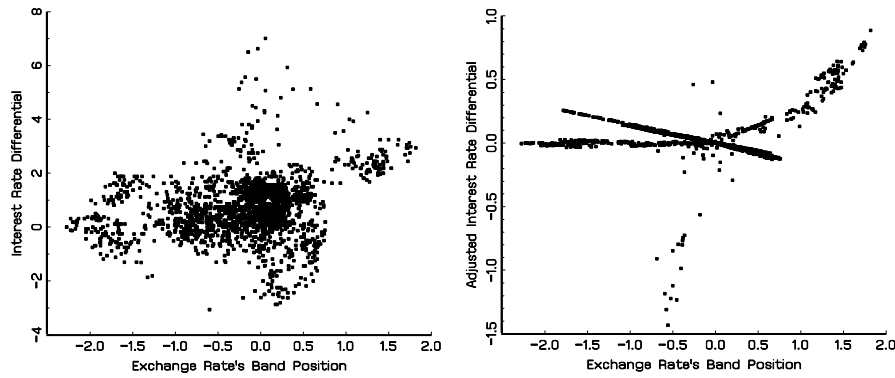
(a) French-German One Month Interest Rate Differentials



(b) Italian-German One Month Interest Rate Differentials



(c) Dutch-German One Month Interest Rate Differentials



rate target zones were credible in the sense of displaying a negative correlation between adjusted interest rate differentials and the exchange rate's band positions.. Rather, the low-noise correlations found between devaluation expectations adjusted interest rate differentials and exchange rates appear to be positively sloped, as is suggested by models of non-credible target zones.

The underlying relationship to the credibility of the target zone estimates becomes even more transparent when adjusting interest rate differentials for expected realignment risks. Figure 4.50 displays such realignment risk adjusted interest rate differentials versus the exchange rate's band positions for the estimated non-linear specification. Only the Dutch estimates are consistent with a credible exchange rate target zone, whilst the French and Italian estimates suggest a lack of credibility of the target zone arrangements.

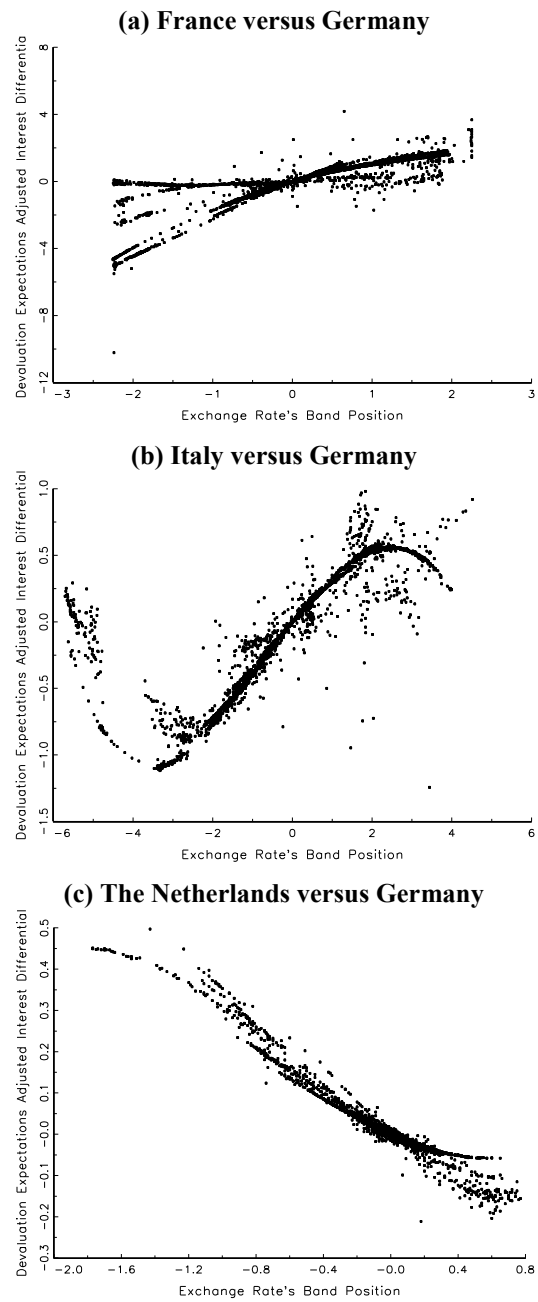
To summarise, the evidence about the credibility of EMS exchange rate target zones reported above indicates that by mid-1990 decline of expected devaluation rates has to be viewed as being insufficient to ensure that the EMS may be viewed as system of credibly target zones. Almost perfect credibility was only achieved by the Dutch-German exchange rate link. On the other hand, the lack of exchange rate target zone credibility is found to be particularly pronounced in the case of Italy. In view of these estimates, which are derived on the basis of daily data for the period of March 1979 to August 1990, the events of September 1992, when the Italian Lira was forced to leave the exchange rate mechanism of the EMS and float its currencies, come as little surprise.

4.4. Country by Country Summary of the Main Results

In the previous sections an extensive discussion of policy credibility, both within the policy game and the target zone context, has been presented. In each section the main results were already summarised. The discussion here provides some reflections on these results by considering each of the EMS countries in turn.

In general the results reported in this study raise some doubt about the hypothesis that the EMS may be viewed as a disinflation devise for all non-German EMS members. In particular the early bipolar nature of the EMS - the joint existence of a hard and a soft currency option, seriously undermines the borrowing reputation hypothesis since the EMS can no longer automatically be taken as exhibiting a disinflationary bias. Depending on whether they pegged to a hard or a soft centre country, policymakers in EMS economies may have borrowed a good or a bad counterinflation reputation. The bipolarity hypothesis, furthermore, accounts fairly well for the fact that disinflation in the EMS has been slower and less than complete initially. But after 1986, and in particular in the period after German unification an increased commitment of EMS member countries to targeting the German mark has been found in the data. It has been argued that this was due to the fact that the German hard stance has mellowed in the aftermath of German unification and this has rendered the fixed parities more credible.

Figure 4.50.
Realignment Risk Adjusted Interest Rate Differentials and Exchange Rate and Positions, Non-Linear Specification, Daily Data, 21/03/1983 to 5/10/1992



Germany is found to have established and maintained a high counterinflation reputation via consistently low inflation performances prior to 1987. In particular, the inflationary impact of the 1979 oil price shock in Germany was relatively small. Disinflation therefore was not a major problem. Recently German unification has pushed up inflation to about 5 percent and counterinflation reputation has eroded somewhat. The German success in controlling and containing inflation in the early 1990's could not be attributed to the use of any particularly credible monetary policy instrument. This may be on account of the publicly acknowledged policy stance of the German Bundesbank of not strictly adhering to any particular policy rule, but adopting whatever policy measures appear adequate at the time in order to achieve the prime policy target of a low inflation rate. Low inflation still is the Bundesbank's prime policy objective in post-unification Germany, but the strong wage-push component of inflation, as well as the inflationary consequences of the growing budget deficits, have recently made inflation more difficult to contain.

French anti-inflation reputation is found to have been low and remained relatively low throughout the EMS due to higher French inflation. Double-digit inflation rates persisted throughout 1979 to early 1983, and the stringent austerity programme adopted after the March 1983 realignment succeeded in bringing inflation down to 3% in late 1987. Since then inflation has roughly stayed at that level. The widespread adoption of foreign exchange controls has allowed France to circumvent many of the disciplinary effects of fixed exchange rates and enabled policymakers to effectively pursue an independent monetary policy. Deflation in France has therefore been largely home-made. After 1987 the convergence of inflation rates between Germany and France was achieved by constant French inflation and a rise of German inflation. This suggests that the recent convergence of the EMS has involved two elements: France has belatedly embraced the hard option, whilst Germany has slightly mellowed its hard stance. Initially this resulted in a more stable system, but since the complete abolition of foreign exchange controls the tensions within the system has grown again as countries contemplate the transition to economic and monetary union (EMU). Disputes over these issues have greatly destabilised the system despite a substantial degree of economic convergence.

Given the reputation of both major EMS countries for initially being hard or soft about inflation, the smaller EMS members were in principle free to choose amongst these alternative deflation scenarios offered by EMS membership.

The Netherlands entered the EMS with inflation rates only slightly above the levels of Germany. By late 1982 the Dutch central bank increased the credibility of its commitment to the German mark exchange rate and the positive inflation differential had disappeared. Throughout the remaining EMS period Dutch inflation closely followed that of Germany and counterinflation reputation in both countries was found to have been equally high. The Dutch disinflation process during the EMS period may therefore be explained by the hypothesis of borrowing reputation from the German Bundesbank via credible exchange rate policies. This is indicated by the credibility estimates from both the policy game and the target zone literature. In fact the closeness of discount rate announcements by the Nederlandsche Bank and the Bundesbank largely enhances the credibility of the Dutch exchange rate commitment.

Belgium, which maintained a very close bilateral exchange rate linkage with the Netherlands during the European currency snake system, also entered the EMS

with inflation rates only slightly above those of Germany. However, in June 1982 the Belgian policy shift from credibly pegging to the Dutch guilder (and hence indirectly to the German mark) to adopting the soft currency option of credibly pegging to the French franc resulted in a rise in inflation to French levels. Thereafter Belgium and France experienced similar inflation performances and macroeconomic policies, which were dominated by direct price and wage controls and attempts to reduce the inflationary impacts of automatic wage indexation schemes. However, despite the decline in Belgium inflation during 1983-86, there was almost no convergence to the also declining German and Dutch inflation rates. The soft currency option of credibly pegging to the French franc in connection with the higher French inflation rates explains why Belgium despite its gain in counterinflation reputation could not disinflate more quickly. The more recent commitment to level pegging the German mark exchange rate, confirmed by Belgian participation in the so-called 'Euro-rounds' of discount rate changes, has been associated with a gradual convergence of its inflation rate to German levels in the post-1987 period. Whilst some degree of exchange rate credibility has materialised, it is still far from being as credible as the Dutch-German link, as the speculative attacks during 1992-92 point out.

Denmark also entered the EMS with inflation rates lower than those in France. Inflation then jumped to French levels as a result of the second oil price shock just after the onset of the EMS and remained there for some time. During the deflation period 1982-1986 the inflation performances of Denmark and Belgium were almost identical, with an emphasis on wage de-indexation. Thus, the slow Danish disinflation has been in keeping with its embracing of the soft currency option. There is less evidence of any possible recent shift towards the hard option. Denmark has only recently taken part in co-ordinated discount rate changes, and no particularly credible policy instrument was found.

The Irish disinflation experience was different from that of Belgium and Denmark. First the inflationary impact of the oil price increase in Ireland was massive. After a slight decline in 1980-81 Irish disinflation started in 1982 with the adoption of an austerity and fiscal consolidation programme. Tight fiscal policies and not taking advantage of the two EMS realignments in 1982 helped Ireland to reduce inflation substantially by mid 1983. Between 1983 and early 1986 fiscal consolidation largely eliminated budget deficits and Irish inflation declined slowly along with the French rate. Throughout this time, credibly pegged exchange rates relative to the soft currency bloc in the EMS were maintained. After a period of weakness in mid-1986 and a drastic devaluation (of -8%) in August 1986, the Irish pound switched to the hard currency bloc. Despite the initial reflationary impact of this drastic devaluation, inflation had declined to the low levels of Germany and the Netherlands by late 1989. The recent Irish participation in the co-ordinated discount rate changes has provided support for the new policy stance of containing inflation.

No credible form of intermediate monetary targeting has been detected for Italy. Whilst the Giavazzi and Spaventa (1989) hypothesis that exchange rate targets are more credible than monetary targets is verified, it does not follow that exchange rate targets have been credible. In fact, all Italian EMS exchange rate commitments have been non-credible, a finding which is consistent with the trend movements of most Italian bilateral exchange rates throughout the EMS period. The most credible form of intermediate monetary targeting in Italy has been interest rate targeting.

Yet, even this strategy has not been implemented in a way consistent with fixed exchange rates, as indicated by the still prevailing interest rate and inflation differentials with the remaining EMS countries. In view of these findings it is not surprising that amongst all EMS countries Italy faced the most problems during the 1992 EMS crisis, and was forced to leave the system.

The fact that all the remaining countries except the Netherlands in mid-1993 ran into similar problems as Italy leaves little hope for the future of the system, which de facto has been suspended by the adoption of extremely wide bands

Endnotes to Chapter 4

¹ The empirical estimates below are based on applying the MPKF to the logarithms of the quarterly consumer price indices for the period 60Q1 to 90Q4. The filter is initialized in 60Q3 by using the actual price level P_{t-1} and inflation rate $(P_{t-1}-P_{t-2})$ prior to the estimation period as an estimate of the initial state vector a_{t-1} for all four individual process models. Furthermore, the initial prior and posterior probabilities were chosen as $\pi_{t-1}=0.25$ for all four models, which implies an initial reputation estimate of $\psi_{t-1}=0.5$.

² Artis (1987) defines a "crawling peg" as an exchange rate arrangement in which inflation differentials are not fully accommodated, and realignments are underindexed adjustments.

³ These cuts together were roughly equivalent to a 4 percent reduction in the consumer price index. For details see OECD Economic Surveys: Ireland, 1975, p. 6.

⁴ See OECD Economic Surveys: Ireland, 1975, p. 6.

⁵ The United Kingdom was subsumed in this group because it only participated in the ERM for the short period of October 1990 to September 1992.

⁶ These minor changes were accounted for in this study by trying to use announcements for one monetary aggregate consistently throughout the sample where possible. For the United Kingdom target growth rates for M3 were used throughout, while for France no adjustment was made. Hence, some reservations with respect to the estimates for France between 1984 and 1986 are in order.

⁷ Before March 1978 currency held by banks was included in the currency position and afterwards was accepted as part of required reserves. The series used here is adjusted for this change in reserve requirements.

⁸ See Deutsche Bundesbank (1985), page 25, or Schlesinger (1983) who reports that in 1977-1978 the Bundesbank accepted substantial 'overshooting' of monetary growth in order to counteract an excessive 'real' appreciation of the D-Mark.

⁹ See Wyplosz (1988b) for this interpretation of French post 1983 monetary policy.

¹⁰ See Suzuki (1985). For details of monetary targeting in Japan see also Shimamoto (1983), and for comparative studies see Dotsey (1986), Wagner (1989), and the recent contribution by McCallum (1993).

¹¹ The identification of the most likely point of structural break is based on the likelihood ratio test $(-2\ln\lambda)$ of Quandt (1958, 1960) and Goldfeld and Quandt (1973a,b 1976). The Quandt (1960) test statistic does not follow a χ^2 -distribution, but Lehner and Möller (1981) demonstrate that a modified χ^2 -distribution can be used to construct a conservative test for structural break points. This modified "distribution" is used here to evaluate the significance of $-2\ln\lambda$. In addition, the test $F_{k,t-2k}$ of Chow (1960) for the constancy of the regression coefficients with k and $t-2k$ degrees of freedom is considered. A problem with the Chow (1960) F-test is, as has been demonstrated by Toyoda (1974), that it is biased in the presence of heteroscedasticity. See also Jaytissa (1977) and Schmidt and Sickles (1977) on this point. For problems of the Chow test under misspecification see Thursby (1982). Furthermore, two versions of the CUSUM-of-Squares test of Brown, Durbin and Evans (1975), a forward test CSF and a backward test CFB, are reported. These tests are based on a plot of the cumulated sum or recursive least squares residuals from the Kalman filter run against certain upper and lower significance bounds for different significance levels, which were taken from Harvey (1981a), pp 364. Finally, two F-tests for heteroscedasticity, $H_{n,m}$ and $H_{s,n-k}$ are reported, $H_{n,m}$ is the Goldfeld & Quandt (1965) heteroscedasticity test based on a division of the sample

of t observations into two sub-samples of m and n ($n=t-m$) observations and tests the hypothesis that the variance of residuals increases over time. This test corresponds to the test of Harvey and Phillips (1974) if no central observations are omitted. $H_{s,n-k}$ tests the hypothesis that the variance of the residuals is heteroscedastic because it is proportional to the fitted values. This test is by a regression of squared residuals on squared fitted values.

¹² Suzuki (1985) explains that the use of projections rather than targets is giving the central bank flexibility and freeing it from political pressure. See also Fischer (1988).

¹³ Meltzer (1986b, 1987a) reports this policy switch to a system of less freely fluctuating exchange rates in Japan after the September 1985 Plaza agreement of the G5 countries.

¹⁴ Expectations are seen as being influenced by official target announcements or by chartist (backward looking) behaviour. See Chapter 3, in particular Equation (18.3) in Box 18, for this feature of the MC estimate.

¹⁵ This important point has been raised by Malinvaud in the General Discussion of the Weber (1991a) paper. For details, see Weber (1991a), p. 95.

¹⁶ Consult, for example, the calendars of main economic events in the OECD Country Studies for these countries.

¹⁷ The MC credibility measure refers to the slope rather than the intercept estimate. The latter captures the announcement bias.

¹⁸ The forward regressions start with a minimum of $k+2$ observations at the start of the sample and recursively update via the Kalman filter the state estimates by incorporating the information content revealed by subsequent observations. The backward regressions are initialised at the end of the sample and update the state estimates by going back in time. If EMS target zones were non-credible in the early EMS period and have become more credible in the late EMS period, then the state estimates of these backward recursions should towards the sample end be more consistent with the credible target zone model.

CONCLUSIONS

Based on empirical estimates of pre-specified counterinflation reputation and policy credibility measures, the present study shows that 'borrowing counterinflation reputation' from the Bundesbank in order to disinflate was not a feature of the European Monetary System. Such a 'DM-zone' view of the EMS had been postulated by Giavazzi and Pagano (1988). The present study shows that France and Italy have not managed to use the EMS as a disinflation device by locking into German monetary policy. However, the estimates indicate that 'borrowing reputation' has, to various degrees, worked for the smaller EMS countries. The role of the EMS in this process is unclear: similar counterinflation reputation gains have also been obtained by Austria, which did not formally participate in the EMS, but has targeted the German mark exchange rate.

The present study explains the differences in the extent to which countries have profited from German counterinflation reputation during the EMS period by differing degrees of exchange rate credibility. It is demonstrated that not all EMS countries have shown the same commitment to targeting the German mark exchange rate. An important finding of the present study is that credible commitments to fixed exchange rates, which were the rule under the Bretton Woods system, have been the exception under the EMS. In particular, the present study shows that after some short initial transition phase the EMS has functioned as a bipolar system with a 'hard currency' option supplied by the German Bundesbank and a 'soft currency' option offered by the Banque de France: whilst the Netherlands, almost from the onset of the EMS, has been committed to the 'hard currency' option, the 'soft currency' alternative has played an important role for the remaining small EMS economies, Belgium, Denmark and Ireland, at least in the early stages of the EMS. At a later stage of the EMS this 'soft currency' bloc disintegrated and some countries, most noticeably Ireland and to a lesser extent also France, shifted towards the 'hard currency' standard. In the wake of German unification the 'hard currency' stance of the Bundesbank has eroded somewhat. Initially this increased convergence. When German inflation exceeded inflation rates in the remaining EMS countries the potential gains from credible

exchange rate pegging policies disappeared. This destabilised the system and contributed to its collapse in August 1993.

The potential benefits and drawbacks of systems of exchange rate target zones such as the EMS are at the heart of the recent target zone literature. This literature has been reviewed in the present study, and its empirical implications have been confronted with the data from the EMS. It has thereby been shown that the EMS did not appear to function as a system of credible exchange rate bands. Rather, for much of the initial EMS period, realignment expectations were high and credibility was low. The present study finds no compelling evidence of the type of non-linearities implied by fully credible target zone models, and the probability distributions of exchange rates within the band are not as they ought to be if exchange rate credibility were present. Thus, in keeping with the credibility measures derived from the policy game literature, the target zone framework points towards a serious lack of central bank commitment to targeting fixed exchange rates. However, the tests also indicate that recently exchange rate credibility has increased for all EMS countries. Except for the Netherlands, the decline of devaluation expectations must, nonetheless, still be viewed as insufficient to ensure that the EMS may be viewed as a system of credible target zones: rather, the estimated positive correlations between interest rate differentials and exchange rates point towards the presence of destabilising speculation when exchange rates approach the boundaries of the band. This presents no problem as long as exchange rates stay well within the middle of the band. But when they move towards the boundaries, financial markets will test whether or not the current parities are immutable. Devaluation expectations raise interest rate differentials, and this in turn fuels the speculative attack. The present study finds that in particular for the Italian lira the lack of exchange rate credibility appears to have been very pronounced. In view of these estimates it is hardly surprising that speculative attacks have forced the Italian Lira (and the British Pound) to leave the exchange rate mechanism in September 1992. For the remaining EMS countries, which abandoned their narrow bands in August 1993, target zone credibility was far from being perfect, but it was probably higher than during most of the previous EMS period. In addition, economic fundamentals were not vastly diverging. It is therefore difficult to find a consistent explanation for the collapse of the EMS system without further research into the intrinsic dynamics of exchange rates within bands under speculative attacks.

Appendix A
Analytical Solution of Parabolic Partial Differential Equations

Expected Exchange Rates in a Target Zone

Svensson (1991b) shows that in a fully credible target zone the expected maturity exchange rate $h(f,c,\tau)$ is the solution for the partial differential equation:

$$h_{\tau}(f,c,\tau) = \eta h_f(f,c,\tau) + \frac{\sigma^2}{2} h_{ff}(f,c,\tau), \quad f_L \leq f \leq f_U, \quad \tau \geq 0, \quad (\text{A1a})$$

with initial condition:

$$h(f,c,0) = x(f,c), \quad f_L \leq f \leq f_U, \quad (\text{A1b})$$

and derivative boundary conditions:

$$h_f(f_L,c,\tau) = 0 \text{ and } h_f(f_U,c,\tau) = 0 \text{ for } \tau \geq 0. \quad (\text{A1c})$$

An analytical Fourier-series solution of this parabolic partial differential equation can be obtained by drawing on methods developed for boundary value problems in thermal diffusion processes in physics, as described for instance in Churchill and Brown (1987).

Defining $a = (f_U - f_L) / \pi$ and $\theta = 2\eta / \sigma^2$, the analytical Fourier series solution for equations (A1a,b,c) is derived by Svensson (1991b) as:

$$h(f, c, \tau) = \sum_{n=0}^{\infty} c_n y_n(f, c) e^{-\lambda_n \tau}, \quad f_L \leq f \leq f_U, \quad \tau \geq 0, \quad (\text{A3})$$

with

$$y_0(f, c) = 0, \quad (\text{A4})$$

$$y_n(f, c) = e^{\frac{-\theta(f-f_U)}{2}} \left\{ 2n \cos \left[\frac{n(f-f_L)}{a} \right] + \theta a \sin \left[\frac{n(f-f_L)}{a} \right] \right\}, \quad n \geq 0, \quad (\text{A5})$$

$$c_0 = \int_{f_L}^{f_U} x(f, c) df \frac{1}{f_U - f_L}, \quad \text{for } \eta = 0, \quad (\text{A6})$$

$$c_0 = \int_{f_L}^{f_U} e^{\theta f} x(f, c) df \frac{\theta}{e^{\theta f_U} - e^{\theta f_L}}, \quad \text{for } \eta \neq 0, \quad (\text{A7})$$

$$c_n = \int_{f_L}^{f_U} e^{\theta(f-f_L)} x(f, c) y_n(f, c) df \frac{1}{4(f_U - f_L) \lambda_n a^2 / \sigma^2}, \quad n \geq 1 \quad (\text{A8})$$

$$\lambda_0 = 0 \quad (\text{A9})$$

$$\lambda_n = \frac{(n^2/a^2 + \theta^2/4) \sigma^2}{2} > 0, \quad n \geq 1. \quad (\text{A10})$$

Clearly, the series $h(f, c, \tau)$ in equation (A3) involves a summation of infinitely many terms, and in practice this analytical solution has to be computed numerically as a summation of a truncated series. In the present application (Graphs 3.4 to 3.6) a truncation at $n=9$ was found to be sufficiently accurate in calculating the expected maturity exchange rate $h(f, c, \tau)$ such that the analytical Fourier-series solution produced the same results as the direct numerical solution discussed in Appendix B below.

Appendix B The Numerical Solution of Parabolic Partial Differential Equations

B1. Expected Exchange Rates in a Target Zone

The numerical solution of parabolic partial differential equations will be discussed below in two steps. At first a solution is derived for fundamentals which lie strictly in the interior of the fundamentals band, $f_L < f < f_U$. This solution is identical for both fully credible and imperfectly credible exchange rate target zones. In a second step a solution for the boundaries ($f=f_L$, $f=f_U$) of the target zone is obtained, which is distinctly different for fully credible and imperfectly credible target zones due to differences in the boundary conditions (smooth pasting versus jumps).

Svensson (1991b) shows that strictly inside the target zone the expected maturity exchange rate $h(f,c,\tau)$ is the solution to the parabolic partial difference equation:

$$h_\tau(f,c,\tau) = \eta h_r(f,c,\tau) + \frac{\sigma^2}{2} h_{ff}(f,c,\tau), \quad f_L < f < f_U, \quad \tau \geq 0, \quad (B1a)$$

with initial condition:

$$h(f,c,0) = x(f,c), \quad f_L < f < f_U, \quad (B1b)$$

A numerical solution may be obtained by employing the so-called direct method from Gerald and Weatley (1989). Thereby a second order Taylor expansion forward and backward of the twice differentiable function $h(\cdot)$ in equation (B1a) is taken. For this purpose a $I \times J$ grid for (f,τ) is defined, where for a given positive integer I a state space for fundamentals is defined:

$$f_i = f_L + (i-1)\Delta f, \quad \text{for } i = 1, \dots, I, \quad \text{with } \Delta f = (f_U - f_L) / (I-1) \quad (B2)$$

whilst for a positive integer J and a given positive real time-step $\Delta\tau$:

$$\tau_j = j \Delta\tau, \quad \text{for } j = 1, \dots, J-1 \quad (B3)$$

is postulated. Approximating the derivatives h_r and h_{ff} by central differences:

$$h_r(f_i, \tau_j) = \frac{h(f_{i+1}, \tau_j) - h(f_{i-1}, \tau_j)}{2\Delta f} \equiv \frac{h_{i+1}^j - h_{i-1}^j}{2\Delta f} \quad (B4a)$$

$$h_{ff}(f_i, \tau_j) = \frac{h(f_{i+1}, \tau_j) - 2h(f_i, \tau_j) + h(f_{i-1}, \tau_j))}{(\Delta f)^2} \equiv \frac{h_{i+1}^j - 2h_i^j + h_{i-1}^j}{(\Delta f)^2} \quad (B4b)$$

and the derivative h_τ by a forward difference:

$$h_\tau(f_i, \tau_j) = \frac{h(f_i, \tau_{j+1}) - h(f_i, \tau_j)}{\Delta\tau} \equiv \frac{h_i^{j+1} - h_i^j}{\Delta\tau} \quad (\text{B4c})$$

a forward solution in τ of the original partial differential equation can be obtained as:

$$h_i^{j+1} = (r + s)h_{i+1}^j + (1 - 2r)h_i^j + (r - s)h_{i-1}^j, \quad 2 \leq i \leq I-1, \quad (\text{B5})$$

with $r \equiv \frac{\sigma^2 \Delta\tau}{2(\Delta f)^2}$, and $s \equiv \frac{\eta \Delta\tau}{2\Delta f}$ whereby $r \leq 0.5$ is required for convergence.

This difference equation approximates the original differential equation in the interior of the band. Following Svensson (1991b) and Bartolini and Bodnar (1991) the boundary conditions now have to be incorporated into the solution, as will be discussed below.

B2. Expected Exchange Rates at the Boundaries of a Fully Credible Target Zone

Svensson (1991b) shows that the above difference equation (B5) holds only in the interior of the band, that is for $2 \leq i \leq I-1$. In order to incorporate the derivative boundary conditions:

$$h(f_L, c, \tau) = 0 \text{ and } h(f_U, c, \tau) = 0 \quad (\text{B6})$$

into the solution, one extra grid points is added above and below the previous grid f_i ($i=1, 2, \dots, I$):

$$f_0 = f_L - \Delta f \text{ and } f_{I+1} = f_U + \Delta f \quad (\text{B7})$$

And the derivative boundary conditions may then be expressed as:

$$h_r(f_1 = f_U, \tau_j) = \frac{h(f_2, \tau_j) - h(f_0, \tau_j)}{2\Delta f} \equiv \frac{h_2^j - h_0^j}{2\Delta f} \quad (\text{B8a})$$

$$h_r(f_I = f_L, \tau_j) = \frac{h(f_{I+1}, \tau_j) - h(f_{I-1}, \tau_j)}{2\Delta f} \equiv \frac{h_{I+1}^j - h_{I-1}^j}{2\Delta f} \quad (\text{B8b})$$

which implies:

$$h_0^j = h_2^j \text{ and } h_{I+1}^j = h_{I-1}^j. \quad (\text{B9})$$

Substituting (B9) back into (B5) then results in the difference equations for the boundaries:

$$h_1^{j+1} = (1 - 2r)h_1^j + 2rh_2^j \tag{B10a}$$

$$h_1^{j+1} = (1 - 2r)h_1^j + 2rh_{1-1}^j \tag{B10b}$$

Combined with the solution for the interior of the band from equations (B4a,b,c) and (B5) this may be written in matrix form as:

$$\begin{bmatrix} (1-2r) & 2r & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ (r+s) & (1-2r) & (r-s) & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & (r+s) & (1-2r) & (r-s) & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \dots & (1-2r) & (r+s) & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & (r+s) & (1-2r) & (r-s) & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & (r+s) & (1-2r) & \dots & 0 & 0 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & (r+s)(1-2r) & (r-s) & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & (r+s) & (1-2r) & (r-s) \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 2r & (1-2r) \end{bmatrix} \begin{bmatrix} h_1^j \\ h_2^j \\ h_3^j \\ \vdots \\ h_{(1-1)/2}^j \\ h_{1/2}^j \\ h_{(1+1)/2}^j \\ \vdots \\ h_{1-2}^j \\ h_{1-1}^j \\ h_1^j \end{bmatrix} = \begin{bmatrix} h_1^{j+1} \\ h_2^{j+1} \\ h_3^{j+1} \\ \vdots \\ h_{(1-1)/2}^{j+1} \\ h_{1/2}^{j+1} \\ h_{(1+1)/2}^{j+1} \\ \vdots \\ h_{1-2}^{j+1} \\ h_{1-1}^{j+1} \\ h_1^{j+1} \end{bmatrix},$$

or in more compact notation as:

$$h^{j+1} = \Omega h^j \tag{B11}$$

Combined with the initial condition that the zero-term expected forward exchange rate is equal to the current spot exchange rate, $h^0 = x(f,c)$, this results in the linear forward iteration:

$$h^{j+1} = \Omega^j x(f,c). \tag{B12}$$

The initial vector of exchange rates $x(f,c)$ may be obtained by mapping the fundamentals into exchange rate space using equations (3.20e-m) from Box 3.1 of Chapter 3. Based on this, a vector of forward exchange rates for any maturity may then be obtained by recursively iterating the above linear transformation Ω , whereby Δf and Δt must be chosen such that $r=s^2\Delta t/(2(\Delta x)^2) \leq 0.5$ is satisfied in order to ensure the stability of the system.

B3. Expected Exchange Rates at the Boundaries of an Imperfectly Credible Target Zone

Bartolini and Bodnar (1991) show that that the boundary conditions describing the jumps of the exchange rate at the edges of a number of N bands in fundamental space with I steps in each band are given by:

$$h_{(n-1)I}^{j+1} = \pi h_{(n-1/2)I+D/\Delta f}^{j+1} + (1 - \pi) h_{(n+1/2)I+D^*/\Delta f}^{j+1} \quad (B13a)$$

$$h_{nI}^{j+1} = \psi h_{(n+1/2)I+R/\Delta f}^{j+1} + (1 - \psi) h_{(n-1/2)I+R^*/\Delta f}^{j+1} \quad (B13b)$$

whereby it is assumed that the top of the highest band ($i=1$) and the bottom of the lowest band ($i=N/I$) are defended by infinitesimal intervention with probability one:

$$h_1^{j+1} = h_2^{j+1}, \text{ and } h_{NI}^{j+1} = h_{N(I-1)}^{j+1} \quad (B14)$$

Combined with the solution for the interior of the band from equations (B4a,b,c) and (B5) this may be written in matrix form as:

$$\begin{bmatrix} A & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 & 0 \\ B & C & D & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & B & C & D & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \dots & C & D & 0 & \dots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & B & C & D & \dots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & B & C & \dots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & B & C & D & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & B & C & D & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 & E & 0 \end{bmatrix} \begin{bmatrix} h_1^j \\ h_2^j \\ h_3^j \\ \vdots \\ h_{n-1}^j \\ \left[h_{(n-1)I+1}^j \right] \\ \vdots \\ h_{nI}^j \\ h_{n+1}^j \\ \vdots \\ h_{(N-2)I}^j \\ h_{(N-1)I}^j \\ h_{NI}^j \end{bmatrix} = \begin{bmatrix} h_1^{j+1} \\ h_2^{j+1} \\ h_3^{j+1} \\ \vdots \\ h_{n-1}^{j+1} \\ \left[h_{(n-1)I+1}^{j+1} \right] \\ \vdots \\ h_{nI}^{j+1} \\ h_{n+1}^{j+1} \\ \vdots \\ h_{(N-2)I}^{j+1} \\ h_{(N-1)I}^{j+1} \\ h_{NI}^{j+1} \end{bmatrix}$$

The initial (NI) vector of exchange rates can, in analogy to the case of a fully credible target zone above, be obtained by mapping the (NI) vector of fundamentals into exchange rate space using equations (3.20e-m) from Box 3.1 of chapter 3. Based on this, a vector of forward exchange rates may then be obtained for any maturity by recursively iterating the above linear transformation Ω . As above, Δf and Δt must be chosen such that $r = s^2 \Delta t / (2(\Delta x)^2) \leq 0.5$ is satisfied in order to ensure the stability of the system.

DATA SOURCES

7.1. Quarterly Data

Consumer Price Indices

International Monetary Fund, International Financial Statistics, various issues.

7.2. Monthly Data

Nominal Exchange Rates

International Monetary Fund, International Financial Statistics, various issues.

Government Bond

International Monetary Fund, International Financial Statistics, various issues.

Call Money

International Monetary Fund, International Financial Statistics, various issues.

Interest Rates

International Monetary Fund, International Financial Statistics, various issues.

Consumer Price Indices

International Monetary Fund, International Financial Statistics, various issues.

Monetary Aggregates

International Monetary Fund, International Financial Statistics, various issues.

7.3. Daily Data**Nominal Exchange Rates**

Data from Flood, Rose and Mathieson (1991), Bank for International Settlements Databank.

Nominal Interest Rates

2 Day, 1 Month and 12 Month Euro Rates Data from Flood, Rose and Mathieson (1991), Bank for International Settlements Databank.

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