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EXCHANGE RATE REGIMES

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ABSTRACT

The paper reviews the recent literature on exchange rate target zones and on speculative attacks on fixed exchange rates. The influential Krugman model of exchange rate target zones has two main results, namely that credible target zones stabilize exchange rates more than fundamentals (the "honeymoon effect") and that exchange rates depend on fundamentals according to a nonlinear "S-curve" with "smooth pasting." Almost all the model's empirical implications have been overwhelmingly rejected. Later research has reconciled the theory with empirical results by allowing for imperfectly credible exchange rates and for intra-marginal central bank interventions. That research has also shown that non-linearities and smooth pasting are probably empirically insignificant and that a linear managed-float model is a good approximation to exchange rate target zones. The speculative attack literature has developed models built on the principles of no anticipated price discontinuities, endogenous timing of the speculative attack, and the attack occurring when a finite amount of foreign exchange reserves remain. These models have been extended to include random timing of attacks and alternative post attack regimes. Some empirical tests have been undertaken. In contrast to target zone models, speculative attack models have been influenced by empirical results only to a small extent.

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The Operation and Collapse of Fixed Exchange Rate Regimes*

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1. Introduction

Since the end of the Bretton Woods system in 1973, the exchange rates of the three major currencies have not been officially pegged. These twenty-one years are the longest period in modern economic history during which the values of major currencies have been allowed to float. Nevertheless, even in this era of floating exchange rates, most of the smaller central banks have maintained policies of pegging their exchange rates to the major currencies. Alternatively, as in the European Exchange Rate Mechanism, an individual central bank in a group of central banks may peg its currency to a weighted average of the values of the group's currencies. Even the major currency central banks frequently intervene in exchange markets to prevent the values of their currencies from moving excessively. Occasionally, they agree to impose informal upper and lower bounds on exchange rates.

Because of the still dominant position of fixed exchange rates in central bank operating policies, it is important to understand how fixed exchange rate systems operate and how they come to an end. In this chapter, we will report on recent research contributions to our understanding of the dynamics of a fixed exchange rate system. These contributions can

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be placed readily into two categories – research on target zones and research on speculative attacks on fixed exchange rate regimes. We will also briefly discuss the various rationales for selecting a fixed exchange rate system over a floating exchange rate regime. Our focus, however, will be almost entirely on the positive economics of fixed exchange rates. This focus is consistent with most of the research in the past decade: that is, given that a target zone or fixed exchange rate system is chosen, researchers have concentrated mainly on determining its dynamic development. Although, as we will report, much empirical research has been done to examine the theoretical models, the recent literature is, in a sense, primarily a theoretical one. Most research in this area is based on the simple monetary model of the exchange rate, which, as shown in the chapter by Frankel and Rose, does not perform well empirically in the short run. Nevertheless, this literature has had great influence in central banks, given the background of the existence of important target zone systems and of major exchange rate crises in the past decade.

2. The Choice of a Fixed Exchange Rate Regime

Several explanations have been advanced for the existence of fixed exchange rate regimes. First, under some conditions, a fixed exchange rate may minimize instabilities in real economic activity, so that on a macroeconomic level the fixed exchange rate would be the preferable policy regime. Second, because of a past inability to control itself from launching inflationist policies, a country's central bank may lack credibility with the public, which expects an inflationary policy. In an attempt to acquire credibility, the central bank may fix the exchange rate of its currency to that of a more disciplined central bank. Third, disruptions of the exchange rate may arise from bubbles generated by a speculative financial system. A fixed exchange rate would muffle such extraneous disturbances and insulate the real economy from them. Finally, on a microeconomic level, a country with poorly developed or illiquid money markets, may fix the exchange rate to provide its resident with a synthetic money market with the liquidity of the markets of the country that provides the vehicle currency.

In an influential article Poole (1970) discussed in an IS-LM framework the choice between a monetary policy aimed at stabilizing the interest rate and one aimed at stabilizing the money supply. He showed that the choice depends on the nature of the shocks to the economy, especially whether the shocks are real or monetary in origin. Poole's approach has since been extended to open economies and to the choice of the exchange rate regime depending upon the nature of the shocks that hit the open economy. Starting with Turnovsky (1976), Boyer (1978) and Parkin (1978), a very large literature has developed. An excellent survey is available in Genberg (1989).

This literature lays out a model of a small open economy that is hit by real and monetary domestic and foreign shocks. The problem is to choose the optimal monetary regime, and hence exchange rate regime, from a short-run stabilization point of view. The information set is incomplete and the underlying shocks – disturbances to the LM and IS functions – are unobservable. Policy rules contingent upon the available information are chosen to minimize a weighted sum of output and inflation variances.

The results of this type of model can be summarized as follows: If the variance of the LM shock is sufficiently large relative to the variance of the IS shock, a fixed exchange rate will be better than a floating exchange rate. In the reverse case, a freely floating exchange rate will be better than a fixed exchange rate. In the general case, when neither IS nor LM shocks dominate, a managed float will be the best policy.

When an aggregate supply function and wage indexation are added, the implications

of the relative variance of the IS and LM shocks for the choice of exchange rate regime still hold. When there are only LM shocks, a fixed exchange rate is still optimal. When there are only IS shocks, however, the optimal policy is not a free float, and the policy depends on the degree of wage indexation. In the general case with both kind of shocks, the optimal policy is still a managed float that depends in complicated way on the nature of the shocks and the structure of the economy.

As Genberg (1989) points out, the general result in this kind of work is that the optimal exchange rate regime is neither a fixed exchange rate nor a freely floating rate, but instead a managed float monetary rule, where money supply reacts to exchange rates, interest rates and other indicators that convey information about the shocks that hit the economy. The optimal monetary rule depends, however, in an exceedingly complicated way on the nature of the shocks and the structure of the economy. The ranking of the restricted simple monetary rules, fixed and floating exchange rates, varies from case to case. The information requirement for choosing the optimal rule, or for ranking the simple regimes, is simply overwhelming. Therefore, there seem to be no operationally useful results.

In the mid-1980's, a class of models was developed that explained the choice of particular policy rules as a means of avoiding the social losses that might emerge in the presence of a central bank with complete discretion to set the monetary variables. As extensions of Kydland and Prescott's (1977) results, the literature on rules versus discretion was developed mainly in the context of a closed economy but has been extended to the choice of exchange rate regime. Persson and Tabellini's chapter in this volume provides an extensive development of these models.

The intuition behind the rules vs. discretion models is relatively straightforward in the context of a one-shot game between the central bank and the public, but also emerges in a repeated interaction. The monetary authority has the dual objective of raising output above a natural rate that is considered too low and of reducing the deviation of inflation from some target. Weighted to coincide with social preferences, these objectives are combined to form both the social and the monetary authority's objective function. Output can move away from the natural rate through monetary intervention only if the public's expectation of inflation is incorrect. Thus, the monetary authority can affect output only through acting contrary to the public's expectations. Knowing that the monetary authority will seek to increase inflation above their expectations, the public will increase its expected rate of inflation. In reaction, the monetary authority will have to increase inflation yet more, but as the realized inflation moves away from the target,

further efforts to affect output become ever more costly in terms of social welfare. The equilibrium of this one-shot game emerges when the public's expectations of inflation coincide with realized inflation. The equilibrium, however, is sub-optimal: inflation is higher than the target, and since the public is correct in its expectations there is no movement of output away from the natural rate.

As one means of implementing a lower inflation, Rogoff (1985) suggests appointing an independent central banker known to have a greater aversion to inflation than the general public, thereby generating a lower equilibrium inflation rate. As an alternative to finding its own reputed anti-inflationist, a central bank may piggy-back on the reputation of any already established conservative central banker by implementing a fixed exchange rate. For example, it is often argued (Giavazzi and Pagano (1988), Giavazzi and Giovannini (1989, Chapter 5), Currie (1992)) that the countries in the European Monetary System with a reputation for relatively high inflation were able to employ the tough reputation of the Bundesbank to buy some credibility for the disinflationary programs of the 1980's, thereby reducing the severity of the potential associated recessions. Of course, a self-imposed fixed exchange rate can be ephemeral and is often a fig-leaf for an inveterate inflationary government. Acting in a manner that forces the abandonment of a fixed exchange rate regime does impose some direct costs on a central bank in the form of lost reserves of potentially large magnitude if the central bank suffers a speculative attack, and this potential loss may buy some credibility. Even this loss is limited, however. First, the public does not know how much of its reserves the central bank will use to defend the currency. Second, if it ceases to intervene while it still has positive net reserves, the central bank will realize a capital gain in the ensuing devaluation. Also, abandonment of a fixed exchange rate is immediately obvious, so a switch to discretionary policy cannot be obfuscated.

A fixed exchange rate arranged cooperatively with other countries should be more conducive to discipline than a unilateral system because domestic policies that tend to force its abandonment would incur additional costs in the form of a loss of face with other sovereign monetary authorities. Cooperation in defending the multilateral system against speculative attack may also increase its viability relative to that of a unilateral system.

In their chapter in this volume, Frankel and Rose show that the movement of floating exchange rates cannot be readily explained from the movements of standard measures of market fundamentals. They explore the possibility that speculative bubbles drive exchange rates. If speculators generate extraneous volatility in exchange rates and if such

volatility has a real impact, then it may be desirable to fix exchange rates. If speculation is self-driven, official intervention to fix rates may short circuit the dynamic of expectations of exchange rate movements and eliminate this source of volatility at little cost. As will be shown in the discussion of the speculative attack literature, however, a fixed exchange rate system can itself generate a set of beliefs that can lead to a speculative attack and collapse of the system.

As indicated by our description, none of these normative approaches is a generally satisfactory explanation of the prevalence or even the existence of fixed exchange rates. The normative issues of fixed exchange rate regimes remain an open area for future research.

3. Exchange Rate Target Zones

3.1. Introduction

Fixed exchange rate regimes used to be modelled in the literature as having a constant fixed exchange rate, with occasional discrete jumps, or realignments. However, fixed exchange rate regimes in the real world typically have explicit finite *bands* within which exchange rates are allowed to fluctuate. For instance, before their widening in August 1993 to ± 15 percent the bands within the exchange rate mechanism of the European Monetary System (ERM) were ± 2.25 percent around a central parity (Portugal and Spain had ± 6 percent bands). The bands within the Bretton Woods System were ± 1 percent around dollar parities.

For concreteness, *Figure 1a* shows a typical exchange rate band. The curve shows the logarithm of the French franc/Deutsche mark exchange rate from the start of the ERM in March 1973 through March 1992. The ± 2.25 percent band around the central parity is shown as the thin horizontal lines. The central parity (not shown) is in the center of the band. The vertical axis measures percentage deviation from the initial March 1973 central parity. Realignments, shifts in the central parity, took place in September 1979, October 1981, June 1982, March 1983, April 1986 and January 1987. On all these occasions the franc was devalued against the mark, that is, the FF/DM exchange rate (the number of francs per mark) increased. *Figure 1b*, which we shall refer to below, shows a 3-month FF/DM Euro interest rate differential, that is, the difference between a franc interest rate and a mark interest rate on the Euromarket for deposits with 3-month maturity.

The existence of such exchange rate bands raises two main questions, one positive and one normative. The first, positive, question is: how do exchange rate bands work compared to completely fixed rates; or, more precisely, what are the dynamics of exchange rates, interest rates and central bank interventions within exchange rate bands? The second, normative, question is: does the difference between bands and completely fixed exchange rates matter and, if so, which of the two arrangements is best; or, more precisely, what are the tradeoffs that determine the optimal bandwidth?

Exchange rate target zones – which has become the name given to fixed exchange rates regimes with bands – have been the subject of intensive research in recent years. This research has by now dealt fairly thoroughly with the first, positive question, whereas the second, normative question has hardly yet been touched upon. This section will present an interpretation of some selected recent theoretical and empirical research on exchange rate

target zones, with emphasis on main ideas and results and without technical detail. The section is selective and not a survey of the literature. Bertola (1994) gives a comprehensive and detailed survey with an extensive bibliography.¹

3.2. The Krugman Target Zone Model

After some earlier work on exchange rate target zones (for instance, Williamson (1985), Frenkel and Goldstein (1986), Williamson and Miller (1987) and Dumas (1992))² the recent work took off with Paul Krugman's elegant target zone model (Krugman, 1991). This paper, first circulated in 1988, presented what has become the standard target zone model and the starting point for almost all the research that followed.³

Krugman started from the presumption that the exchange rate, like any other asset price, depends on both some current fundamentals and expectations of future values of the exchange rate. In order to simplify, the log exchange rate at time t , s_t , is assumed to depend linearly on an aggregate "fundamental" at time t , f_t , incorporating the different fundamental determinants of the exchange rate (like domestic output and money supply; foreign interest rate, money supply, price level, etc.,) and the instantaneous expected rate

¹The section builds upon Svensson (1992b).

²Williamson (1985) and Williamson and Miller (1987) advocated a rather wide target zone for *real* exchange rates as a method for international economic policy coordination, without using an explicit target zone model. Williamson-type target zones are quite different from the narrow *nominal* exchange rate bands that are the focus of this article and it is perhaps confusing that the same name is used for both. Dumas (1992), in a remarkable paper first presented and circulated under a different title in the summer of 1987, developed a general equilibrium model of an endogenous target zone for the real exchange rate, which contained most of the ingredients in the later work on nominal exchange rate target zones. A parallel literature on real investment under uncertainty, especially contributions by Avinash Dixit, was the source of many of the techniques used in the target zone literature (see Dixit (1992) for a survey).

³A forerunner, Krugman (1987), was circulated in the late fall of 1987. It used a discrete-time model and did not resolve all technical difficulties.

of exchange rate depreciation, $E_t[ds_t]/dt$, according to the "exchange rate equation"⁴

$$s_t = f_t + \alpha \frac{E_t[ds_t]}{dt}. \quad (3.1)$$

The fundamental is assumed to consist of two components,

$$f_t = v_t + m_t. \quad (3.2)$$

One component, "(the log of) velocity" v_t , is exogenous to the central bank and stochastic; the other component, "(the log of) money supply" m_t , is controlled by the central bank and changed by "interventions." By controlling the money supply, the central bank can control the aggregate fundamental, and thus the exchange rate. In an exchange rate target zone, the central bank controls the money supply to keep the exchange rate within a specified band around a specified central parity, for example ± 2.25 percent for most of the EMS bands before August 1993.⁵ We denote this band by

$$\underline{s} \leq s_t \leq \bar{s}, \quad (3.3)$$

where \underline{s} and \bar{s} are the lower and upper edges of the exchange rate band.

The Krugman model has two crucial assumptions. First, the exchange rate target zone is perfectly credible, in the sense that market agents believe that the lower and upper edges of the band will remain fixed forever, and that the exchange rate will forever stay within the band.⁶ Second, the target zone is defended with "marginal" interventions only. That is, the money supply is held constant and no interventions at all occur as long

⁴The positive constant α is the semi-elasticity of the exchange rate with respect to the instantaneous expected rate of currency depreciation. The instantaneous expected rate of currency depreciation is the limit of $E_t[s_{t+\Delta t} - s_t]/\Delta t = E_t[\ln(S_{t+\Delta t}/S_t)]/\Delta t$ when Δt approaches zero, where E_t denotes expectations conditional upon information available at time t , and S_t is the exchange rate expressed in units of domestic currency per unit foreign currency at time t . This model was used by Flood and Garber (1983) in studying endogenously-timed policy regime switches in foreign exchange markets.

The model can be derived from the so-called monetary model of exchange rate determination. That model has a poor empirical record. (See Frankel and Rose's chapter in this volume for details.) However, the simple linear structure allows a convenient closed form solution, whereas the general results are likely to be robust to the inclusions of sticky prices and other factors that would make the model more realistic (cf. Sutherland (1994)).

⁵It does not matter precisely how the central bank implements its monetary policy, for instance whether it is using the interest rate or the money supply as an instrument. Here for concreteness we consider money supply to be the instrument.

⁶The crucial restriction is actually that the target zone is perfectly credible when the exchange rate is in the *interior* of the band. Krugman discussed the possibility of a collapse to a free float the first time the exchange rate reaches the *edge* of the band.

as the exchange rate is in the interior of the exchange rate band. When the exchange rate reaches the weak edge of the band, the money supply is reduced (by an infinitesimal amount) to prevent the currency from weakening further; vice versa when the exchange rate reaches the strong edge of the band. Both these crucial assumptions are counter to empirical facts, something that we shall return to below.

For an explicit solution to the model, the stochastic process for the exogenous component of the fundamental, velocity, must also be specified. A very convenient assumption is that velocity is a Brownian motion with drift μ and rate of variance σ^2 ,

$$df_t = \mu dt + \sigma dW_t, \quad (3.4)$$

where dW_t is the increment of a Wiener process.⁷

The assumption of a Brownian motion for velocity is attractive, because it implies that the free-float exchange rate will also be a Brownian motion, which matches the empirical observations that free-float exchange rates seem to behave like random walks (Meese and Rogoff, 1983). Let a free-float exchange rate regime be characterized by no interventions, that is, a constant money supply. Then it is easy to see that the free-float exchange rate is given by

$$s_t = \alpha\mu + f_t. \quad (3.5)$$

The two crucial assumptions mentioned above for the target zone, together with the Brownian motion assumption about velocity, allow the target zone exchange rate to be expressed as a function of the aggregate fundamental, the “target zone exchange rate function” $s_t = S(f_t)$, where the fundamental is restricted to band that corresponds to the exchange rate band,

$$\underline{f} \leq f_t \leq \bar{f}, \quad (3.6)$$

where the lower and upper edges of the fundamental band fulfill $\underline{s} = S(\underline{f})$ and $\bar{s} = S(\bar{f})$.

Figure 2 shows the relation between the exchange rate and the fundamental, both for the free float and the target zone, for the simplest case when the drift μ is zero. The fundamental is measured along the horizontal axis, the exchange rate along the vertical

⁷Krugman actually assumed that the fundamental is a Brownian motion without drift, that is, with $\mu = 0$, the continuous-time analog of a random walk. The intricacy of Brownian motions is a frequent stumbling block for new students of the target zone literature. However, for the purpose of the present discussion, the reader needs to know only two things about a variable that follows a Brownian motion drift: its realized sample paths are continuous over time and do not include discrete jumps; and changes in the variable over any fixed time interval t , $f_t - f_0$, are distributed as a normal random variable with mean μt and variance $\sigma^2 t$, which hence are proportional to the time interval's length.

axis. The free-float relation is simply the 45-degree dashed line FF ; the exchange rate is simply equal to the fundamental. The target zone exchange rate function is the S-shaped solid curve TT . The horizontal dashed lines show the edges of the exchange rate band.

In order to derive the exchange rate function, the expected exchange rate depreciation on the right-hand side of (3.1) is rewritten with the help of Ito's Lemma. This results in a second-order differential equation for the exchange rate as a function of the fundamental, the general solution to which is

$$s_t = \alpha\mu + f_t + A_1e^{\lambda_1 f_t} + A_2e^{\lambda_2 f_t}, \quad (3.7)$$

where $\lambda_1 = -\frac{\mu}{\sigma^2} + \sqrt{\frac{\mu}{\sigma^2} + \frac{2}{\alpha\sigma^2}}$ and $\lambda_2 = -\frac{\mu}{\sigma^2} - \sqrt{\frac{\mu}{\sigma^2} + \frac{2}{\alpha\sigma^2}}$, and where A_1 and A_2 are constants.⁸ The constants are determined by the conditions that the exchange rate function is flat at the edges of the fundamental band,

$$S_f(f) = S_f(\bar{f}) = 0. \quad (3.8)$$

(where subscript denotes derivative).

These conditions are generally called “smooth pasting” conditions, a concept known in option-pricing theory (see Dixit (1992)). The intuition for the smooth-pasting conditions is far from easy, and another frequent stumbling block for new students of the target zone literature. The smooth pasting conditions mean that at the boundary of the exchange rate band, the exchange rate is completely insensitive to the fundamental. Why might this be so? It is easy to understand in the case when the drift of the fundamental is zero. Then, first we note that there is a clear jump, a discontinuity, in the expected change of the fundamental at the edge of the band. In the interior of the band, the fundamental is a Brownian motion, without drift, so its expected change is zero. At the edges of the band, the fundamental can either remain at the edge or drift back into the band, so its expected rate of change is suddenly *not* zero; at the upper edge it is negative, at the lower edge it is positive. Second, there can be no jump or discontinuity in the expected change

⁸By Ito's Lemma we have $E_t ds_t = S_f E_t df_t + (1/2)S_{ff} E_t df_t^2$, where S_f and S_{ff} denote the first and second derivative of the exchange rate function. By the property of Brownian motions, $E_t df_t = \mu dt$ and $E_t df_t^2 = \sigma^2 dt$. Substitution into (3.1) results in the second-order ordinary differential equation

$$S_{ff}(f) + \frac{2\mu}{\sigma^2} S_f(f) - \frac{2}{\alpha\sigma^2} S(f) + \frac{2}{\alpha\sigma^2} f = 0.$$

of the exchange rate at the edge. To see this, recall that the exchange rate is a linear function of the fundamental and the expected change in the exchange rate. Now, there can be no jump in the exchange rate at the edge of the band, otherwise there would be a safe arbitrage (a one-sided bet) since it could only jump one way, into the exchange rate band. Furthermore, the fundamental is continuous and does not jump.⁹ Therefore, the expected change in the exchange rate must also be continuous and not take a jump. Third, if the expected change in the fundamental takes a jump, but the expected change in the exchange rate does not, the exchange rate must be completely insensitive to the fundamental at that point.¹⁰

There are two main results in the Krugman model. These results follow from the shape of the exchange rate function TT .

The first main result is that the slope of the S-shaped curve is less than one at all times. This result is sometimes called the “honeymoon” effect, from a reference in Krugman (1987) to a “target zone honeymoon.” The intuition behind the honeymoon effect is straightforward enough. When the exchange rate is higher (the currency is weaker) and closer to the upper (weak) edge of the exchange rate band, the probability that it will, within a given finite time, reach the upper edge is higher. As a result, the probability of a future intervention to reduce the money supply and strengthen the currency is higher. This means that a future currency appreciation is expected, which the market turns into an immediate appreciation and a lower exchange rate. In this case, the exchange rate is less than the rate predicted by the current fundamental alone, because an expected currency appreciation is being taken into account. In other words, the target zone exchange rate is less than the free-float exchange rate, for a given level of the fundamental. Symmetrically, when the exchange rate is stronger and closer to the lower (strong) edge of the band, a future currency depreciation is expected, implying that the exchange rate is higher (the currency is stronger) than the free-float exchange rate, for a given level of the fundamental.

The honeymoon effect leads to the important insight that a perfectly credible target zone is inherently stabilizing: the expectations of future interventions to stabilize the exchange rate makes the exchange rate more stable than the underlying fundamental. Put differently, a target zone means stabilizing the fundamentals (between the vertical dashed

⁹The velocity component is continuous since it is a Brownian motion. The money supply component is constant except at the edge where it moves infinitesimally just enough to prevent the fundamental from going further in the “wrong” direction.

¹⁰By Ito’s Lemma we have $E_t ds_t = S_f E_t df_t + (1/2) S_{ff} E_t df_t^2$, where $E_t df_t^2 = \sigma^2 dt$. Now, if $E_t df_t$ is discontinuous at the edges, but $E_t ds_t$ is not, the first derivative must be zero at the edges, $S_f = 0$.

lines in Figure 2), but the exchange rate stabilizes even more (between the horizontal dashed lines in Figure 2).

The second main result is the smooth-pasting property mentioned above. This property has received considerable theoretical interest. Besides being a neat result, it also has more practical implications. It means that the exchange rate should rather be a nonlinear function of the underlying fundamentals. This could perhaps partially explain why existing linear exchange rate models behaved so badly empirically (Meese and Rogoff, 1983, see also Frankel and Rose's chapter in this volume). The theory of exchange rate target zones actually to a large extent became identified with smooth pasting and marginal interventions. Soon after, several researchers clarified and extended the Krugman results, and also confronted the model's implications with data. That confrontation was close to calamitous.

3.3. Empirical Tests of the Krugman Model

The Krugman model has clear empirical implications for exchange rates and interest rate differentials. It also has empirical implications for the aggregate fundamental, which is not directly observable but can be estimated from the observed variables. These empirical implications have been tested extensively on data from the ERM, the Nordic countries (especially Sweden), the Bretton Woods system and the Gold Standard. These tests have consistently rejected the model.

3.3.1. Exchange rates

The Krugman model implies numerous predictions about the behavior of exchange rates. One implication is that the distribution of the exchange rate within the band must be U-shaped – that is, the exchange rate must spend most of the time near the edges of the band. To understand this implication, recall the S-shape of the exchange rate function and the “smooth pasting” at the edges of the band, which implies that the exchange rate is very insensitive to the fundamental near the edges of the band. Hence the exchange rate will move slowly near the edges of the band; where the exchange rate moves slowly, it will appear often. The fundamental, in contrast, moves with a constant speed between its bounds, hence its distribution is uniform.

The U-shape of the exchange rate's density is clearly rejected by the data. The data shows that the distribution is hump-shaped, with most of the probability mass in the interior of the band and very little near the edges of the band (Bertola and Caballero,

1992; Flood, Rose and Mathieson, 1991; Lindberg and Söderlind, 1994). This is, for instance, the case for the FF/DM exchange rate in *Figure 1a*, which spends most of the time well into the interior of the exchange rate band.

3.3.2. Interest Rate Differentials

The Krugman model has specific predictions also for interest rate differentials between domestic and foreign currency interest rates. These predictions are particularly specific under the assumption of uncovered interest parity, that the interest rate differential between the domestic and foreign currency interest rates equal the expected rate of currency depreciation,

$$i_t - i_t^* = \frac{E_t[ds_t]}{dt}, \quad (3.9)$$

where i_t and i_t^* are the domestic and foreign-currency interest rates.¹¹

We define the (log) exchange rate within the band, x_t , as the deviation of the log exchange rate from the log central parity,

$$x_t \equiv s_t - c_t. \quad (3.10)$$

It follows that the expected rate of currency depreciation can be written

$$\frac{E_t ds_t}{dt} \equiv \frac{E_t dx_t}{dt} + \frac{E_t dc_t}{dt}; \quad (3.11)$$

the sum of what we shall call the expected rate of currency depreciation within the band and the expected rate of realignment (the expected rate of change in the central parity). Under the assumption of perfect credibility (one of the two main assumptions of the Krugman model), no realignments are expected to occur, and the expected rate of currency depreciation is the same thing as the expected rate of currency depreciation within the band. Then we can write

$$i_t - i_t^* = \frac{E_t dx_t}{dt}. \quad (3.12)$$

¹¹Uncovered interest parity is equivalent to a zero (nominal) foreign exchange risk premium, the difference between the expected domestic currency rate of return on a foreign currency investment and the expected rate of return on a domestic currency investment. For floating exchange rates, uncovered interest parity is usually strongly rejected by the data, see Froot and Thaler (1990). For exchange rate target zones, Svensson (1992a) argues that the foreign exchange risk premium is likely to be small, and that hence uncovered interest parity should be a good approximation.

The expected rate of currency depreciation within the band is in the Krugman model negatively-related to the exchange rate as shown by the negatively sloped curve in *Figure 3*. The intuition behind the negative slope is easy (in order to save space, we will skip explaining the particular nonlinear shape). When the exchange rate is high and at the upper edge of the exchange rate band, the currency is weak and cannot depreciate further. The exchange rate can either remain at the weak edge or drift back towards the interior of the band, in which case the currency appreciates. There is an expected currency appreciation: the expected rate of currency depreciation is negative. Analogously, when the exchange rate is at the lower edge of the band, the expected rate of currency depreciation is positive.

The negative relation between the expected rate of currency depreciation within the band and the exchange rate within the band implies that the exchange rate within the band displays *mean reversion*, that is, the expected future exchange rate within the band is closer to the long-run mean of the exchange rate within the band the further away in time it is. This mean reversion is an important general property of target zone exchange rates that is independent of the validity of the specific Krugman model, and it will be important in the discussion of extensions of the model below.

Now, under the two assumptions of uncovered interest parity and perfect credibility, the interest rate differential should equal the expected rate of currency depreciation within the band. Then the Krugman model predicts a negative deterministic relation between the interest rate differential and the exchange rate, and the correlation between the two should be strongly negative (the correlation need not be -1 since the relationship is a bit nonlinear).

However, this deterministic relationship is rejected by the data. Plots of interest rate differentials against exchange rates result in wide scatters of observations. The correlations between exchange rates and interest rate differentials are often positive or zero, and only occasionally negative, depending upon the sample and the sample period (Svensson, 1991c; Flood, Rose and Mathieson, 1991; Lindberg and Söderlind, 1994). It is not difficult to see that a plot of interest rate differentials in *Figure 1b* against the deviations between the exchange rates and the central parity (the centre of the band) in *Figure 1a* results in anything but a negative deterministic relation!

3.3.3. Testing the Crucial Assumptions Directly

The crucial assumptions of the Krugman model, perfect credibility and only marginal interventions, can be tested separately. Perfect credibility seems unrealistic given the frequency of realignments that have actually occurred, for instance for the FF/DM exchange rate in Figure 1a. Furthermore, there is clear direct evidence, for instance in Figure 1b, of many of these realignments having been anticipated. The large interest rate differentials observed immediately before some of the realignments must be interpreted as investors demanding very high franc interests as compensation for an anticipated devaluation of the franc. The easiest way of testing the credibility assumption more formally is the “simplest test” described in Svensson (1991a); it consists of examining whether forward exchange rates for different maturities fall outside the exchange rate band. If forward exchange rates fall outside the exchange rate band for some maturity, under the maintained assumption of international capital mobility the exchange rate target zone cannot be perfectly credible; if it were perfectly credible, unexploited profit opportunities would exist on the forward foreign exchange market. The assumption of perfect credibility is clearly rejected for most exchange rate target zones and most sample periods (Svensson, 1991a; Flood, Rose and Mathieson, 1991).

Tests of the other crucial assumption, that the central bank undertakes only marginal interventions, require data on (or indications of) central banks’ actions. Where those are available, the assumption is clearly rejected. In fact, interventions that occur in the interior of the exchange rate band, “intra-marginal” interventions, are the rule rather than the exception (Giavazzi and Giovannini, 1989; Mundaca 1990; Dominguez and Kenen, 1992; Edison and Kaminsky, 1991; Lindberg and Söderlind, 1995).

In summary, the Krugman model with its assumptions of perfect credibility and only marginal intervention has been overwhelmingly rejected by the data. The experience may seem an excellent example of “the great tragedy of Science – the slaying of a beautiful hypothesis by an ugly fact” (T.H. Huxley). We think it is fair to state that some of the many researchers who had enthusiastically embraced the theory felt some embarrassment and even pessimism because of the glaring mismatch with the data. Nevertheless, the empirical rejection stimulated researchers to get back to the drawing board. It soon appeared that two extensions of the Krugman model seemed to resolve the empirical difficulties. These extensions, examined in sections 3.4 and 3.5, involve removing the two crucial assumptions by incorporating imperfect credibility and intra-marginal interventions.

3.4. Extension 1: Imperfect Credibility

Clearly, as Figure 1a demonstrates, exchange rate bands are sometimes shifted, realigned. Then the central parity – the centre of the band – takes a jump to a new level. If the change in the central parity is so large that the new exchange rate band does not overlap with the old, as in October 1981, the exchange rate must jump as well. If the new band does overlap with the old band, as in September 1979, the exchange rate may or may not jump. Furthermore, the realignments seem, at least to some extent, to be anticipated, as indicated in Figure 1b by the large interest rate differentials observed shortly before some of the realignments. One obvious extension of the Krugman model is, therefore, to incorporate time-varying realignment risk. We shall begin by discussing how the theory can be modified, then consider the empirical implications of doing so.¹²

3.4.1. Time-varying Realignment Risk

Let us now consider the situation where the exchange rate band can move. The central parity jumps at realignments and remains constant between realignments. Investors are uncertain as to when realignments will occur and how large they will be, and they form expectations of realignments given the available information. This means that we can express the expected rate of (total) currency depreciation as the sum of two components as in (3.11), the expected rate of depreciation within the band and the expected rate of realignment. The latter component should be interpreted as the product of two factors, the first being the probability per unit of time of a realignment, the other being the expected size of a realignment if it occurs. Consider the simplest case when the expected rate of realignment is exogenous and does not directly depend on the exchange rates.

Substitution of (3.11) into (3.1) and some rewriting results in the modified exchange rate equation

$$x_t = h_t + \alpha \frac{E_t dx_t}{dt}, \quad (3.13)$$

¹²Bertola and Svensson (1993) presented the first target zone model with time-varying realignment risk. Several papers in the literature (including Krugman, 1991) had previously considered imperfect credibility in the form of possible realignments at the edges of the band but not inside the band. Empirically, perfect credibility has been rejected in periods when the exchange rates have been far from the edges of the band. Actual realignments have occurred both when exchange rates have been near as well as further away from the edges (cf. June 1982 and April 1986 in Figure 1a). This supports the presumption that realignment risk is relevant also when exchange rates are away from the edges of the band.

where a new composite fundamental h_t is defined as

$$h_t \equiv f_t - c_t + \alpha \frac{E_t dc_t}{dt}, \quad (3.14)$$

the sum of the old aggregate fundamental (less the central parity) and the product of α and the expected rate of realignment.

The new linear relation between the exchange rate within the band, the new composite fundamental and the expected rate of currency depreciation within the band is formally identical to the old linear relation between the exchange rate, the old aggregate fundamental and the expected rate of (total) currency depreciation. This implies that there may exist a relation, an exchange rate function, between the exchange rate within the band and the new composite fundamental that is similar to the relation between the exchange rate and the old fundamental in the Krugman model, the relation displayed in Figure 2. (In fact, in the special case in which the expected rate of realignment is perceived to be an exogenous Brownian motion, the new exchange rate function is of exactly the same form as the solution to the Krugman model.)

Despite the similarity with the Krugman model, behind the new composite fundamental there are now *two* fundamentals, the old aggregate fundamental, f_t , and the expected rate of realignment, $\frac{E_t dc_t}{dt}$, (which in turn may depend on additional variables). It no longer makes sense to plot the exchange rate against only one of the state variables – the old aggregate fundamental – since it omits the expected rate of realignment, which is another state variable.

The introduction of time-varying realignment risk has important consequences for how interest rate differentials are determined, and how plots of interest rate differentials against exchange rate should be interpreted. Under the assumption of uncovered interest parity, the interest rate differential equals the expected (total) rate of currency depreciation, equation (3.15), but this is now equal to the sum of the expected rate of currency depreciation within the band and the new term, the expected rate of realignment,

$$i_t - i_t^* = \frac{E_t dx_t}{dt} + \frac{E_t dc_t}{dt}. \quad (3.15)$$

Hence, for an observation of the interest rate differential and exchange rate within the band, such as point *A* in Figure 3, the vertical difference between point *A* and the downward-sloping curve (the expected rate of currency depreciation within the band) is explained by the expected rate of realignment. Including time-varying realignment ex-

pectations hence offers a reason why there need not be a deterministic relation between interest rate differentials and exchange rates. Even though the expected rate of currency depreciation within the band is negatively correlated with the exchange rate within the band, depending upon how the expected rate of realignment fluctuates over time and is correlated with the exchange rate, any correlation pattern between the interest rate differential and exchange rate is possible.

3.4.2. The "Drift-Adjustment" Method to Estimate Realignment Expectations

The credibility, or rather the lack thereof, of exchange rate target zones is always an issue of great interest, not only for the central bankers and finance ministers directly involved, but also for investors and economics journalists. The approach to determine interest rate differentials presented above has led to a new method to measure realignment expectations and evaluate the credibility of exchange rate target zones. This method has much better precision than the "simplest test" of target zone credibility referred to above.

From (3.15) we can write

$$\frac{E_t dc_t}{dt} = i_t - i_t^* - \frac{E_t dx_t}{dt} \quad (3.16)$$

the expected rate of realignment equals the difference between the interest rate differential and the expected rate of currency depreciation within the band. From this two things follow: First, unless the expected rate of currency depreciation within the band is negligible, the interest rate differential is a misleading indicator of realignment expectations. Second, a direct estimate of the expected rate of realignment results if an estimate of the expected rate of currency depreciation within the band is constructed and this estimate is subtracted from the interest rate differential. This method can be called the "drift-adjustment" method to estimate realignment expectations, since the interest rate differential is adjusted by the "drift" of the exchange rate within the band.¹³

The difficulty with the method lies in estimating the expected rate of future currency depreciation within the band, that is, to predict the expected future exchange rate within the band. For floating exchange rates, predicting future exchange rate is usually considered a futile exercise, and a simple random walk usually out performs other forecasting

¹³The drift-adjustment method was suggested by Bertola and Svensson (1993) and is empirically implemented in Rose and Svensson (1994b), Lindberg, Söderlind and Svensson (1993), and Svensson (1993).

models (Meese and Rogoff, 1983). However, what is at stake here is predicting the expected future exchange rate *within the band*; that is, the future exchange rate's expected deviation from the future central parity. Predicting this has turned out to be much more fruitful than predicting (total) future exchange rates, since – unlike floating exchange rates – exchange rates within the band, both theoretically (see above) and empirically, display strong mean-reversion. In practice, a simple linear regression of future exchange rates within the band on the current exchange rate within the band and current domestic and foreign interest rates seems to predict quite well. This way of estimating the expected rate of realignment has the great advantage that it does not depend on any specific theory of exchange rates; nor does it matter whether expected rates of realignments are exogenous or endogenous (for instance, whether or not they are influenced by the exchange rate's position within the band).

Estimates of expected rates of currency depreciation within the band done for ERM exchange rates and Nordic exchange rates indicate that for time horizons up to one year, the estimates are often of the same order of magnitude as the interest rate differentials (up to 2-3 percent per year). Therefore, the use of interest rate differentials as indicators of target zone credibility, without adjusting for expected rates of depreciation within the band, is potentially misleading for horizons up to one year.

Estimating the confidence intervals for expected rates of depreciation within the band results in confidence intervals for expected rates of realignments. These can be used for statistical inference and hypothesis tests. For short horizons, the drift-adjustment method seems to have much better precision and power than the “simplest test.” In many cases, with the drift-adjustment method the hypothesis that expected rates of realignment are zero can be rejected also for short horizons down to one month, whereas the “simplest test” is usually inconclusive for short horizons (Lindberg, Söderlind and Svensson, 1993). Typically, estimated expected rates of realignment vary quite a bit over time, and they vary more than the interest rate differentials. EMS expected rates of realignment are smaller in later years than in earlier ones, showing an increase over time in the system's credibility, except shortly before the September 1992 crisis (Svensson, 1992a, Rose and Svensson, 1994a).¹⁴

¹⁴When estimation is done for a particular finite maturity or time horizon $\Delta t > 0$, interest rate differentials of that maturity are adjusted by estimates of the expected rate of depreciation within the band over the same horizon, $E_t[x_{t+\Delta t} - x_t]/\Delta t$. The estimated expected rate of realignment $E_t[c_{t+\Delta t} - c_t]/\Delta t$ can then be interpreted in the following way. Suppose the time horizon is 3 months, and that an estimated expected rate of realignment is 12 percent per year. Conditional upon a given expected size of the realignment if it occurs, the expected conditional realignment size, a probability of a realignment

3.5. Extension 2: Intra-marginal Interventions

The earlier discussion pointed out that empirical distributions of exchange rates within the band are hump-shaped, with most of the observations in the middle of the exchange rate band, in contrast to the U-shape predicted by the Krugman model, where most of the observations would occur near the edges of the band. The most obvious explanation for this hump-shape is that the exchange rate is kept in the middle of the band by intra-marginal interventions, that is, central bank interventions that occur in the interior of the exchange rate band.¹⁵

In the real world, central banks' intervention behavior is by all accounts both complicated and shifting over time. A first approximation to this complicated behavior is to propose that in addition to marginal interventions at the edges of the band there are intra-marginal "leaning-against-the-wind" interventions, that is, interventions that aim at returning the exchange rate to a specified target level within the band. A simple way to model such interventions, in terms of the target zone model with imperfect credibility described in the previous section, is to specify that the intra-marginal interventions result in the expected rate of change (the drift) of the composite fundamental towards central parity is proportional to the distance to central parity, that is,

$$\frac{E_t dh_t}{dt} = -\rho h_t, \quad (3.17)$$

where ρ , the rate of mean reversion, is a positive constant.¹⁶

The result of this modification is illustrated in *Figure 4*. The dashed 45-degree line marked *FF* again corresponds to the free-float exchange rate regime, when no interventions are undertaken. Let us then first consider a "managed-float" exchange rate regime, when interventions are mean-reverting towards a central parity, but there is no specified band and no marginal interventions. The result will be the dashed line *MM* in *Figure 4*, which

within the time horizon can be constructed. Suppose the expected conditional realignment size is 5 percent. Then the expected "frequency", probability per unit of time, of realignment is the expected rate of realignment divided by the expected conditional realignment size, that is, in our case 2.4 per year. Per 3 months, this is $\frac{1}{4}$ of 2.4, that is, 0.6. Hence, the market expects a realignment to occur within 3 months with probability 60 percent, conditional upon the realignment size 5 percent.

¹⁵Mean-reversion of the fundamental in the Krugman model was first discussed by Froot and Obstfeld (1991) and Delgado and Dumas (1991). Its practical and empirical importance was established by Lindberg and Söderlind (1995). See also Lewis (1993).

¹⁶Realignments, which were discussed in the previous section, can be seen as another kind of intervention.

is less sloped than the free-float line. The equation for the *MM* line is

$$x_t = \frac{h_t}{1 + \alpha\rho}. \quad (3.18)$$

In other words, a honeymoon effect operates in the managed-float regime even without an exchange rate band. This effect results in the exchange rate fluctuating less than in the free-float regime, for given fluctuations in the composite fundamental. This is because the mean-reverting interventions imply that when the exchange rate is above the central parity (the currency is weak) the currency is expected to appreciate, which by itself reduces the exchange rate.

Now add an explicit target zone regime to the intra-marginal interventions, which means specifying a band and marginal interventions in case the exchange rate reaches the edge of this band. The resulting exchange rate function is plotted as the solid curve *TT* in Figure 4. The curve is close to the *MM* line corresponding to the managed float, except that it has a slight S-shape and smooth pasting at the edges of the band. As drawn here, there is an additional honeymoon effect relative to the managed float, but it is much smaller than the honeymoon effect in the managed float relative to the free float. For the same parameters and a significant degree of mean-reversion, the S-shape is much less pronounced than in the Krugman model of Figure 2.

Why is it plausible that the S-shape is less pronounced than in the Krugman model? And why is the exchange rate function so close to that in a managed float?

When the exchange rate is above the central parity (the currency is weak) the currency is expected to appreciate for two reasons. One reason is expected intra-marginal interventions to appreciate the currency towards the central parity. This reason is present also in a managed float. The other reason is expected future marginal interventions to prevent the exchange rate moving outside the band, in the event that the future exchange rate reaches the upper edge of the band. That reason is only present in the target zone regime. However, the probability of the future exchange rate ever reaching the edges of the band is smaller with mean-reverting interventions than in the Krugman model. The expected currency appreciation caused by the second reason is therefore smaller than that caused by the first reason.

In a target zone with mean-reverting interventions, the unconditional distribution of the composite fundamental is hump-shaped (Lindberg and Söderlind (1995) show that it is actually a truncated normal distribution). With sufficiently strong mean-reverting interventions added, the exchange rate function is almost linear and very close to the exchange

rate function for a managed float. As a consequence, the unconditional distribution of the exchange rate will be hump-shaped (with possibly some small extra probability mass at the edges of the band).

These predictions square well with the empirical hump-shaped exchange rate distributions. That the exchange rate function may be almost linear is consistent with the difficulty of finding empirical evidence of nonlinearities. In a structural estimation of a target zone model with mean-reverting interventions for the Swedish krona, Lindberg and Söderlind (1995) find reasonable parameter values, fairly strong mean-reversion, and that the overall fit of the model is quite good, much better than the Krugman model.

This analysis leads to the conjecture that the initial emphasis in target zone models on nonlinearities, smooth pasting and infrequent marginal interventions was misplaced. Target zones are better described as similar to managed floats with intra-marginal mean-reverting interventions, with additional marginal interventions defending the target zone in the rare cases when the exchange rate reaches the edge of the band. The honeymoon effect is probably important, whereas smooth pasting and nonlinearities seem empirically insignificant. An official exchange rate band should consequently not be seen as a commitment to mostly marginal interventions, but as a practical way of expressing a verifiable general commitment to limit exchange rate variability with intra-marginal interventions. After all, it would be impractical and unverifiable to announce a commitment to stabilize exchange rates in terms of a degree of mean-reversion or in terms of a standard deviation.

That the Krugman model has turned out to be misleading as a model of real world exchange rate bands should not detract from Krugman's important *technical* contribution, namely how to analyze how expectations of *future* infrequent intervention (rather than current continuous intervention) matter for current asset prices.

3.6. Why Exchange Rate Bands?

The issues we have discussed so far all concern the first, positive, question that was mentioned above: what are the dynamics of exchange rates, interest rates and central bank interventions in exchange rate target zones? Let us now turn to the second, normative, question: are exchange rate bands optimal?

Let us first narrow down the normative question. It can be separated into three consecutive questions: First, when is a fixed exchange rate regime better than floating, where a fixed exchange rate regime in practice means a more or less narrow band around a central parity with possible occasional realignments of the central parity? Second, how

often (if ever) and by how much should the central parity be realigned? Third, how narrow should the band be? The first and second questions have been extensively discussed in the traditional literature on exchange rate regimes (see Genberg (1989) for a recent survey) and in the recent literature on macroeconomic policy and credibility (see Persson and Tabellini (1990) for a survey). They are discussed in section 2 of the Chapter and in Persson and Tabellini's chapter of this volume. Here we shall briefly discuss the third question, which has received very little attention in the literature.¹⁷

Why have a nonzero band instead of just a zero band, since the latter seems simpler?¹⁸ One reason for a nonzero band that was emphasized by Keynes (1930, pp. 319-331) is that it allows some degree of national monetary independence, so that monetary policy can to some extent be used for domestic stabilization. That monetary independence can arise in a fixed exchange rate regime with free capital mobility may be a surprise to many readers, given the standard textbook result that a fixed exchange rate and free capital mobility implies a complete loss of monetary independence, in the sense that the central bank cannot then set the domestic interest rate at a level different from the foreign interest rate. Let us first explain the textbook result, then show how it is modified with nonzero exchange rate bands.

Recall the assumption that investors, in order to invest in both domestic and foreign currency, demand that the interest rate differential between the domestic and foreign interest rate equals the sum of the expected rate of realignment and the expected rate of currency depreciation within the band, equation (3.15). With a zero band, the last term is equal to zero and the interest rate differential is simply equal to the expected rate of realignment,

$$i_t - i_t^* = \frac{E_t dc_t}{dt} \quad (3.19)$$

The domestic central bank has then no choice but to let the domestic interest rate fulfill this condition. If it tries to set a lower domestic interest rate there will be a capital outflow because investors shift their investment to the foreign currency, and a loss of foreign

¹⁷Cukierman, Kiguel and Leiderman (1994) develop a positive theory of when a central bank chooses an exchange rate band, how wide the band is, and when it will be realigned. This is done in a setup where the central bank can make a commitment to a band and faces a given cost if it reneges on the commitment. Their paper is hence related to the literature on escape clauses and monetary policy, for instance, Flood and Isard (1989) and Lohmann (1992).

¹⁸For simplicity we disregard that for technical reasons the minimum bandwidth is not exactly equal to zero but a small positive number, since the bandwidth must exceed the normal interbank bid-asked spread for exchange rates if the central bank does not want to take over all currency trade. The normal spread is very small, though, say around 0.04 percent.

exchange reserves will force the central bank to raise the interest rate. If it tries to set a higher domestic interest rate, there will be a capital inflow because international investors shift their investment to the domestic currency, and an increase in foreign exchange reserves will increase liquidity in the economy and force the domestic interest rate down. This is the textbook case of a complete loss in monetary autonomy.¹⁹

With a nonzero band, the expected rate of currency depreciation within the band is no longer always zero. Now the central bank can control the domestic interest rate via control over the expected rate of currency depreciation within the band in equation (3.15). The way to control the expected rate of currency depreciation within the band is to exploit the mean reversion of the exchange rate within the band. If the central bank increases the exchange rate above its mean within the band, the exchange rate is expected to fall in the future towards the mean. That is, an expected currency appreciation within the band is created, which will reduce the domestic interest rate. Similarly, reducing the exchange rate below its mean generates an expected currency depreciation within the band, which increases the domestic interest rate.

This monetary independence allows the central bank some freedom to adjust the domestic interest rates to local conditions, for instance lowering the interest rate in a recession and increasing it during a boom. We believe this degree of monetary independence is the best explanation of why fixed exchange rate regimes have nonzero bands. Put differently, governments and central banks prefer to have some monetary independence; they therefore prefer nonzero bands in fixed exchange rate regimes.²⁰ However, even if bands result in some monetary independence, it does not follow that this monetary independence in a fixed exchange rate regime is sufficiently large to matter, in the sense of

¹⁹Strictly speaking, the domestic interest rate equals the foreign interest rate only if the expected rate of realignment is zero, that is, if the exchange rate regime is completely credible. Also, technically the central bank can still control the domestic interest rate if it can somehow manipulate the expected rate of realignment, but that is not usually considered an example of monetary independence.

²⁰Another reason for nonzero bands, discussed in De Grauwe (1992, pp. 103-107), is that sufficiently wide bands (and sufficiently small realignments) allow the new and old bands to overlap at realignments. This way realignments are possible without discrete jumps in exchange rates, that is, realignments need not imply one-sided bets on which way the exchange rate will move. This should reduce the amount of speculation and interest rate movements before each realignment. In Figure 1, at the two realignments with overlapping bands (September 1979 and January 1987) it appears that the interest rate differential was indeed less volatile than at the other realignments.

having significant effects on output or inflation.^{21 22}

The optimality of exchange rate bands in fixed exchange rate regimes remains an under-researched area. With the improved understanding of the positive questions of how the exchange rate target zones actually work, it should now be possible to deal with the normative issue of their optimality.²³

3.7. Conclusion

In summary, the recent work on exchange rate target zones took off in 1988 with Krugman (1991). The Krugman model employs two crucial assumptions: perfect credibility

²¹Note that this monetary independence is limited to interest rates of short maturities, say less than one year. The reason is that the expected rate of currency depreciation within the band over a longer maturity is by necessity small: the amount of currency depreciation is bounded by the bandwidth, and it is divided by a long maturity in order to be expressed as a rate. Furthermore, the control is only temporary, in the sense that the average expected rate of currency depreciation within the band must be zero since on average the exchange rate within the band cannot deviate from its mean. Thus, the average interest rate differential over a longer period must still equal the average expected rate of realignment. Temporarily, expected rates of depreciation within the band can clearly be sizeable, though: If the exchange rate is 1 percent above the central parity, still far from the the upper edge of an ERM ± 2.25 percent band, and is expected to reach the center of the band in 6 months, the expected rate of appreciation within the band is 2 percent per year, which is a sizeable reduction of the 6-month domestic interest rate. The control over the domestic interest rate is limited even in the short run if the expected rate of realignment is sensitive to exchange rate movements within the band: suppose an increase in the exchange rate above central parity (weakening of currency) leads to an increase in the expected rate of realignment. This by itself increases the domestic interest rates and counters the decrease because of an expected currency appreciation within the band.

²²The monetary independence can be exploited in order to smooth domestic interest rates, a behavior often attributed to central banks (Goodfriend, 1991). When there is an increase in the the domestic interest rate, say because the foreign interest rate or the expected rate of realignment increases, the central bank can dampen the effect on the domestic interest rate by increasing the exchange rate and create an expected currency appreciation within the band. A tradeoff between domestic interest rate variability and the exchange rate band results. Svensson (1994) uses Swedish krona data to quantify this tradeoff, as a measure of the amount of monetary independence in an exchange rate band. The amount of monetary independence then appears to be sizable in some instances: An increase in the exchange rate band from zero to ± 2 percent allows the standard deviation of the 1-month domestic interest rate to be reduced by a half.

²³Williamson (1985, 1989) advocates a target zone for the real value of the dollar. He argues that floating exchange rates are subject to irrational destabilizing speculation which leads to excessive volatility and "misaligned" real exchange rates. A target zone would remedy this, but it should be fairly wide (say ± 10 percent) to allow sufficient latitude for monetary policy, for changes in the central rate without discontinuous changes in exchange rates, and for uncertainty about the correct level of target rate. Recently Corbae, Ingram and Mondino (1990) and Krugman and Miller (1992) have expressed this excess-volatility case for target zones in formal models. Although the excess-volatility argument is sometimes used in general support of fixed exchange rates rather than floating exchange rates, it does not seem to be very relevant for the choice of bandwidth for ERM-type narrow nominal exchange exchange rate bands. As discussed by Krugman and Miller (1992), the excess-volatility argument may however be important in understanding the G-3 (Germany, Japan and the United States) Louvre agreement in 1987 to stabilize the dollar.

of the target zone and exclusively marginal central bank interventions to defend it. Two main results follow: the “honeymoon effect,” that target zones are inherently stabilizing, and “smooth pasting,” that the exchange rate is a nonlinear function of its fundamental determinants and insensitive to these fundamentals at the edge of the exchange rate band. The Krugman model has very specific empirical implications. These have been consistently rejected by the data, as have the two crucial assumptions. New work by several researchers has extended the Krugman model by removing the two crucial assumptions, which has made the theory fit the data very well.²⁴

Allowing for realignment expectations can explain observed correlations between exchange rates and interest rate differentials, and has led to a new method to empirically estimate realignment expectations, the “drift-adjustment” method. Allowing for intra-marginal interventions can explain the fact that exchange rate observations tend to cluster in the centre of the bands. Such interventions also imply a strong honeymoon effect but insignificant non-linearities and smooth pasting. A target zone then appears very similar to a “managed float” with a target central parity but without an explicit band.

From this it appears that the initial emphasis in the target zone literature on exclusively marginal interventions, nonlinearities and smooth pasting was largely misplaced. Real world exchange rate target zones are in practice better understood as managed floats with a target exchange rate level which is mainly defended by frequent mean-reverting intra-marginal interventions, and in addition infrequently supported by marginal interventions at the edges of the band in the very rare cases when the exchange rate actually reaches the edges of the band. The official bands are then best seen as a practical and verifiable way of expressing a general commitment to stabilize exchange rates relative to a central parity (and definitely not as a commitment to marginal interventions only). With this much improved understanding of the actual working of exchange rate target zones, it should be possible to direct future research more towards the under-researched normative issue of the optimality of exchange rate bands.

Much work remains to be done. The models are still extremely simplified, and would surely be more realistic with more state variables, sticky prices, and real effects (perhaps along the lines of Miller and Weller (1991a,b), Klein (1990) and Beetsma and van der Ploeg (1994)). There is certainly room for more realistic intervention policies – for instance, explicit smoothing of exchange rates and interest rates – and for attempts to estimate

²⁴On the other hand, the fact that the theory more easily encompasses different constellations of data means that it is more difficult to test, since some strong, testable implications have been removed.

changes in the intervention policy. The theory for multilateral target zones, as opposed to unilateral and bilateral target zones, is not yet worked out.²⁵ We suspect there is more to be said on the role of exchange rate uncertainty inside the band, the foreign exchange risk premium, and the degree of substitutability between domestic- and foreign-currency denominated assets. The amount of monetary independence that arises in an exchange rate band, and whether it has significant real effects, certainly needs to be clarified further.

The period from the Fall 1992 to the Fall 1993 has been a dramatic period for fixed exchange rate regimes, with intensive speculative attacks against both ERM currencies and Nordic currencies. At the time of writing (August 1994), Italy and the United Kingdom have left the ERM and allowed their currencies to float. The bands for the other ERM currencies have been widened to ± 15 percent, except for the Dutch guilder and the deutschemark which remain in the narrow band. Finland, Sweden and Norway have one after the other abandoned their unilateral fixed exchange rate regimes for flexible rate regimes.

A view that is expressed with increasing frequency is that with free international capital mobility only the extreme regimes of either a common currency or floating separate currencies are viable, whereas the intermediate one of fixed exchange rates between separate currencies are not. This view is contradicted by the experience so far of Europe's hard currency bloc: Germany, Holland and Austria, where the latter two countries clearly seem able to maintain their fixed rates against the deutschemark. The specific reasons why some countries can maintain credible fixed exchange rates should be a fruitful area for further research.

Recent events have led to renewed interest in the literature on speculative attacks and regime collapses. This literature is covered in the next section of our paper.

²⁵See Jørgenson and Mikkelsen (1993) for a discussion of a trilateral target zone model.

4. Speculative Attacks on Fixed Exchange Rate Regimes

4.1. Introduction

A salient feature of fixed exchange rate regimes is their inevitable collapse into some other policy regime. The collapse is frequently spectacular – extraordinarily large interventions into foreign exchange markets and losses by central banks, large jumps in short term interest rates aimed at squeezing short positions in the attacked currency, remarkable widening of spreads in financial markets, impositions of capital controls, large and discontinuous shifts in the value of the exchange rate, and a period of turbulent floating in a transition to the new regime. Such events obviate comparisons of the exchange rate volatility under a floating rate regime to that under a fixed rate regime. Rather, the relative merits of a fixed exchange rate regime must be judged on the basis of the reduced exchange rate volatility while the regime lasts together with the extreme turbulence of the collapse and transition to a new regime. Making such a comparison requires a model in which the timing and magnitude of balance of payments crises emerge endogenously. In this section, we will describe the features of the basic speculative attack models and show that it and its extensions form a template for a typical speculative attack, such as the attacks on the European Exchange Rate Mechanism. Our intent is to present a schematic flavor of how the model operates. For a more extensive review of the speculative attack literature, the reader is referred to Agenor, Bhandari, and Flood (1992).

Modern models of speculative attacks on fixed exchange rates are driven by a presumption that the adherence to a fixed exchange rate is a secondary policy—it is to be maintained only as long as it is compatible with policies that have priority. This is true of models both in which the primary policy is pursued while the fixed exchange rate is in effect and in which the primary policy is implemented only after the collapse of the fixed exchange rate as in the models with multiple equilibria described below. Because a central bank can always preserve a fixed exchange rate through a sustained high interest rate or, equivalently, through a sufficiently drastic contraction in monetary base, the presumption of priority of other goals is an obvious starting point. Primary policy goals may include the maintenance of stability of some other prices such as government securities or stock market prices, the maintenance of economic stability through activist monetary policy, the maintenance of price level stability, the preservation of solvency of a banking system,

or even the support of real estate prices. Typically, the priority of these other policies is expressed in speculative attack models as an exogenous growth in domestic credit that eventually leads to the collapse of the fixed exchange rate, though other forces such as a shift in real exchange rates or real money demand may also lead to an attack.

The speculative attack literature is an offshoot of the general area of regime switches that emerged through the development of forward looking macroeconomic models in the 1970's, of which Sargent and Wallace's (1973) article on shifts in money creation regimes is most relevant. In this model, Sargent and Wallace presume a shift from an inflationist to a zero money growth regime at a known future time and solve for the current value of the price level prior to the regime shift. The solution methodology requires the determination of the post-reform price level and the principle of price level continuity at the moment of the regime shift. Price level continuity establishes a boundary condition, which, when the law of motion of the price level is solved backwards, uniquely determines the current price level.

The methods of the policy-switching approach achieved popularity because they permitted investigators studying macroeconomic data come to grips with the "peculiar" behavior that surrounds crises and other discrete events. As one of its most valuable products, the approach has allowed economists to combine economic behavior in times of crisis with behavior during more normal times in a continuous series of observations. This approach has been most fruitful when applied to speculative attacks on asset price fixing schemes.

The seminal articles in the speculative attack literature were Salant and Henderson's (1978) study of attacks on buffer stocks held to peg the real price of gold and Krugman's (1979) study of attacks on fixed exchange rate regimes. Salant and Henderson postulated a model of a fixed world supply of bullion, a growing demand for gold for industrial and consumption purposes, and a buffer stock held by an authority that would be sold at a fixed real price. Eventually, rising demand would have to exhaust the buffer stock of gold, so there would be a switch in regime from a fixed real price to a rising price. The departure in Salant and Henderson from the previous exogenous regime switching models lay in their realization that the timing of the regime switch was endogenous and that the buffer stock would not drop continuously to zero at the time of the switch but would be attacked and forced discontinuously to zero. At the time of the switch in regime, there would be a jump in the continuous rate of capital gains on holding gold—the rate of change of the real gold price would jump from zero to a positive value. This would now

make it worthwhile for private speculators to hold gold bullion, and they would move to acquire the gold left in the buffer stocks. If there were no gold left in the buffer stock at this moment, the increased demand for gold would cause a discontinuous jump in the real price of gold. The principle of ruling out such unusual anticipated capital gains was carried over from the previous regime switching literature. Thus, the attack must come when the buffer stock still has gold holdings—indeed, the attack should occur at exactly the moment that the transfer of the remaining stock into private hands would satisfy speculative demand without a price jump.

These principles – no anticipated asset price discontinuities, endogenous timing of attack on a buffer stock, a discontinuity between pre-attack and post-attack rates of capital gain, and the attack’s occurring when a finite buffer stock was still in the hands of the authorities – were the concepts that Krugman applied to attacks on fixed exchange rate regimes. Krugman’s model simultaneously studied the dynamics of an endogenous exchange rate and endogenous real income, however, so it did not lend itself readily to determining explicitly the timing and magnitude of a speculative attack. Most further developments of the Krugman crisis model avoided two dimensional dynamics for expositional ease. In the examples that follow, therefore, we will use a log-linear version of the one-dimensional, special case of fixed real income developed by Flood and Garber (1984b), which has been the basis of several of the further developments in the literature.

4.2. A Basic Model of Speculative Attacks

In the basic speculative attack model, the central bank of a small country fixes the exchange rate of its currency relative to that of a large country whose logarithmic price level and interest rate, p^* and i^* , respectively, are treated as parameters. The model is summarized in equations (4.1) through (4.5):

$$m_t - p_t = -\alpha i_t, \quad (4.1)$$

$$m_t = \ln(D_t + R_t), \quad (4.2)$$

$$\frac{dD_t}{dt} = \mu D_t, \quad (4.3)$$

$$p_t = p^* + s_t, \quad (4.4)$$

$$i = i^* + \frac{ds_t}{dt}. \quad (4.5)$$

The variables m_t , p_t , i_t , D_t , and R_t are the logarithm of the domestic money base, the logarithm of the price level, the instantaneous domestic interest rate, domestic credit assets at the central bank, and the book value of net foreign reserves of the central bank, respectively. Equation (4.1) is a money market equilibrium condition, where the real money demand depends negatively on the instantaneous domestic interest rate. Equation (4.2) is an accounting identity in logarithmic form from the central bank's balance sheet: the monetary base equals central bank domestic credit assets plus net foreign reserves. Equation (4.3) reflects that presumption that the fixed exchange rate policy is secondary–primary policy goals dictate that domestic credit is programmed to grow at the constant rate μ . Equations (4.4) and (4.5) reflect assumptions of purchasing power parity and open interest rate parity, respectively.

From this model, the operating properties of both a floating exchange rate and a fixed exchange rate regime can be determined. Substituting for p_t and i_t in equation (4.1) from equations (4.4) and (4.5) yields the law of motion of the exchange rate:

$$s_t = -\beta + m_t + \alpha \frac{ds_t}{dt}, \quad (4.6)$$

where $\beta = p^* - \alpha i^*$.

If the exchange rate is fixed at \bar{s} , the anticipated rate of change of the exchange rate is zero, $\frac{ds_t}{dt} = 0$, so m_t is constant and increases in domestic credit must be exactly balanced by declines in reserves. The continual growth in domestic credit will cause reserves to decline steadily as the central bank intervenes in foreign exchange markets to maintain the fixed exchange rate. The fixed exchange rate policy will eventually be terminated if the central bank will not permit net reserves to fall below some minimum value, and in this basic model it is assumed that a permanent floating exchange rate regime will ensue. The minimum level of reserves may be negative, reflecting foreign exchange denominated borrowing on the part of the central bank. Establishing a minimum reserve level reflects either a desire on the part of the central bank to limit its risk of foreign exchange losses from an excessively unbalanced position or credit line limits imposed by potential lenders. Both constraints are important factors in speculative attacks. For expositional purposes, we will assume that the minimum reserve level is zero.

The determination of the time that the fixed exchange rate terminates proceeds in two steps. First, from the law of motion of the exchange rate, solve for the floating exchange rate given the current level of domestic credit and contingent on net reserves being at the minimum level of zero. This contingent exchange rate is known as the *shadow floating*

exchange rate, \tilde{s}_t – it will not be the exchange rate in effect prior to the collapse of the fixed exchange rate, but afterwards it will be identical to the value of the floating exchange rate. Second, find the time T that the shadow exchange rate equals the fixed exchange rate \bar{s} . Invoking the principle of the continuity of the exchange rate at the time of the collapse, this must be the time of the collapse.

It can be verified that in the floating regime, after the collapse of the fixed exchange rate, $\frac{ds_t}{dt} = \frac{dm_t}{dt} = \frac{dd_t}{dt} = \mu$, since money supply m_t is identical to $d_t = \ln D_t$. By substitution in (4.6) the solution for the floating exchange rate is

$$s_t = \tilde{s}_t = \alpha\mu - \beta + m_t = \alpha\mu - \beta + d_t. \quad (4.7)$$

So at the time T of the collapse, the exchange rate fulfills

$$\bar{s} = \tilde{s}_T = \alpha\mu - \beta + d_T. \quad (4.8)$$

Finally, since $d_T = d_0 + \mu T$, the time of the collapse can be determined as

$$T = [\bar{s} + \beta - d_0]/\mu - \alpha = [m_0 - d_0]/\mu - \alpha = \ln(1 + R_0/D_0)/\mu - \alpha. \quad (4.9)$$

The time of the collapse can be delayed by increasing the initial level of net reserves relative to domestic credit and accelerated if the rate of change of domestic credit increases. Note that even a large current fractional foreign reserve backing of the domestic money stock will not preclude a collapse.

Why do reserves jump downward discontinuously in an attack? The intuition for this result can be derived by considering the money market equilibrium in the moment before and the moment after the collapse. Before the collapse, anticipated depreciation is zero, so the demand for domestic money evaluated in foreign currency is $m - \bar{s} = \beta$. Immediately after the collapse anticipated depreciation jumps up discontinuously because the steady growth in domestic credit then translates into a steady growth of money during the floating rate regime. Since the exchange rate is continuous at the collapse, there is a downward jump in demand for domestic nominal money, and this can be satisfied by exchanging domestic currency at the central bank's foreign exchange window for the remaining reserves. *Figure 5* depicts the movements of the money stock, domestic credit and reserves before and after the attack. Prior to the attack, the exchange rate is fixed with no anticipated depreciation, so nominal money demand and supply are constant.

Nevertheless, domestic credit is continually rising, and this is matched by a mirror-image fall in reserves. At the time of the attack, nominal money demand falls discontinuously to D_T ; and the supply is reduced accordingly through an attack that drives reserves discontinuously to zero. From T onward, the money stock is identical to and grows with domestic credit.

4.3. Extensions of the Basic Model

Although they are closely related in content and technique, the literatures on target zones and on speculative attacks experienced remarkably different paths of development. Krugman's (1991) initial paper on target zones was released in different forms in two working papers distributed in 1987 and 1988. These led to such an immediate explosion of jointly evolving theoretical and empirical studies that by the time the initial paper was published, the field was already mature. In contrast, the development of the speculative attack literature was initially very slow. After Krugman's (1979) publication, nothing further was published until 1984, though, of course, papers incorporating Krugman's technique were under development in the early 1980's. It was only in the last half of the 1980's that the literature was substantially filled out. More importantly, relatively few empirical studies were undertaken to test the speculative attack theory, and these generally were calibrations that ratified the predictions of the speculative attack model.

4.3.1. Random Timing of Attacks

The speculative attack model lends itself easily to further development. For example, in the basic model, the domestic instantaneous interest rate will not deviate from the foreign rate during the fixed exchange rate regime. Empirically, however, overnight interest rates of countries maintaining fixed exchange rates have deviated substantially from foreign interest rates. This has arisen because there is always some possibility that the fixed exchange rate system may not be continued, even on a day-to-day basis. Also, countries have intervened strenuously to defend their exchange rates by operating an interest rate defense in which the domestic rate is purposely raised to high levels to squeeze sellers of the currency. This drawback of the basic model arises from the assumption of perfect foresight about the timing and magnitude of the attack. In further developments, the perfect foresight assumption has usually been dropped by making the domestic credit process random or by making the minimum reserve level of the central bank uncertain. Krugman (1979) originally argued that uncertainty about the reserves available for intervention

would affect the dynamics of attacks on the exchange rate, leading to recurring periods of attacks on the fixed rate. Flood and Garber (1984b) added randomness to the domestic credit variable in a discrete time version of the model. The operating principles of the altered models are the same as for the basic model except that the requirement of asset price continuity is replaced by a requirement that there be no expected price discontinuity – that is no foreseeable opportunity to make abnormal profits – at any given time.

4.3.2. Alternative Post-Attack Regimes

To gain additional realism, the assumption that the fixed exchange rate collapses into a permanent floating rate can be altered to include a collapse followed by a temporary period of floating that leads to a new, devalued fixed exchange rate, as in Obstfeld (1984). Under a temporary floating regime, the principle of continuity between the fixed exchange rate and the shadow floating exchange rate at the time of the attack remains. However, the law of motion of the post-attack floating exchange rate is driven in part by the future fixing of the exchange rate, which implies that the solution to the differential equation (4.6) will combine the particular solution (4.7) and a homogeneous solution. Alternatively, the attack on the fixed exchange rate may lead immediately to a devaluation to a new fixed exchange rate, or the pre-attack regime may be a crawling peg rather than a pure fixed exchange rate, as in Connolly and Taylor (1984).

4.3.3. Empirical Applications

Attacks on Fixed Exchange Rates Addressing the post-attack exchange rate policy more realistically has been motivated by efforts to breathe empirical life into the speculative attack model. For instance, Blanco and Garber (1986) adapted the model to a regime of recurring discontinuous devaluations to interpret dynamics of the Mexican exchange rate in quarterly data from 1973 through 1982. In this period, there were two major devaluations – in 1976 and 1982. Blanco and Garber noted that the permanent shadow floating exchange rate is the minimum exchange rate that can emerge after an attack. For a policy of devaluation to a new fixed exchange rate to be viable requires that the new exchange rate exceeds the shadow floating rate. Blanco and Garber modeled the difference between the new fixed rate and the shadow floating rate as a policy rule: a policy constant multiplied by a positive, random disturbance. Given the parameters of money demand, the domestic credit creation policy, the minimum reserves of the central bank, and real income, all the variables that drive the shadow floating exchange rate can

be aggregated into a single, hybrid forcing variable whose law of motion can be estimated. Using this law of motion and the devaluation rule, together with a distributional assumption for the disturbances of the model, it is possible to compute theoretical one-quarter ahead expected exchange rates and probabilities of devaluation. Blanco and Garber then estimated the value of the fixed minimum reserve level and the parameter governing the devaluation policy rule by minimizing the deviations of the theoretical one-quarter ahead expected exchange rates from observed forward exchange rates. They found that the estimated probabilities of devaluations one-quarter ahead, jumped to peaks of 20 percent just prior to the major devaluations of 1976 and 1982 and fell to low levels immediately after devaluations. Also, the theoretical exchange rates contingent on devaluation were within a 95 percent confidence interval, albeit quite wide, of the exchange rates that actually emerged in the two large devaluations.

Attacks on Crawling Pegs Cumby and van Wijnbergen (1989) applied the speculative attack model to the Argentine crawling peg of 1979-1981. Connolly (1986) also studied this episode. Under a crawling peg, the central bank will sell foreign exchange an announced exchange rate that depreciates at a predetermined rate. The principle for determining the time of attack on this regime is the same as in a fixed exchange rate regime: when the shadow exchange rate exceeds the official exchange rate, speculators will attack. Instead of a comparison of the shadow floating exchange rate with a fixed, official exchange rate, the shadow floating exchange with an official exchange rate that moves deterministically with time. An attack might lead to a floating exchange rate, a crawling peg with an increased rate of depreciation, or a devaluation. As empirical departures, Cumby and van Wijnbergen estimated the stochastic processes of each of the forcing variables separately, rather than as an arbitrarily constructed aggregate as in Blanco and Garber. Also, they assumed that the minimum level of reserves was not known to the public; rather, they assumed that it was a random variable drawn by the central bank and unknown to the public. Cumby and van Wijnbergen found that the probability of attack was driven primarily by domestic credit creation and that it reached its highest level of about 80 percent just prior to the attack that led to the abandonment of the Argentine policy.

Goldberg (1994) used Mexican data from 1980 through 1986 to study the effects of both fiscal and monetary shocks on attacks on the peso in both the fixed exchange rate period studied by Blanco and Garber and in the ensuing crawling peg regime. Connolly and Fernandez (1987) also studied the Mexican data for this period. Goldberg added to the list of forcing variables of the exchange rate by explicitly modelling real exchange

rate movements and foreign credit disturbances. Also, rather than take a stand on the minimum reserve level, she estimated the model for a range of minimum reserves. The criteria for judging the model are to compare the step-ahead (one month) probabilities that the shadow exchange rate exceeds official rates with periods of exchange rate crises and to compare computed shadow exchange rates with official rates. Goldberg finds that the step ahead probabilities general reach levels of 100 percent in the period before a crisis and that at such times the realized shadow exchange rates exceed the official rates. She also finds that domestic credit creation, not external credit disturbances, drove the timing of speculative attacks.

Government Finance Constraints and the Creation of Domestic Credit For pedagogical ease, the basic speculative attack model is typically driven by exogenously expanding domestic credit, which inevitably leads to the collapse of the system. It is natural to inquire about the source of this domestic credit expansion, and researchers generally presume that it funds exigent government deficits. In the context of the attacks on the United States gold standard during the 1890's, Garber and Grilli (1986) discuss the legally imposed borrowing constraints faced by the U.S. Secretary of the Treasury in trying to fund a deficit and show that they forced the circulation of a silver-backed (i.e. domestic credit) money that undermined the gold standard. The efforts of the Treasury Secretary to preserve the gold standard and satisfy legal constraints on his borrowing authority led to the Belmont-Morgan contract, under which a syndicate underwrote a Treasury bond issue and undertook the responsibility for intervening in the foreign exchange markets to preserve the gold standard, effectively providing a short term credit line to the Treasury. These services were paid for by what was at the time regarded as an excessively large spread between the issue price and immediate market price. Grilli (1990) estimated the parameters of money demand and forcing variables of domestic credit to compute the step-ahead probability of attack on the gold standard. He then examined how these probabilities were affected by the provisions of the Belmont-Morgan contract. Using results from the optimal contracting literature, he concluded that the Treasury Secretary had acted to establish that contract within his legal authority and within the cost that he was willing to pay minimized the probability of attack.

Multiple Equilibria The choice of a fixed exchange rate regime is often motivated from a desire to establish a nominal anchor for monetary policy - in the absence of the requirement to maintain the fixed rate, monetary policy may become inflationary. Under

this motivation, the assumption of an exogenous domestic credit policy is not tenable. Rather, in further developments of the basic model, it has been assumed that the domestic credit policy is endogenous: while the fixed exchange rate is maintained, domestic credit growth is strictly in accord with the indefinite existence of the regime, i.e. $\mu = 0$; but contingent on the fixed exchange rate regime's collapse, the loss of discipline will cause domestic credit growth to increase, i.e. $\mu > 0$. Flood and Garber (1984a) and Obstfeld (1986) showed that such endogeneity of the domestic credit forcing variable can lead to multiple equilibria exchange rate dynamics in models of speculative attacks. The fixed exchange rate can last indefinitely if speculators believe that there will be no collapse. If speculators believe that a collapse will occur, however, the attack on reserves will terminate the fixed exchange rate regime, trigger the contingent jump in domestic credit growth, and ratify the attack. Thus, speculators beliefs about the viability of the regime become the key to the dynamics. In the context of the basic model, suppose that $\mu = 0$ during the fixed exchange rate regime. From the solution for the time of the attack, $T = \infty$, so the fundamentals are correct for the indefinite survival of the regime. Now suppose that contingent on a collapse of the regime $\mu > 0$ and that $\ln(1 + R_0/D_0)/\mu < \alpha$. Then a sudden attack will be justified – the post-attack solution for the floating exchange rate will jump upward, or at least start depreciating sufficiently rapidly to ratify the sudden reduction in the domestic money supply.

More than a technical curiosity, the possibility of multiple equilibria has been invoked as an explanation for some of the speculative attacks that occurred during the collapse of the narrow bands of the European Exchange Rate Mechanism. For example, Goldstein et al. (1993) and Svensson (1994) discuss the the scenario in their study of the ERM crisis, and Eichengreen and Wyplosz (1993) argue strongly that the emergence of multiple equilibria was a principal cause of attacks on some countries adherence to the system. Obstfeld (1994) has extended his results by examining in more detail the exigencies that drive government finance into post-attack domestic credit expansions.

Prior to the attacks on the European Exchange Rate Mechanism, the literature on speculative attacks could have been characterized as a mature literature – that is, one in which most of the interesting questions had been asked and addressed. A review of the references indicates that most of the literature on speculative attacks was published in the mid- to late 1980's. The few articles published in the 1990's were already circulating in unpublished form by the end of the 1980's.

The huge scale of the attacks on the European Exchange Rate Mechanism, together

with the financial tools in the hands of speculators, has been interpreted as a shift in the balance of power between central banks and market forces. The perception of this shift, in turn, has led to a revived interest in the multiple equilibrium versions of the speculative attack models described in section 4.3 of this chapter. It is widely understood, however, that it is difficult to distinguish between situations in which multiple equilibria may be present and situations in which exogenous policies inevitably lead to a collapse of a fixed exchange rate. The development of methods to distinguish between these two models of speculative attacks in the data is an important open issue in the field.

4.4. Conclusion

The theoretical bases of research on exchange rate target zones and speculative attacks on fixed exchange rates are remarkably similar. Both areas rely on the same basic monetary model of exchange rates for ease of describing exchange rate dynamics, and both rely on similar boundary events to determine the dynamic path of the exchange rates.

The development of the two areas, however, proceeded in remarkably different ways. The study of target zones attracted a large research effort that was driven by empirical results; and research interest in it waxed, matured, and waned quickly — five years being an unusually rapid period for an important area of economic study. The study of speculative attacks proceeded at a much more leisurely pace; and the theoretical development, which centered on the extension of the results of the innumerable possible pre- and post-attack regimes, was far less influenced by empirical results. Also, empirical results have tended to be supportive of the theory.

These differences in the influence of empirical research emanate from the demands being made of the data and from the data available. Target zone models — at least the simple ones — make strong statements about exchange rate dynamics within the band and the relation between interest rates and exchange rates that can be tested because of the availability of long time series of financial variables. The large data sets have power to reject the strong implications of the model. Speculative attack models have little to say about the dynamics of exchange rates, except that fixed exchange rates will collapse, which is indeed an important empirical regularity. The only test of the model, given available data, is to determine whether the timing of the attack is consistent with the dynamics of the post attack exchange rate. Because there are usually only a few attacks on a given currency, each episode is almost a single event, so data analysis becomes an exercise in description because of the researcher's freedom to postulate a post-attack regime and an

unobservable minimum reserve level that imply the observed timing of the attack.

Box: The Mechanics of Speculative Attacks Perfect foresight models of speculative attacks involve a sudden, discontinuous collapse of the money supply; but since they abstract away from the banking system they are generally silent about the financial transactions that transmit the attack to the central bank and they generally ignore defensive measures taken by central banks at the time of an attack. Models with uncertainty about the magnitude of intervention or disturbances to the fundamentals of the shadow exchange rate are more forthcoming about phenomena at the time of an attack: they imply a rise in interest rates as a devaluation becomes possible and they admit a decline in the domestic money supply as the uncertainty about devaluation evolves.

In this section, we will explore the mechanism that transmits the attack to the central bank. Specifically, we will outline the instruments normally used by speculators, show how the banking system operates to transmit the attack, and describe the interaction between central bank forex interventions and the simultaneous central bank support for other markets through the discount window. Finally, we will consider post-collapse central bank operations aimed at recovering losses suffered in the attack. For a more detailed description of the micro-finance of a speculative attack, see Goldstein et al. (1993), Annex IV, on which this box is based. Purely for illustration, we will presume that the pound is the currency under attack and that the pound is fixed against the deutschemark.

Forward contracts that settle in one or more months are the instrument of choice of non-bank sellers of currency in a foreign exchange crisis. Forward contracts allow sellers to lock in financing at the relatively low rates prevailing prior to an attack for a protracted period. Typically, a seller can obtain a forward contract from a bank with a margin deposit of ten percent of the face value of the contract. Thus, a relatively small amount of capital can be leveraged into a large foreign exchange sale.

The bank on the other side of this contract finds itself in a long position in pounds – the forward contract commits it to receive pounds and deliver some other currency, e.g. deutschemarks – and it immediately seeks to balance the position through a sale of pounds. The standard wholesale method through which banks rebalance their currency positions is to use a combination of spot currency sales and currency swaps – specifically, they engage in a spot sale of pounds; and in the swap they deliver DM for pounds spot and pounds for DM forward.

Figure 6 illustrates how the receipts and payments associated with these transactions rebalance the bank's position. Suppose that the fixed spot exchange rate is DM3/pound.

In the first step, the forward contract commits the bank to receive 100 pounds and pay 300 DM in one month, thereby generating a currency mismatch. In the second step, a spot sale of pounds for DM balances the currency position of the bank but creates a maturity mismatch. Specifically, a long position in one-month pounds is funded with rollover pounds, and a long position in rollover DM is funded with one-month DM. The purpose of the currency swap is to eliminate this maturity mismatch, as seen in step 3. Note that a forward sale of a currency quickly generates a spot sale of the currency.

If a non-bank buyer of pounds simultaneously arrives at another bank in the world, the opposite positions will be arranged by the selling bank, so on net the banking system will rebalance its pound position. In a crisis, however, non-bank position-taking in pounds will be one-way, so the global banking system can remain balanced in pounds only by borrowing from and trading spot with the Bank of England or with the alliance of central banks involved in defending the pound parity. If the Bank of England intervenes by buying pounds forward from a bank, usually one of the UK clearing banks, a further and opposite round of balancing currency swaps and spot purchases of pounds will ensue to allow the UK bank to rebalance its position. Globally, the banking system does not take a position in currencies or maturities and operates only as a market maker transmitting the attack from the non-banks to the Bank of England. Alternatively stated, the global banking system will take its profits from a speculative attack in the form of increased volume and bid-offer spreads in the markets for all foreign exchange products and short term credit.

While central banks intervene massively in forward markets, there is a limit on the extent of their intervention. One source of limitation is self-imposed – central banks themselves are reluctant to assume an excessively short position in foreign currencies because their capital might be wiped out in the event of a devaluation, thereby forcing them to approach the government for a capital injection and risking their independence. Thus, many central banks will buy in their currency through forward contracts only to the extent that the contracts are covered by holdings of foreign exchange. Indeed, this central bank aversion to capital losses on own account validates the assumption generally made in the speculative attack literature that the central bank under attack will cease intervening when its net reserves reach zero. A second source of limitation arises from the prudential credit line limits imposed by the banking system on any single borrower. The domestic banks, e.g. the UK clearing banks, would not impose a limit on their own central bank, but they, in turn, will face a credit limit cap vis-a-vis the positions they

assume with other banks in covering their positions.

If the central bank does not assume the role of the residual buyer of its currency on forward markets, the balancing operations of the banking system will force the central bank to intervene in spot exchange markets and to provide domestic credit through the discount window to fund the attack. Since the forward sales of the currency trigger an equal net spot sale, the central bank's intervention on the spot market will equal the net forward sales to the banking system plus the net spot sales. In the swap leg of the banking system's balancing operation, however, a counterparty must deliver spot pounds, which are then absorbed by the central bank in the spot exchange intervention. The spot pounds for delivery in the swap contract are acquired by discounting eligible paper at the central bank's discount facility, which in most countries is available without limit at an interest rate that is usually above interbank rates. In an exchange crisis, however, the discount rate becomes the market rate, and the central bank provides the credit in domestic currency needed by short sellers of the currency.

That the central bank continues to fuel the attack against itself rather than to raise the interest rate to extreme levels is another manifestation of the dual goals of the central bank – it wants the fixed exchange rate, but it also wants to put a floor under the value of those assets eligible for discount. It can always defeat that attack by setting a high enough interest rate and avoiding the sterilization through the discount window of the reserve outflow. Its refusal to do so signals that it prefers to stabilize domestic asset prices rather than to stabilize the foreign exchange rate.

A. Suggestions for further reading

A.1. Exchange Rate Target Zones

Bertola (1994) provides a comprehensive and more technical survey of the recent target zone research, including an extensive bibliography.

Froot and Obstfeld (1991) give a rigorous presentation of the Krugman model, with several extensions and a treatment of regime shifts. The Krugman model is critically evaluated in Krugman and Miller (1992). Miller and Weller (1991a,b) present an important variant of the Krugman model with sticky prices and real effects. Further extensions along this line are provided by Klein (1990) and Beetsma and van der Ploeg (1994). Flood and Garber (1991) extend the Krugman model to include finite interventions inside the band, Perraudin (1990) extends it to include discrete jumps in the fundamental. Svensson (1991b) derives empirical implications of the Krugman model for exchange rates and interest rate differentials; Svensson (1991c) derives and test implications for the term structure of interest rate differentials. Extensive empirical tests of the Krugman model are presented in Flood, Rose and Mathieson (1991), Smith and Spencer (1991), and Lindberg and Söderlind (1994). Pessach and Razin (1994) estimate a Krugman model on Israeli data.

The extension to time-varying realignment risk is made in Bertola and Svensson (1993). The drift-adjustment method is empirically implemented in Rose and Svensson (1994b), Svensson (1992a), Frankel and Phillips (1992) and Lindberg, Söderlind and Svensson (1993). An alternative model with realignment risk at the edge of the band that can explain the hump-shaped unconditional exchange rate distribution is presented in Bertola and Caballero (1992) and further extended by Bertola and Caballero (1991) and Bartolini and Bodnar (1992).

The extension to intra-marginal mean-reverting interventions is presented in Froot and Obstfeld (1991), Delgado and Dumas (1991) and Pesenti (1990). Lewis (1993) develops a model with occasional intra-marginal intervention. Intra-marginal interventions are documented in Mundaca (1990), Dominguez and Kenen (1991), Edison and Kaminsky (1991) and Lindberg and Söderlind (1995); the latter contains a structural estimation on Swedish data of an extended target zone model that incorporates both intra-marginal interventions and time-varying realignment risk.

A sizable part of the literature has dealt with regime shifts and regime collapses, the role of reserves, and the problem of bubbles. This includes Froot and Obstfeld (1991), Bertola and Caballero (1992), Krugman and Rotemberg (1991), Delgado and Dumas (1991, 1992), Miller and Sutherland (1991), Buiters and Grilli (1991), Buiters and Pesenti (1990) and Dumas and Svensson (1994). Klein and Lewis (1993) estimate learning about, and shifts in, an implicit dollar/deutschemark and dollar/yen exchange rate target zone between the Plaza agreement 1985 and the stockmarket crash 1987.

The excessive-volatility argument for a target zone is developed by Williamson (1985, 1989), Corbae, Ingram and Mondino (1990) and Krugman and Miller (1992). The amount of monetary independence in an exchange rate band, which was discussed already by Keynes (1930, pp. 319-331), is examined again in Svensson (1994).

The techniques used, notably stochastic calculus, are discussed, in order of increasing difficulty, in Dixit (1992), Dixit (1991), Bertola (1994), Harrison (1985) and Karatzas and Shreve (1988).

A.2. Speculative Attacks on Fixed Exchange Rate Regimes

Agenor, Bhandari, and Flood (1992) provide a more extensive review of the speculative attack literature.

While the basic speculative attack models are based on behavioral rules for the public or the authorities, several models have been constructed with optimizing behavior for the authorities or the public. These include models analyzed by Obstfeld (1986a), Claessens (1988, 1991), Penati and Penacchi (1989).

The standard speculative attack models assume that capital is perfectly mobile and implicitly assume that credit in domestic currency is readily available for foreign exchange speculation. As an alternative that is more realistic for many countries, Wyplosz (1986), Bachetta (1990), Dellas and Stockman (1993) have developed models of speculative attack on fixed exchange rates in the presence of capital controls.

For ease of analysis, speculative attack models almost always are based on an assumption of price flexibility so that real variables are exogenous to the exchange rate. Flood and Hodrick (1986), Willman (1988), and Krugman (1979) provide models in which exchange rate movements are jointly determined with real variables.

Except for a few papers, little consideration has been given to the relation between government financing requirements and the creation of domestic credit. Buiters (1987) and van Wijnbergen (1991) study this relationship.

Though it is well-known that the real exchange rate is driven by the nominal exchange rate, speculative attack models generally assume a constant or an exogenous real exchange rate. Connolly and Taylor (1984) and Connolly (1986) study cases in which the real exchange rate is affected by anticipated speculative attacks on the fixed rate.

Rather than a situation in which a fixed exchange rate collapses into a floating exchange rate, there are many cases of countries with floating rates that suddenly fixed their exchange rates. The anticipation of a future fixing of the exchange rate will affect the dynamics of the floating exchange rate in a manner that is studied by Flood and Garber (1983, 1984b), Djajic (1989), Froot and Obstfeld (1991), Smith and Smith (1990), and Smith (1991).

Grilli (1986) has considered in a model of uncertain domestic credit growth the timing of speculative attacks on a country that maintains a fixed exchange rate as long as reserves neither fall below a minimum value nor rise above a maximum value. Once it leaves the fixed exchange rate, however, it does not return.

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Figure 1a. Log FF/DM exchange rate

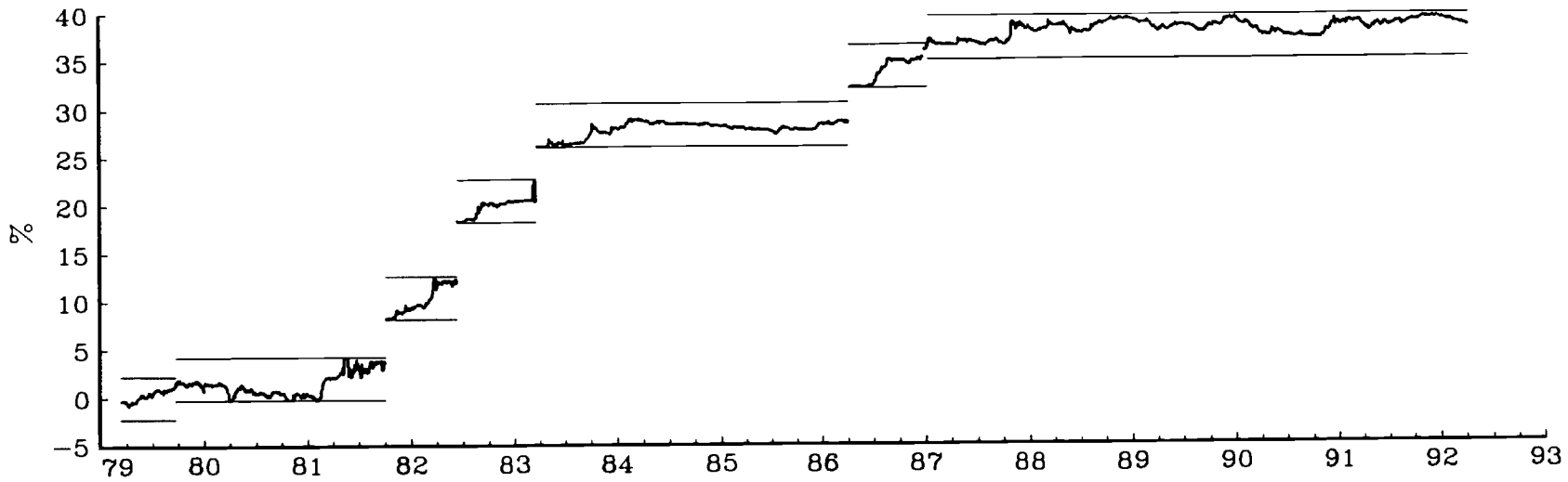


Figure 1b. FF/DM 3-month interest rate differential

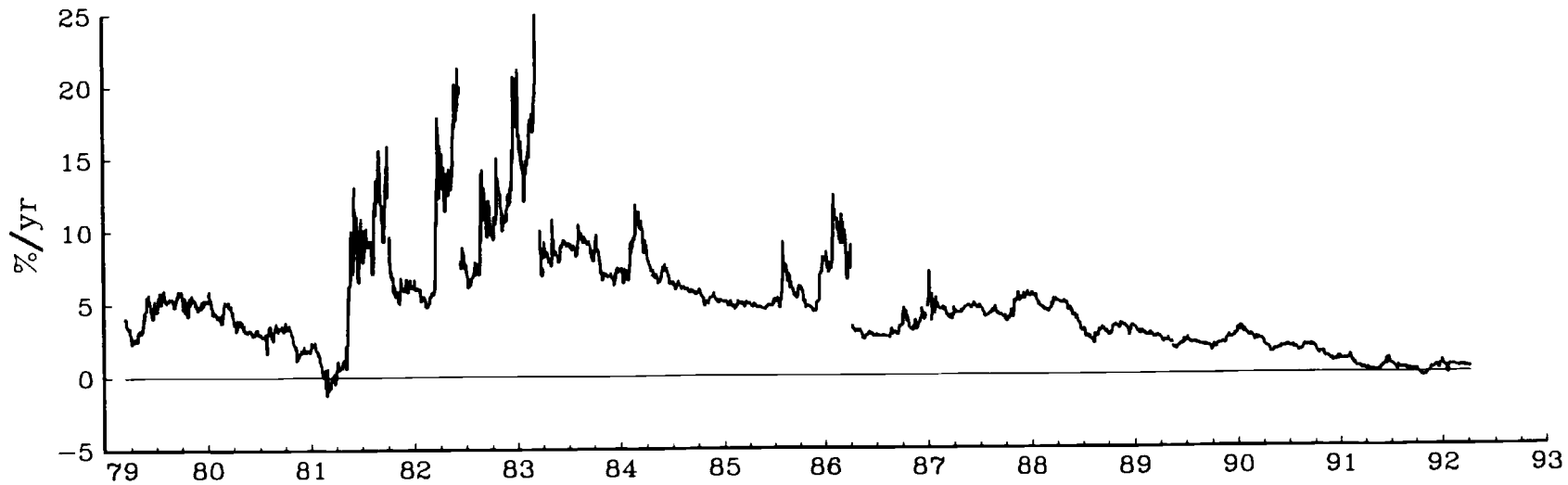


Figure 2. The Krugman model

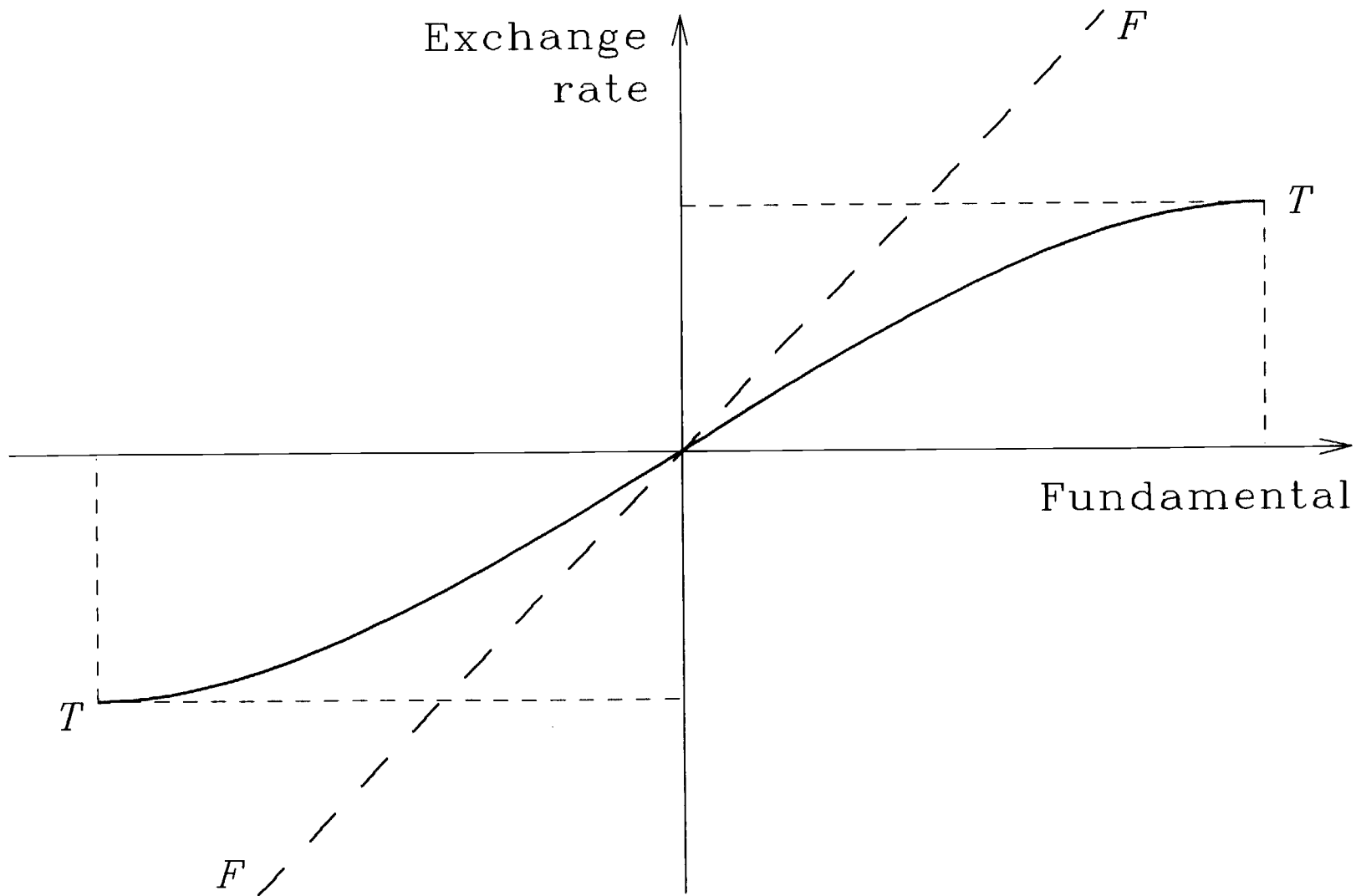


Figure 3. The expected rate of currency depreciation within the band

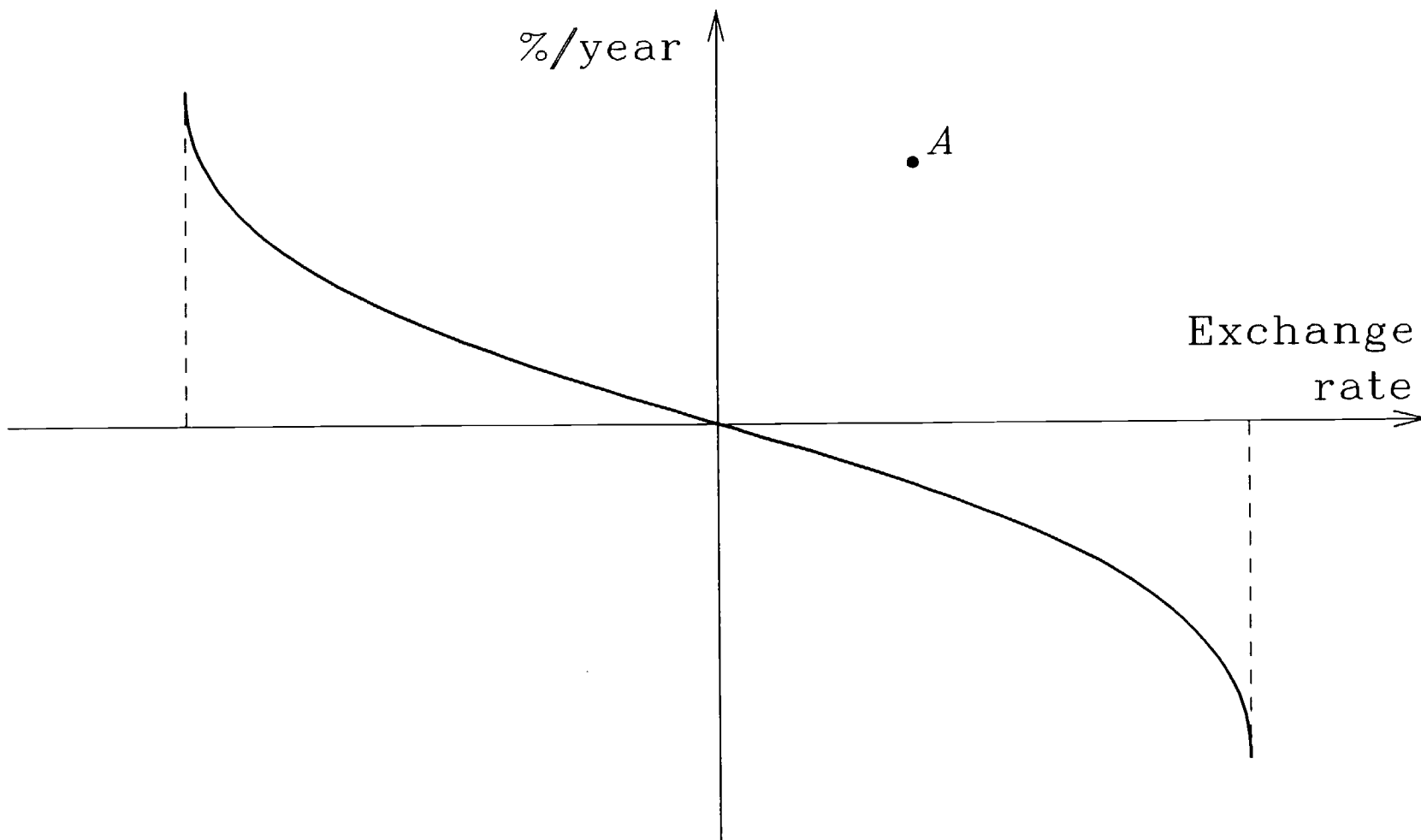
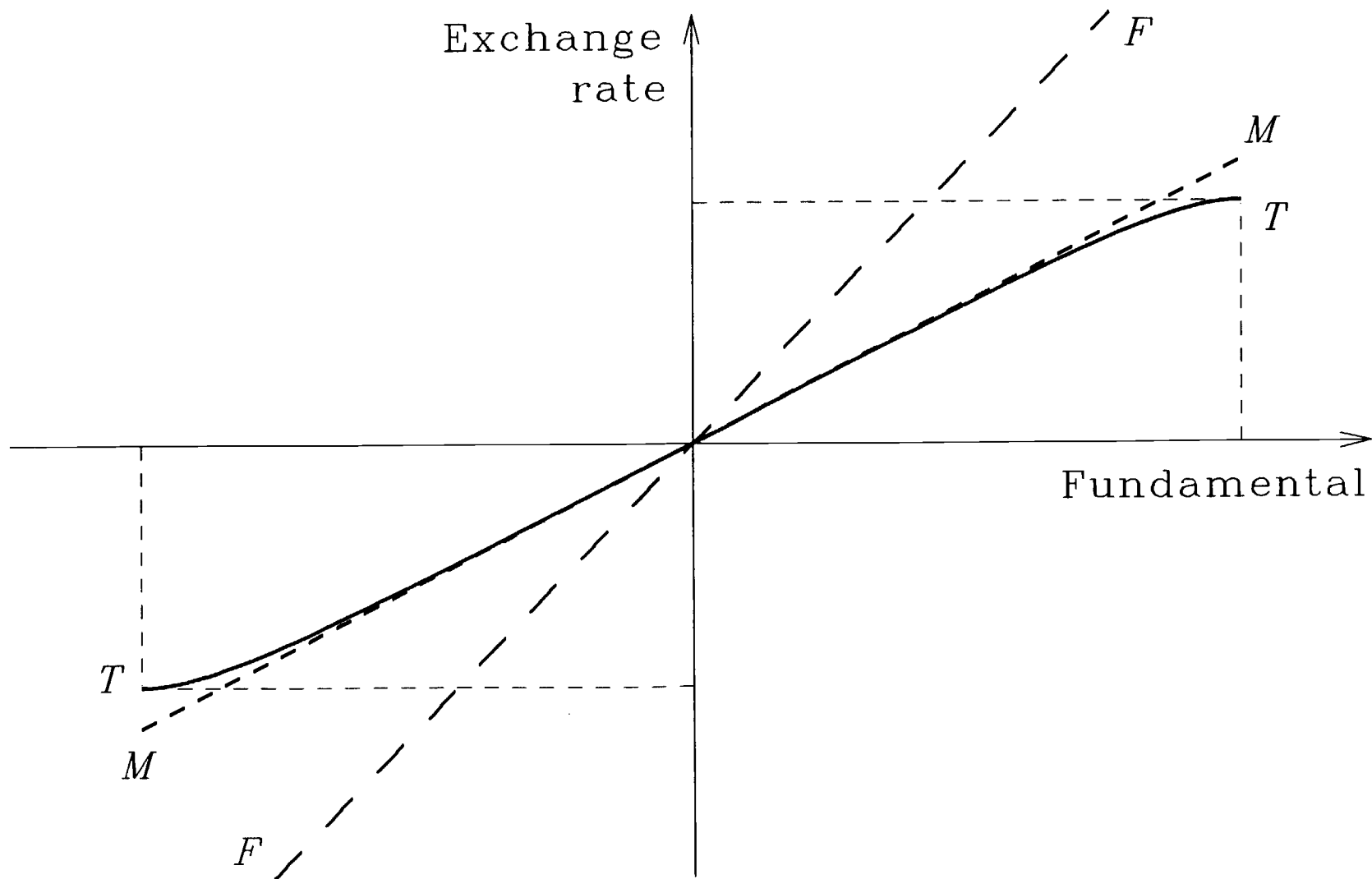


Figure 4. Intra-marginal interventions



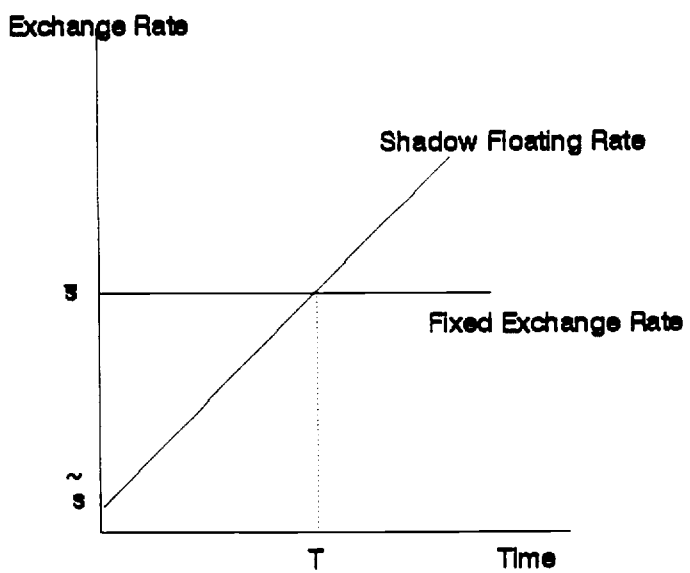
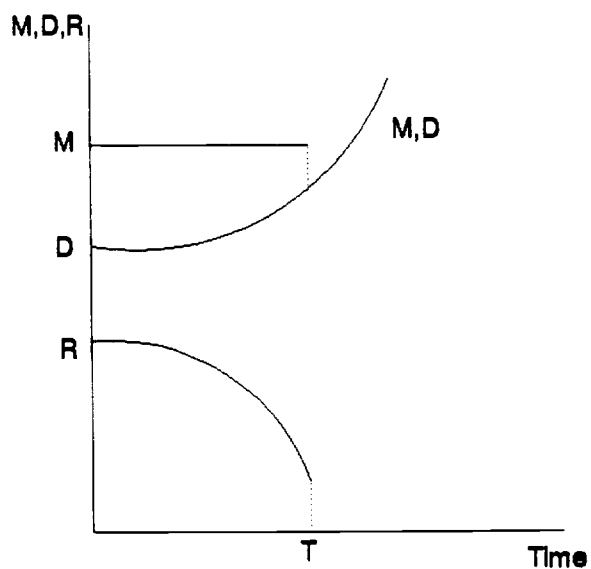


Figure 5 Money, Domestic Credit, and Reserves in a Speculative Attack

Step 1. Forward Contract = Currency Mismatch

Receipt		Payment	
Pounds in one month	100 300	DM in one month	

Step 2. Forward Contract + Spot Sale = Maturity Mismatch

Receipt		Payment	
Pounds in one month (Forward)	100 100	Pounds in two days (Spot)	
DM in two days (Spot)	300 300	DM in one month (Forward)	

Step 3. Forward + Spot + Swap = Balanced Position

Receipt		Payment	
Pounds in one month (Forward)	100 100	Pounds in one month (Swap)	
Pounds in two days (Swap)	100 100	Pounds in two days (Spot)	
DM in one month (Swap)	300 300	DM in one month (Forward)	
DM in two days (spot)	300 300	DM in two days (Swap)	

Figure 6. Receipts and Payments from Forward Contract Operations