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Abstract

The desire to avoid speculative runs on currencies appears to be one of the main reasons leading policy-makers to impose currency bands; but the standard analysis of target zones rules out any speculative inefficiencies by assumption. As an alternative, we first present simple models of excess volatility due to stop-loss trading; and then go on to consider what target zones might accomplish in this context. The principle result is that the speculation of informed traders shifts from being destabilising to being stabilising, once the target zone assures them that stop-loss orders will not be triggered.

Introduction

With the breakdown of the Bretton Woods System, the major industrial countries moved in 1973 from pegged to floating exchange rates. Later, in 1979, the European Monetary System (EMS) was established to peg intra-European exchange rates; but there was no corresponding attempt to stabilize the key exchange rates between the dollar, the mark and the yen. Indeed, the governments concerned took the view that "it would be wrong in principle for them to second-guess the markets' views and futile to pit their reserves against the vast amounts of private capital that it might be bet against them" (Kenen, 1988).

This confidence in laissez-faire was sapped by the relentless rise of the dollar under President Reagan; and, by 1985, the link between the strong dollar and the demand for protectionism became too strong to ignore. Consequently, with the Plaza Communiqué of September 1985, the G-5 countries (USA, Japan, Germany, France and the UK) agreed to use coordinated foreign exchange intervention to drive the dollar down: and then in 1987, the same countries (plus Canada) signed the Louvre Accord to stabilize rates in target zones around then-current levels.

The reference ranges involved were not publicly announced, however, unlike the currency bands of the EMS; and while EMS members have maintained their bands without any realignment since 1987, the covert target zones system of the Louvre Accord has been quietly abandoned, to be replaced by occasional rounds of ad hoc coordinated intervention.

Setting bands for the exchange rates raises a host of issues: why set currency bands rather than simply fix rates? Is there not a risk that intervention only at the edge of the band will trigger destabilizing behaviour? How will such bands cope with shifts in terms of trade - - by inflation/deflation or by "realignment"?

Some of these issues have been tackled in the academic literature that has blossomed since December 1987, when a technically elegant method was developed for analyzing target zones using the stochastic calculus (subsequently published as Krugman, 1991). The original target zone model was introduced primarily to address the criticism that target zones-far from including stability-would have the opposite effect; that they would actually encourage speculative runs on currencies, by making them rational and self-fulfilling (a point of view that still has some defenders; see Buiter and Pesenti, 1990). In order to make the point clearly, the target zone model assumed efficient, rational foreign exchange markets-and showed in that context that a target zone would in fact be stabilizing rather than destabilizing.

Since then there have been many papers both extending the model (for a sample, see Krugman and Miller, 1992) and also testing the consistency of its predictions with data from actual target zones (see Svensson, 1992). But these extensions and tests have all continued to assume market efficiency -- and for the most part have also assumed that prices are perfectly flexible. They are not therefore well suited to tackling some of the other questions posed above, for as Milton Friedman (1953, p.165) remarked in discussing the case for flexible rates, "if internal prices were as flexible as exchange rates, it would make little economic difference whether adjustments were brought about by changes in exchange rates or by equivalent changes in internal prices."

In retrospect, indeed, one could argue that the academic target zone literature has fallen between two stools. It has not incorporated sufficient economic detail to tackle the welfare issues involved in choosing between exchange rate regimes; nor has it addressed the case for target zones made by policymakers themselves.

For the main motivation for target zones in real life, we will argue, has been the desire to avoid destabilizing speculative runs on currencies -- precisely the kind of destabilizing speculative behaviour that the canonical target zone model rules out by assumption. This suggests a very different justification for a target zone than that considered by recent literature: the aim of the zone is not to induce rational stabilizing expectations, but to keep asset prices from fluctuating enough to generate irrational speculative selling.

Trying to discuss policies that are aimed at countering irrational markets is difficult, since there is no obvious place to begin. Yet if we want to make any sense of why target zones have appeal in the real world, we must make the attempt. Our strategy in this paper is to offer simple models of excessive volatility in exchange rates that seem to correspond to the real concerns of policymakers, and show what target zones might accomplish in this context. Inevitably, the models we present seem crude and ad hoc compared with the awesome sophistication of the most recent rational target zone literature and are too simple for a proper welfare analysis; but since our charge in this paper is to discuss the real reasons for such zones, we have no choice but to make this compromise.

This paper is in five parts. We begin with a brief review of the basic target zone model, and point out its weaknesses. The second part of the paper briefly reviews the motives that have led to attempts at enforcing target zones, showing that beliefs of policymakers contradict the basic premises of the usual models -- and that empirical evidence on exchange rates and other asset prices in general supports these beliefs. The third part offers a simple analysis of how stop-loss trading can produce excessive volatility in the foreign exchange market. The fourth part shows how a target zone might stabilize the exchange rate in the kind of market that policymakers seem to have in mind. The final part offers some concluding thoughts.

The basic target zone model

As a starting point for the discussion of target zones, we briefly restate the simplest target zone model, which has achieved more or less canonical status. It is also, unfortunately, completely unsuited for analyzing the real reasons for the adoption of target zones in practice -- but this point will be easier to see once the model has been stated.

Consider, then, a stripped down monetary model of the exchange rate. We suppose that at any point in time the logarithm of some country's exchange rate is a linear function of its money supply, a shift term, and the expected rate of change of the exchange rate:

$$s = m + v + \gamma E[ds]/dt \qquad (1)$$

where the shift factor v is a general purpose term encompassing changes in real output, money demand, and anything else other than the money supply and expected depreciation that could affect the exchange rate.

We will treat m as a policy variable; indeed, the behaviour of m will define an exchange rate regime. The shift term v, however, will be assumed to be subject to random shocks. In this simplest model, v has no forseeable dynamics, simply following a random walk:

$$dv = \sigma dz \qquad (2)$$

This model can be used to represent a variety of exchange rate regimes. First consider freely floating exchange rates. In this case we simply think of the monetary authority as leaving m unchanged, and allowing s to go wherever it goes. Given the absence of any predictable trend in v, it seems natural to suppose that under pure floating E[ds]/dt will be zero, and thus that the exchange rate will simply equal m+v. In a plot of s against m+v, the exchange rate would slide up and down the 45-degree line.

Under a fixed exchange rate, by contrast, the monetary authority would alter m to offset any change in v. Again E[ds]/dt would be zero, so we would stay at some particular point in m+v, s space.

Under a stylized target zone system the monetary authority would stand ready to buy foreign exchange at some minimum price s_{min}, and to sell it at a maximum price s_{max}, thus keeping s within a band.

It might seem reasonable to suppose that the target zone would function like a cross between a fixed rate and a floating rate: that the exchange rate would slide up and down the 45-degree line as long as it would lie within the band, but be constrained from wandering from outside the band. The central insight of the target zone literature is, however, the demonstration that if investors have rational expectations this supposition would be wrong.

To see why, imagine for a moment that the supposition were true, and ask what would happen if s were very close to the maximum value s_{max}. Then a fall in v would lead to an equal fall in s; but a rise in v would be offset by a fall in m, and thus would not lead to a rise in s. But this means that near the top of the band s would be on average be expected to fall, i.e., there would be an expected appreciation. Such an expected fall in s would itself tend to drag s down; so near the top of the band the relationship between m+v and s would lie below the 45-degree line. Similarly, near the bottom of the band the relationship would lie above that line. Intuitively, it becomes obvious that if investors know that the central bank is committed to defense of a target zone, the equilibrium relationship between m+v and s within the band is not a 45-degree line but an S-shaped curve.

The relationship is dragged off the 45-degree line even when the exchange rate is not close to the edge of the band. The reason is the curvature of the S, which interacts with the randomness of v to give rise to expected appreciation or depreciation through Jensen's inequality. That is, even though v has no trend, $E[ds]/dt$ is negative in the concave upper half of the S and positive in the convex lower half.

To derive an explicit representation of the S-curve, we turn to stochastic calculus. By now a familiar series of steps, one postulates a solution to the model (1) and (2) with m held constant;

this solution takes the form

$$s = m + v + Ae^{(m+v)} + Be^{-(m+v)} \qquad (3)$$

By Ito's lemma we find that

$$E[ds]/dt = \frac{\alpha^2\sigma^2}{2} [Ae^{\lambda(m+v)} + Be^{-\lambda(m+v)}] \qquad (4)$$

which implies that

$$\lambda = \sqrt{2/\gamma\sigma^2} \qquad (5)$$

The first two terms in (3) represent a sort of fundamental exchange rate, the rate that would prevail if no future change is expected. Under a freely floating rate, m+v can range without limit. If we impose the reasonable condition that the exchange rate cannot diverge arbitrarily far from its fundamental value, then under a free float we must have A = B = 0, implying the equation

$$s = m + v \qquad (6)$$

Under a target zone, the possible range of variation of m+v is bounded. We can simplify by choosing units so that $s_{min} = -s_{max}$. We may then suppose that the relationship is symmetric around zero, so that B = -A, giving the exchange rate equation

$$s = m + v + A[e^{(m+v)} - e^{-(m+v)}] \qquad (7)$$

For A negative, this defines a family of S-shaped curves. But which S-curve is the right one? The answer, which can be derived in several different ways, is that it is the particular curve is <u>tangent</u> to the edges of the band. Perhaps the easiest way to motivate this result is to notice that if the curve were to hit the edge of the band at an angle, there would be a kink in the relationship between v and s. Such a kink would, by Ito's lemma, imply an infinite rate of expected appreciation or depreciation -- in effect, a one-way option. So arbitrage rules out any curve except one that is tangent.

This tangency condition bears a close relationship to the concept known in option-pricing theory as "high order contact" or "smooth pasting". Without question, the possibility of applying the elegant mathematics of continuous time finance to international macro explains much of the appeal of the target zone model.

In economics, unfortunately, elegance does not imply correctness. The canonical target zone model has been useful as a way of clarifying thinking, and especially for dispelling the confusion over whether and how target zones might actually be destablilizing. But as a model of what actually happens, it has a number of weaknesses. We would identify four weaknesses in particular: unrealism of the basic exchange rate model, lack of realism in the description of intervention, failure to allow for realignments, and excessive rationality on the part of investors. Of these, the first three can be accommodated at the expense of elegance and simplicity. The last is, however, fatal for the policy applicability of the target zone model.

Unrealism of the basic model

Perhaps the most obvious weakness of the canonical model is that the underlying model of the exchange rate is one that has been refuted by other evidence. The model as stated relies on a simple flexible-price monetary approach to the exchange rate; yet in nearly 20 years of research on floating exchange rates, such models have had almost no empirical success. Indeed, money supplies, if they enter at all, typically enter with the wrong sign. Purchasing power parity, a component of most monetary models, has failed utterly; and there is (to us) overwhelming evidence that sluggish price adjustment is key to any exchange rate analysis.

Admittedly, this weakness is to some extent repairable. The canonical model can be stated more cautiously - in terms of movements of an unspecified "fundamental" which could include such things as the sluggishly moving domestic price level. Such a broadly defined fundamental would be unlikely to follow a random walk, but as Miller and Weller (1991) among others have shown, the qualitative behaviour of the canonical model remains if fundamentals have an autoregressive component such as that which would be generated by Dornbusch (1976) -style overshooting.

In practice, however, the target zone literature has in effect given a new lease of life to an exchange rate model that has otherwise been thoroughly discredited; this is unfortunate.

Unrealism of the description of intervention

The elegance of the canonical model's description of a target zone follows largely from its assumption of a very clean intervention policy by central banks: do nothing while the exchange rate is inside the band, stand ready to buy or sell at the band's edges. This implies, in essence, infinitesimal interventions that take place only at the maximum or minimum exchange rate values.

Unfortunately, central banks in real target zone systems like the EMS do not behave in this way. Direct evidence on intervention shows that most EMS intervention takes place intramarginally; beyond this, much of the actual work of exchange rate stabilization is achieved not by intervention in the foreign exchange market but through adjustments in domestic monetary policy that are not specifically triggered by hitting the edge of the band.

At an analytical level, putting in more complex intervention policies does not pose much of a problem. A policy of leaning against the wind inside the band can be represented by a tendency toward autoregression in the fundamental; as already pointed out above, this eliminates the nice analytical solution of the canonical model, but leaves the qualitative behaviour of the exchange rate intact. With even a modest amount of autoregression, however, it is the autoregression, not the band, that does most of the work of exchange rate stabilization. Or to put it another way, the nonlinearity of the "S", which is the most striking result of the canonical model, and which purports to explain why exchange rates are stablilized by a band, quickly becomes both invisible and unimportant if there is strong stabilizing intervention inside the band. ("Smooth pasting" remains the condition that ties down the exchange rate's behaviour: but the exchange rate will rarely lie in the range in which the this tangency condition is approached).

Unrealism about realignments

For more than half of the life of the EMS, and for a larger fraction of the life of such target zones as the ones unlilaterally adopted by Scandinavian nations, the zones have suffered from considerable uncertainty about whether they will remain in place. That is, at any given time there is a perceived possibility that, say, Sweden will devalue its central parity.

As Svensson (1992) has pointed out, expectations of a realignment are in effect part of the true fundamental driving the exchange rate within the band. If investors perceive an increase in the probability of a devaluation of the central parity, they will bid up the price of foreign exchange, just as if the domestic money supply had been increased. Changing probabilities of realignment, however, wreak havoc with the simple notion that the expected rate of appreciation of a currency depends only on its position within a band. If movement toward the edge of the band is perceived as increasing the risk of realignment, then the curvature of the "S" may turn backwards; if the risk of realignment changes for reasons independent of the current level of the fundamental, there may be no stable fundamental-exchange-rate relationship at all.

Again, none of these complications poses any basic conceptual difficulty. If they are important enough, however, the standard target zone approach seems to lose much of its point; the stabilizing effects of the band's existence don't matter nearly as much as the shifting expectations of devaluation.

Modelling Markets

It is somewhat ironic that the target zone literature has given a new lease on life to flexible-price monetary models of the exchange rate, in the teeth of the empirical evidence, because a monetary model seems to suit the new techniques most easily. An even larger irony is that the target zone approach has revived the assumption of efficient markets for foreign exchange at a time when other evidence was pointing strongly against that model. As we argue later, there is a growing evidence that financial markets are <u>not</u> efficient. Many of the target zone modelers have in other work taken to heart extensive evidence against rational expectations, or at least against the joint hypothesis of rational expectations and stable risk premia, in asset markets in general and foreign exchange markets in particular.

Existing critiques of the target zone literature have focussed on the first three of our list of problems. We would argue, however, that it is the fourth -- the assumption of market rationality -- that is both the most serious objection to the target zone model and at the same time the best justification for instituting target zones in practice.

To make this point, we first discuss the motives that appear to have led to experiments with target zones, then show how simple stories about how stop-loss strategies by investors can rationalize some of the policymakers' concerns.

Why have target zones been adopted?

The views of policymakers

The European Monetary System (or more precisely its exchange rate mechanism) is the main empirical example of a target zone in practice; most of the other examples come from European nations that are in effect shadowing the ecu.

As a target zone system, however, the EMS bears little resemblance to the kind of system envisaged by target zone advocates such as Williamson (1985). Williamson-type target zones were supposed to be fairly broad ranges that allowed significant exchange rate flexibility. The EMS, by contrast, sets fairly narrow bands for most of its members. While the bands it enforces are somewhat wider than those of the Bretton Woods system, it still resembles that nearly fixed-rate system more than it resembles a Williamson-type compromise between fixed and flexible rates.

The motivations behind the EMS are also somewhat special, and differ from those of more generic target zones. In the early days, an important motive for stabilizing exchange rates within Europe was, by many accounts, the difficulty of managing EC farm price supports in the presence of fluctuating rates (in practice, an administratively cumbersome system of fictitious "green" rates had to be adopted). Over time, the EMS evolved into a system of policy coordination, but of a special kind: it became a device that allowed European nations to gain credibility by tying their monetary policies to Germany. Again, this has little to do with the idea of a target zone *per se*.

Thus to get an idea of why policymakers are drawn to target zones in practice, one should examine cases other than the EMS. In particular, the decision of the G7 nations to adopt a system of "reference ranges" at the Louvre agreement of early 1987 is revealing about the reasons why target zones get adopted.

The Louvre has been the subject of many studies, including some investigative reporting (see, for example, Funbashi, 1988 and Destler and Henning, 1989). These studies give a pretty good sense of the motives of policymakers. What is very striking is that the motive for trying to stabilize exchange rates had very little to do with the usual economic analysis of the tradeoff between fixed and flexible rates, and rested primarily instead on psychological arguments about the behaviour of investors.

The standard economist's argument about exchange rate regimes is based centrally on the "optimal currency area" argument developed by Mundell (1961) and McKinnon (1964). That argument asserts a tradeoff between the macroeconomic advantages of flexible exchange rates and the microeconomic advantages of fixed rates, or better yet a common currency. The main extension to the argument in recent years has been an emphasis on the use of the exchange rate as a way for inflation-prone countries to make a credible anti-inflation commitment.

Little of this is visible in the reported discussion leading up to the Louvre. Admittedly, monetary officials were well aware of the value of flexible exchange rates in giving them the ability to make independent policies. But the desire to stabilize rates did not seem either from a perception that exchange rate flexibility posed costs to international transactions or from any desire to use exchange rates to buttress credibility in the fight against inflation (among other things, the G3 countries all had inflation pretty well under control by the time of the Louvre).

What motivated the Louvre was, instead, fear of unstable market behaviour. Immediately before the Louvre, many officals argued that the dollar was on the verge of a "free fall" (Destler and Henning,1989), which spelled financial danger. And key officials held the view that unless restrained by official commitment to limit exchange rate movements, markets would tend to be unacceptably unstable. Paul Volcker was later to write that "If ... markets come to believe exchange rate stability is not itself a significant policy objective, we should not be surprised that snowballing cumulative movements can develop that appear widely out of keeping with current balance-of-payments prospects or domestic price movements. At that point, freely floating exchange rates, instead of delivering on the promise of money autonomy for domestic monetary or other policies, can greatly complicate domestic economic management." (Quoted in Funbashi, 1988, p.223). On another occasion, Volcker warned of "self-reinforcing, cascading depreciation of a nation's currency"; his views were echoed by a Bundesbank official who warned that "It is very hard to trigger an avalanche, but once it starts, it is much harder to stop".

The Louvre, then, was not produced by men who had a view of exchange markets that looked anything like the assumption of rationality that underlies what has come to be the standard target zone model. It was largely the result of official fears that the foreign exchange market would prove irrational and hence unstable.

The Louvre did not, of course, endure, and the G7 process itself has gradually faded into irrelevance, leaving the EMS as the major remaining example of a target zones. As already pointed out, the EMS at this point largely serves as a coordination and credibility device for monetary policy, and is virtually a fixed rate system. Yet in its early years it, too, was largely seen as a way to avoid unstable and irrational market behaviour.

The point, then, is that the real-world motivation for target zones largely reflects a concern about irrational and unstable market behaviour that is excluded from the recent academic literature by assumption. But is this concern justified? Or should we essentially relegate the target zone phenomenon to the psychology of over-anxious policymakers?

Are concerns about the market justified?

Fears about the instability of foreign exchange markets have always been the key argument of practical men who want to fix or at least manage rates. Economists have usually been uncomfortable with this argument, arguing that the self-interest of speculators will normally imply stabilizing expectations; in its strong form, this becomes the efficient markets hypothesis. We do not want, in this paper, to review this seemingly endless debate. For discussing exchange rate policy, however, three points are worth belaboring.

The first is that extensive testing of the efficient markets hypothesis for foreign exchange markets has produced absolutely no supporting evidence, and has yielded what appears to many analysts to be decisive contrary evidence. As Macdonald and Taylor (1992) document, there has been overwhelming rejection of the hypothesis that forward premia or interest differentials are efficient or even unbiased predictors of changes in exchange rates; indeed, the correlation between forward premia and subsequent changes in the exchange rate is generally negative. Such a result can be rationalized within an efficient markets framework only by invoking very large, shifting risk premia or huge, unobserved low-probability events ("peso problems"). Yet there is no supporting evidence that would make large, changing risk premia plausible - standard asset-pricing models suggest that such premia should be small. The large events that would generate peso problems are unspecified, and are difficult to detect in the conscious perceptions of market participants. Furthermore, direct survey evidence on expectations does not suggest that forward premia typically involve a high risk component. And surveys of the actual behaviour of exchange market participants (such as that of Taylor and Allen, 1989, 1990) find that "chartist" analyses, which should not be useful in an efficient market, in fact play an important role.

Second, the lack of support for an efficient market view with regard to foreign exchange is part of a broader pattern for other asset markets. The work of Shiller (1989) and others shows that equity and bond markets present essentially the same picture as foreign exchange. That is, those formulations of efficient markets that make enough auxiliary assumptions to be amenable to testing fail by wide margins. It is then possible, with difficulty, to rescue the hypothesis of efficient markets by invoking more complex models; but these models simultaneously offer enough degrees of freedom to make the hypothesis of efficiency non-refutable and seem at variance with other evidence about how market participants actually behave.

Finally, the 1980s were in fact marked by some drastic movements in asset prices that seemed to fit very well the vision of worried policymakers of how markets can misbehave. In particular, the 1987 stock crash is surely a classic example of "cumulative, snowballing" decline, of a "self-reinforcing, cascading" process. In the light of what happened to stock prices in late 1987, one can hardly dismiss the worries of policymakers about what might have happened to exchange rates in early 1987 had they not established target zones at the Louvre.

We have argued, then, that the real motivation behind target zones is fear of irrational runs on the exchange rate - something that the standard target zone model rules out by assumption. The next step is to put a little more formalism on this by positing a particular form of market instability, one that we believe corresponds most closely to the worries that motivated both the EMS and the Louvre.

Stop-loss strategies and the exchange rate

There are many ways for asset markets to misbehave. Investors might extrapolate from recent price changes, generating bubbles (we leave aside the issue of rational bubbles, which is a whole different subject). In a series of papers, Lawrence Summers and associates have pushed the idea of "noise traders", market participants who hold randomly shifting incorrect beliefs and thereby create risk for more rational investors. We find the most natural way to formulate the potential misbehaviour that worries exchange market policymakers is, however, to consider exchange rate crashes provoked by the presence of significant groups of investors following "stop-loss" strategies that lead them to sell, not buy, when prices fall.

The 1987 stock market crash produced a brief flurry of interest in the role of stop-loss strategies in market dynamics. This interest was fueled by several factors. First, portfolio insurance schemes evidently played a significant role in the crash. Such insurance schemes involve selling off a risky asset as its price falls, in order to simulate a put option that limits potential losses; as Grossman (1987) prophetically pointed out, however, widespread use of such schemes, if incorrectly factored in by other investors, can leave markets vulnerable to seemingly unprovoked cascading falls in the asset prices - and this was surely part of what happened in 1987. Second, even investors who did not participate in explicit insurance schemes seem to have behaved in a stop-loss fashion. Shiller's (1989) remarkable instant surveys of selling motives in the crash found that the main piece of news, indeed the only broadly reported motivation, that provoked selling was the fact that prices were falling - information that is strongly suggestive of stop-loss behaviour. (This kind of behaviour also doubtless played a key role in the crash).[1]

There is also extensive survey and anecdotal evidence that investors in both equity and foreign exchange markets behave at least to some extent in mechanical ways that one could easily imagine would produce stop-loss-like behaviour. Allen and Taylor (1989, 1990) find that "Chartist" strategies, in which purchases or sales typically occur when the exchange rate crosses some trigger point, are used to at least some extent by most traders. Market analyses by respected investment organizations typically involve a mix of fundamentalist and Chartist analysis (see, for example, the Goldman Sachs briefing by Morrison, 1992).

Recent work by Grossman and Zhou (1991) reflects these observations. They argue that it is important to model traders who are subject to a "draw-down" rule, which forces them to pull out of risky assets as the net worth of their assigned portfolio declines. This modelling strategy apparently reflects the realities of trading in the foreign exchange market; in effect it means that traders, whatever their personal views about particular prices, are obliged to follow a stop-loss strategy with respect to the overall risky portfolio in which they invest. Such constraints on traders may be a rational response to the principal-agent problems that face investment houses; but they certainly can lead to aggregate behaviour that is very different from the standard view of efficient markets.

How will markets behave when there are significant numbers of investors using some kind of stop-loss strategy? Rather complex analyses by Genotte and Leland (1990) and by Grossman (1987) have tried to build a comprehensive rational expectations framework of markets subject to crashes. Here we offer a much cruder but also more intuitive framework that represents a mild extension of earlier post-crash analysis in Krugman (1987); the virtue of this framework is that it makes a clear link to the target zone literature, and thereby also helps show why target zones might appeal to policymakers concerned about speculative inefficiency.

Stop-loss strategies and exchange rate behaviour: a crude model[2]

Suppose that there is a class of foreign investors who currently hold assets denominated in domestic currency, but want to limit their potential capital losses due to the exchange rate. In order to put a floor on their net worth, they adopt the strategy of holding a fixed amount of these assets as long as the domestic price of foreign exchange stays below some trigger value s_{sell} ; at that price, however, they all have standing orders to sell off their domestic asset holdings. (We initially suppose that they follow an all-or-nothing strategy, and that they all have exactly the same trigger point. It will soon become apparent, however, that neither of these assumptions is a necessary condition for crashes).

A decision by these stop-loss investors to shift from domestic- to foreign-currency assets is equivalent to a sterilized intervention against domestic currency. Such an intervention will only have an effect on the exchange rate if domestic and foreign interest-bearing assets are imperfect substitutes, which will in turn be the case only if there is significant risk-aversion; so we need to modify our basic model slightly to introduce risk aversion.

Let us therefore suppose that the exchange rate equation is

$$s = k + \gamma(E[ds]/dt - \beta s') \qquad (8)$$

where k is some general fundamental and β is a risk premium and s' denotes the elasticity of the exchange rate with respect to the fundamental. In an efficient market model the term β would depend on the overall price of risk and on the covariance of the exchange rate with the overall market, as well as the variability of fundamentals themselves[3]. We can, however, allow ourselves to be agnostic about whether we regard this as fully realistic. What we do need to assume is that if the stop-loss traders exit the market (ie. sell their domestic-currency-denomiated assets), this changes the risk premium. Since the remaining investors must make an offsetting move from foreign to domestic assets, the risk premium on foreign assets will fall; so following the exit of the stop-loss traders, the risk premium on foreign assets will fall, say to $\beta_x < \beta$.

The effect of the exit of the stop-loss traders may be illustrated as in Figure 1. In that figure, the schedule NN represents the free-float locus that would prevail if these traders were permanently in; the higher schedule XX is the locus that would prevail with them permanently out.

Exchange rate crashes with static expectations

It is immediately obvious how to tell a story about sudden currency crashes, provided that one initially assumes that investors other than stop-loss traders are unaware of the existence of a large pool of such traders. In that case the exchange rate would evolve as if $E[ds]/dt = 0$ -- that is, investors would have static expectations -- until the stop-loss strategy is triggered. Thus suppose that initially k is less than k_x such that the exchange rate lies below s_{sell}. While this is true, the market will randomly walk up and down NN. Whenever the market happens to cross the trigger price, however, a selling wave will be induced, leading to an abrupt surge of the price of foreign exchange to s_x.

What is wrong with this story? There are two ways in which it appears to be contrived, but which do not really change the logic. First, as we have drawn it, all stop-loss traders are assumed to have the same trigger price. Second, each such trader is assumed to follow an all-or-nothing strategy, rather than the more gradual selloffs that are produced both by portfolio insurance and by the "draw-down" rules modelled by Grossman and Zhou (1991). It is straightforward to see, however, that sudden runs on the exchange market can still happen even if there is a dispersal of trigger prices or a less "bang-bang" stop-loss strategy on the part of individual investors.

Consider Figure 2. In that figure we imagine that there are two groups of stop-loss traders, with trigger prices s_1 and s_2 respectively. If the first group exits the market, the risk premium falls to $\beta_1<\beta$; if the second group also exits, the premium falls further to $\beta_2<\beta_1$. Corresponding to the absence of these two groups are the loci X_1X_1 and X_2X_2. We thus no longer assume that all stop-loss traders will exit the market at the same price.

Nonetheless, for the schedules drawn it is immediately apparent that if the exchange rate drifts up to s_1 , it will trigger both sets of traders. The reason is, of course, that the surge in the price of foreign exchange when the first group exits pushes that price above the trigger point of the second. There is thus a cascade effect (which brings the remarks of Paul Volcker, cited earlier, to mind) that brings both groups out of the market essentially at the same time.

This doesn't have to happen, of course. The picture in Figure 2 depends both on the first group being large enough to push s up substantially and on s_2 being close to s_1. Loosely speaking, the stop-loss traders much (a) have a large weight in the market and (b) have their trigger points packed fairly close together in order to generate a cascading crash.

This story can clearly be generalized to any number of different groups of stop-loss traders with different trigger prices. As long as they carry enough weight and their trigger prices are closely enough packed, there will be a critical level of the exchange rate - a sort of key threshold value - which, once passed, will be followed by a cascading wave of selling that drives the value of domestic currency abruptly down.

What if foreign investors, instead of following all-or-nothing strategies of selling out when the price passes a trigger point, gradually divest themselves of domestic assets, portfolio insurance-style, as the exchange rate rises? The answer is that an individual investor with a continuous draw-down rule is equivalent to a continuum of investors with all-or-nothing selling rules. If draw-downs proceed sufficiently rapidly when the exchange rate rises, this is equivalent to having investors packed closely together; the result once again will be to produce a sudden fall in the exchange rate when some critical value is passed.

The interaction of stop-loss traders with informed investors

The discussion in the last section rested on the assumption that investors who are not following stop-loss strategies have static expectations, or at least are blithely unaware of the presence of a large group of loss-stoppers. If, on the contrary, investors are well-informed about each others' strategies, then the outcome will be considerably less dramatic.

In Figure 3, we revert to the situation in which there is a group of homogeneous investors who will shift from domestic- to foreign-currency-denominated assets as soon as the exchange rate rises above s_{sell} . We now suppose, however, that other investors are aware of the existence and size of this group. In this case, there clearly cannot be a step jump in the price of foreign exchange: if there were, this would offer a known opportunity to make an infinite rate of capital gain in return for limited risk, a one-way option. So the exchange rate will take the presence of the loss-stoppers into account in a way that eliminates that possibility.

The outcome, during the period before exit is triggered, is shown by the schedule TT . This schedule is defined by an equation on the form

$$s = k - \gamma\beta + Ae^{k} \qquad (9)$$

with $A>0$ chosen so that $s(k_x) = s_{sell}$. That is, there is a premium on the exchange rate over the static expectations value, which rises as the trigger price is approached at a rate that just ensures that there is no jump when stop-loss investors are indeed triggered into leaving the market.

Obviously in this case there is no step jump in the exchange rate. This is not surprising. Indeed, both Grossman (1987) in advance of the 1987 crash, and Genotte and Leland (1990) in the aftermath, emphasized that such a sudden fall could only happen if other investors underestimate the size of the pool of capital committed to stop-loss strategies. So this analysis raises two questions. First, how likely is it that informed investors will correctly anticipate the impact of stop-loss selling? Second, even if they do, does such selling increase market volatility?

There is no rigorous answer to the first question. On one side, there is obviously an incentive for sophisticated traders to try to assess the possibilities of a sudden jump in the exchange rate. On the other side, there is no natural mechanism that tends to reveal the underlying strategies of investors. In the case of the stock market, such advocates of automatic trading schemes as Leland have argued for a policy of disclosure that makes the size of these schemes public information (Genotte and Leland, 1990). This does not necessarily solve the problem, however, since automatic, computer-driven selling is not the only form of stop-loss behaviour. Indeed, Shiller's instant survey suggested that informal, "manual" price-induced selling played a much larger role in 1987. What we may perhaps suggest is that while sophisticated investors will try to guess at the extent of stop-loss investing, they will always err on one side or the other, leading to occasional jumps in the exchange rate (in either direction) when the price crosses a threshold and proves them wrong.

The answer to the second question is clearer: even if the presence of stop-loss traders is correctly assessed, it increases volatility -- for exactly the same reason that the presence of a band reduces variability in the canonical target zone model. Note that TT in Figure 3 is steeper than NN: the expectation of a sell-off, which rises with s, makes s more sensitive to variation in k than it would otherwise be. So one may argue that even when informed investors prevent stop-loss traders from triggering crashes, such stop-loss behaviour still leads to a more volatile exchange rate.

Can stop-loss selling make a difference?

A somewhat different question is whether selling triggered by stop-loss behaviour can actually make a large difference to the exchange rate. Policymakers certainly think so; as documented above, fear of such an event was a major motivation for the Louvre Accord. But economists might argue that they are wrong -- that stop-loss behaviour cannot be large enough to move the exchange rate by large amounts. After all, the decision by a group of investors to shift the currency denomination of their holdings is equivalent to a sterilized intervention, and such interventions are widely thought to have very limited effects.

Essentially the same problem has been confronted by economists attempting to explore the relationship between portfolio insurance and the 1987 stock crash. The size of the automatic sell-off triggered during that crash was not sufficient, given normal estimates of the elasticity of demand for stocks, to have moved prices by very much. These are pretty much symmetric points: as Frankel (1988) has pointed out, standard capital asset pricing models suggest that risk premia should be little affected by asset supplies in both foreign exchange and stock markets.

One answer is that de facto stop-loss trading may extend well beyond the set of traders who explicitly declare that strategy, let alone use computerized routines. Genotte and Leland (1990) suggest a more fundamental answer. They argue that most investors have no independent information about the appropriate level of prices, but simply make inferences from actual prices. Faced with a movement, say a decline, in prices, they will place a high weight on the probability that informed investors have received adverse information about future returns, and thus will not respond by buying as the price falls. (Shiller (1989) finds that on Black Monday surprisingly few investors actually changed their positions: indeed, of his sample of individual investors, who may be taken to represent a relatively uniformed group, only 5.2 percent actually changed position. He describes the reponse of participant to the market as "a lot of talk and anxiety, little action.") Since most investors do not see falling prices as a reason to buy, the task of stabilizing the market is largely left up to a relatively small group of informed investors. Under these circumstances, stop-loss traders may move the price much more than standard asset models would suggest. This is indeed the core of the Genotte and Leland analysis.

One might argue that in exchange markets, where exchange rates are ultimately tied down by macroeconomic factors rather than market returns, such passivity on the part of uniformed investors makes less sense. In a flexible-price monetary model of the exchange rate, a currency depreciation raises domestic money demand immediately via its effect on the domestic price level. Even in Mundell-Fleming models currency depreciation raises money demand via a rise in net exports that produces an economic expansion. Doesn't this prevent the exchange rate from moving drastically because of selling by a relatively small group of investors?

Our answer would be that in practice, the combination of sticky prices and lags in the response of trade flows to relative prices mean that any macroeconomic anchor to the exchange rate is on a very long chain. If the rate moves to a basically crazy level, this will eventually become apparent; but eventually may mean several years. Uninformed investors may therefore be led quite badly astray if the exchange rates they observe are driven not by real news but by artitrary sell-offs.

The idea that asset markets in general, and exchange markets in particular, exhibit excessive volatility is by no means universally accepted. The idea that such excessive volatility, if it exists, may be explained by the presence of large numbers of stop-loss traders is still less accepted. There is, however, enough evidence in favour of the idea to make it worth considering how it might be used to justify a target zone.

Target zones to stop loss-stoppers

The canonical target zone model appears at first to suggest an exciting advantage of such zones. Because the "S" is flatter than the 45-degree line, it appears that introducing a zone stabilizes the exchange rate by more than the reduction in the variation of its fundamental determinants. This seeming "multiplier" effect can seem to be an argument for a target zone.

In fact, in the standard model, this is an illusion. The stabilization is the result of the promise future management of the fundamentals; in an efficient markets model, there are no free lunches, and one cannot get more stabilization than one is willing to pay for by adjusting fundamentals. (That is why the apparent stabilization was dubbed a "honeymoon effect!").

Once one introduces a reason why markets may have excessive volatility, however, one has a reason to believe that one may in fact get more stabilization than one pays for by reducing the variation in fundamentals. If investors have static expectations, a sufficiently narrow target zone can rule out crashes. Even if informed investors rule out such crashes in any case, there can (as we show below) be extra stabilization as a result of the commitment to a target zone.

A static expectations story

Figure 4 shows a highly simplified situation in which all investors are fairly stupid. There is a group of stop-loss foreign investors who will divest themselves of their holdings of domestic-currency-denominated assets if the prices of foreign exchange rises above some value s_{sell}. There is a corresponding group of stop-loss domestic investors who will sell off their foreign holdings and buy domestic-currency-denominated assets if the price falls below s_{buy}. And the remaining investors are assumed to behave passively, behaving as if $E[ds]/dt=0$. (We do not argue that this is a reasonable model; it is simply useful as an initial sketch).

As long as the exchange rate has not crossed either its upper or its lower trigger, it will slide up and down the locus NN. In the absence of some form of intervention, however, it will eventually reach a trigger price, and the exchange rate will abruptly jump either up to XX or down to YY.

The potential role of a target zone is now obvious. Suppose that the monetary authorities of one or both countries act to keep fundamentals inside the range from k_Y to k_X, within limits shown as $\underline{k}$, $\bar{k}$ in Figure 4. Then they will lop off the potential for crashes -- and, by any reasonable measure, therefore reduce the variation of the exchange rate by more than the direct degree of stabilization of fundamentals.

This description seems to fit fairly well the concern of monetary authorities about "avalanches" or "cascading" falls in prices. In our more extended quotation from Paul Volcker, however, he seemed to place more weight on the expectations of investors, and on the need to reassure them that there are limits on exchange rate variability. To make sense of this concern, we need to reintroduce informed investors.

Target zones with some informed investors

Figure 5 shows a mixture of the stop-loss story with informed investors, and the canonical target zone model.

As in Figure 4, we imagine that there are foreign and domestic stop-loss investors, whose respective exit will drive the static-expectations locus from NN up to XX or down to YY. We now assume, however, that at least some other investors are fully informed about the prospects for sell-offs, and that as a result any step-movements in s are ruled out.

In the absence of a target zone, the exchange rate will move along the locus TT : as in Figure 3, the expectation of stop-loss investor exit is built into the behaviour of sophisticated investors, and is reflected in a bending of the locus away from the 45-degree line. Two points are worth noting about this story. First, the exchange rate will evidently be more variable than the fundamental, because TT is steeper than the 45-degree line NN . Second, the source of this excess variability lies in the expected rate of depreciation, which (because of the nonlinearity of TT) is higher, the weaker is the domestic currency. This appears to correspond to the view of Volcker and others that in the absence of a commitment to limit exchange rate variation, market expectations will tend to destabilize rather than stabilize rates.

But now suppose that monetary authorities commit themselves to holding the exchange rate inside a target zone that is smaller than the range from s_{sell} to s_{buy} . What will happen? The shape of the exchange rate locus will shift to the familiar S-curve SS , flatter than the 45-degree line, with marginal intervention at $\underline{k}$ and $\bar{k}$. The exchange rate will therefore be stabilized. Part of this stabilization can be thought of as resulting from the shift from NN to SS ; this is the stabilization that is familiar from the canonical target zone model, and does not represent any sort of free lunch. But here the initial locus is TT ; the prospect that wide variations in the exchange rate will generate selling waves creates an additional source of exchange rate variation that the target zone also eliminates. Or to put it another way, once informed investors have been assured that the exchange rate will not be allowed to vary enough to trigger the loss-stoppers, their speculation will shift from destabilizing to stabilizing.

Clearly this model does not prove anything: it depends critically on the ad hoc assumption that a significant part of the market is following more or less mechanical investment strategies. It does, however, come much closer to the real concerns of those who have tried to institute target zones than does the standard academic model.

Conclusion

In this paper we have tried to present a rationale for exchange rate target zones that reflects the real concerns of their advocates rather than the convenience of economic modelers. We argue that the essential case for a target zone rests on the potential for irrational behaviour of foreign exchange rates, a case which is therefore intrinsically undiscussable in the context of the now-popular canonical model. This should not be news: the real-world case for exchange rate stabilization has always rested on fears of excessive speculation, not on the microeconomic concerns of the optimal currency area approach.

Are the advocates of target zones right to be worried? Almost certainly yes. There is no evidence supporting the view that exchange markets are efficient, or even that speculation will generally be stabilizing. We certainly have no grounds for dismissing the views of experienced market practitioners who warn of the potential for large exchange rate swings that are unjustified by the fundamentals.

There remains the question of whether one can really expect central banks to do better. In particular, the solution shown above, in which the central bank manages to set its target zone neatly inside the range of variation that would provoke stop-loss selling, may be too good to be true.

Our basic point, however, is that the policy case for taget zones depends not on an idealized view of efficient asset markets but on the question of how (if at all) to manage markets that, on the basis of all available evidence, are speculatively inefficient.

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Footnotes

We are grateful for research assistance supplied by Lei Zhang.

1. In the 1929 stock-market crash, explicit stop-loss orders placed with brokers, together with the practice of buying stock on margin with automatic liquidation, played much the same role as portfolio insurance 1987 (see Genotte and Leland, 1990).

2. In the text that follows, we assume that when stop-loss investors exit the market, they do so permanently at an exogenously determined trigger price. A better, but more complicated, story would have them exit the market whenever prices have fallen more than some percentage from their previous peak, then re-enter whenever they have risen by some (perhaps) different percentage from their previous trough. This makes the behavior of the exchange rate depend not only on the fundamental and on the number of stop-loss investors but also on its past history, as is shown in the model outlined in the Appendix.

3. See Pindyck (1991) for example, where contingent claims analysis is used to show that $\beta = \phi\rho 6$, where ϕ is the market price of risk, ρ denotes the covariance of the exchange rate with the market portfolio and 6 is instantaneous variance of fundamentals. On this basis, the entry and exit of stop-loss traders affects β via its impact on ρ.

Figures

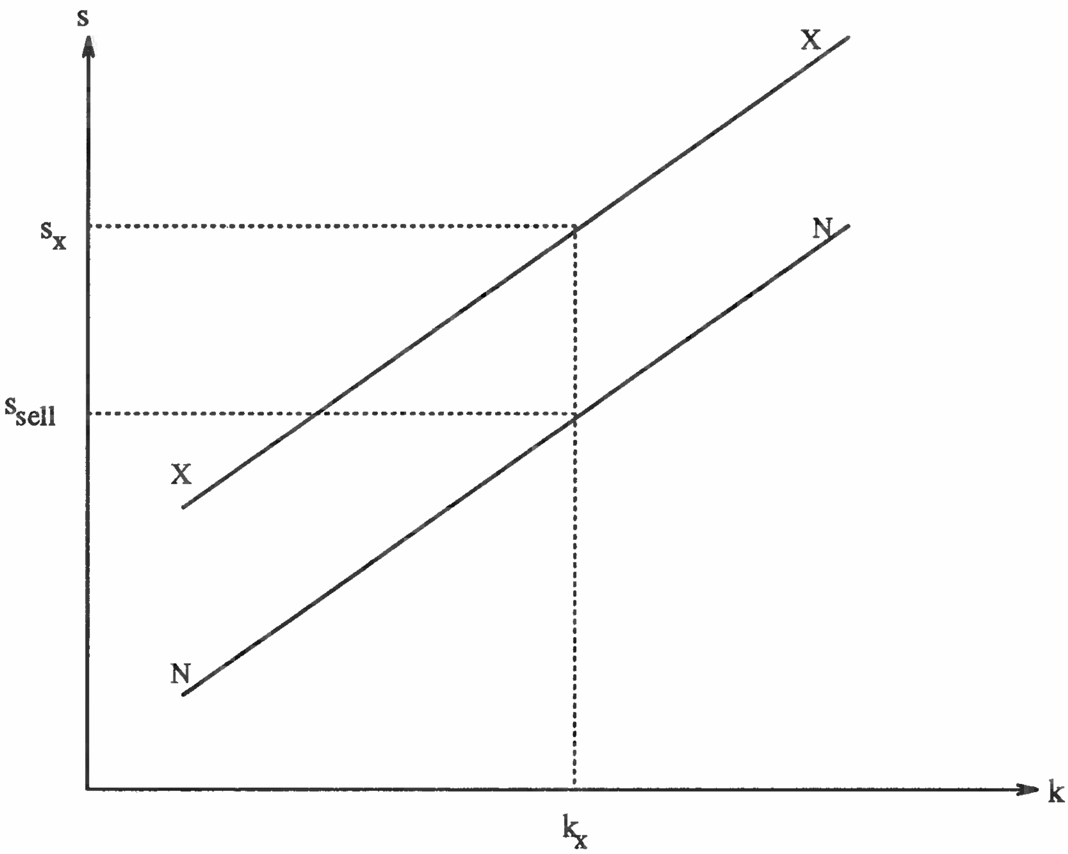

Figure 1: Effect of Exit by Stop-loss Traders.

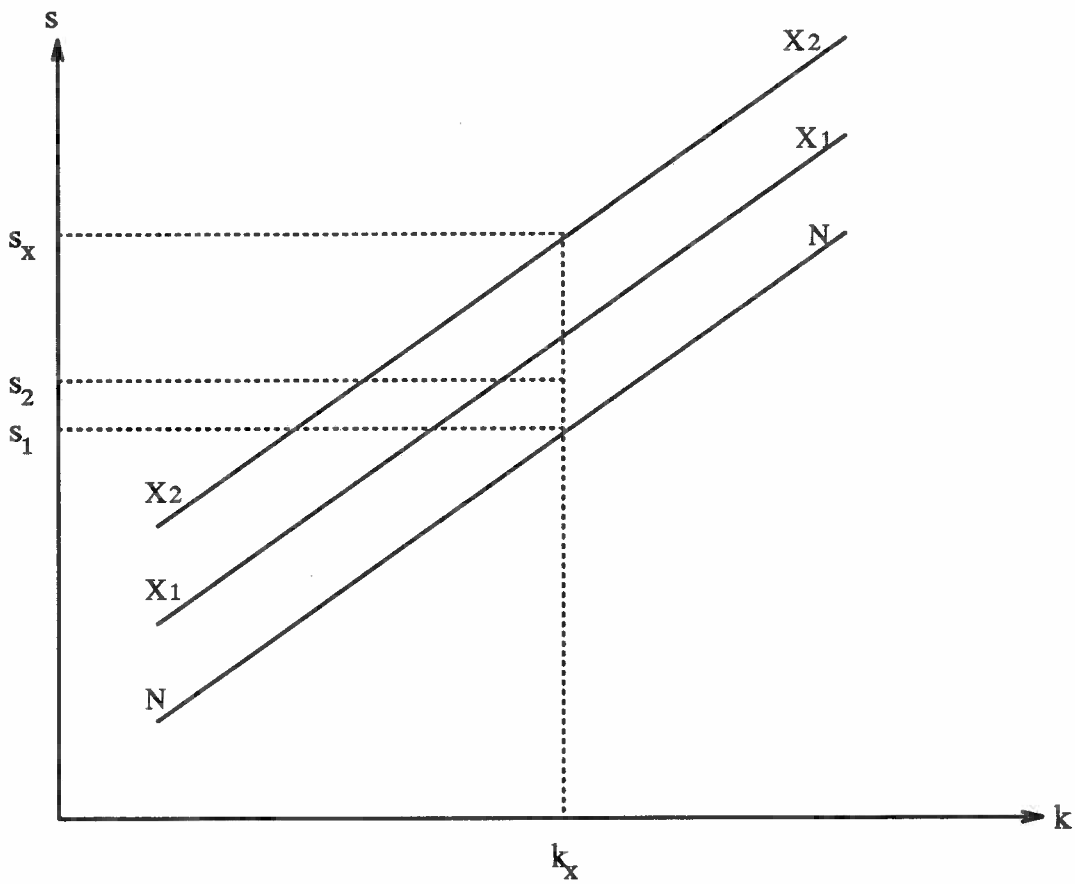

Figure 2: The Cascade Effect.

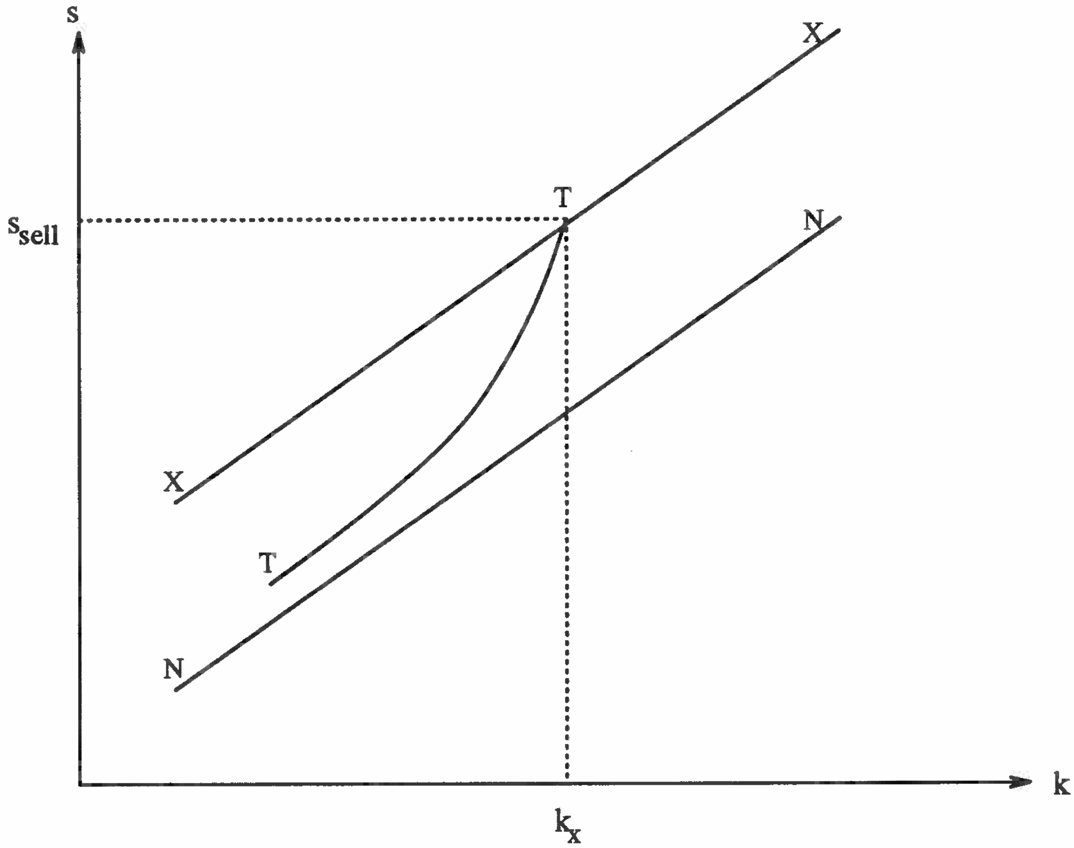

Figure 3: Stop-loss Traders and Informed Investors.

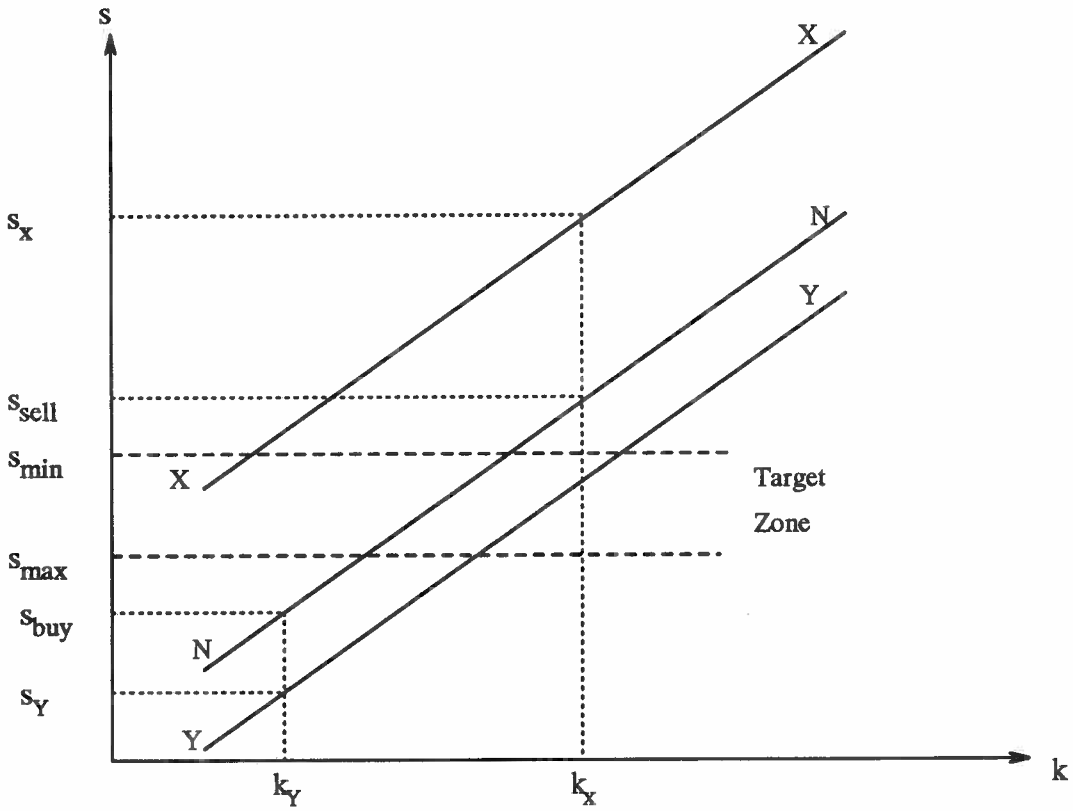

Figure 4: Target Zone with Static Expectations.

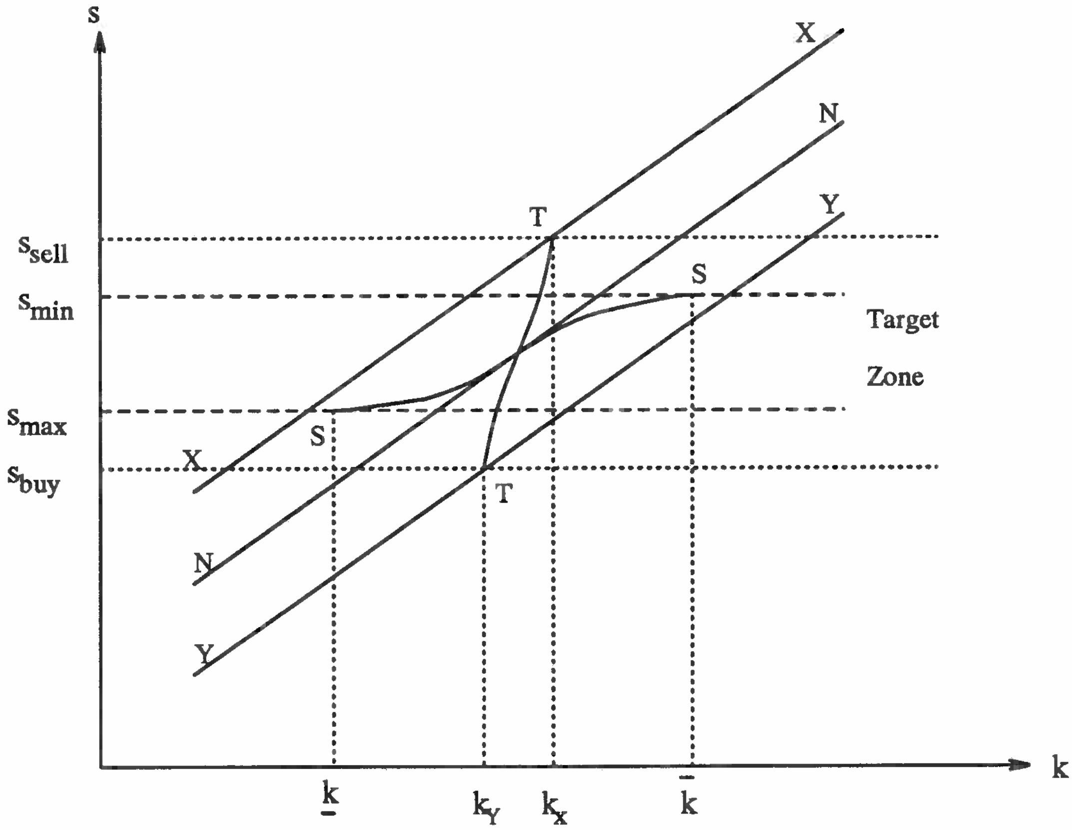

Figure 5: Target Zone with Informed Investors.

Appendix

Endogenous Triggers for Stop-loss Traders

The analysis of market equilibrium in the text depends on trigger points which have been specified exogenously; and it assumes irreversible exit. Here we outline a model in which (a) the trigger points are endogenous, being related to previous peaks and troughs in the market; and (b) exit is irreversible, given market recovery. The approach adopted follows the study by Grossman and Zhou (1991), who analyze "the optimal risky investment policy for a portfolio manager who, at each point of time wants to lose no more than a fixed percentage of the maximum value of his portfolio has achieved up to that time."

The problem they study arises if the manager is supervised using a "draw-down" rule under which one "books" (commits to other uses) a proportion $1 - \delta$ of the funds the manager has at his disposal when they reach an all time high. "So if he loses δ of the all time high, then it is as if the manager has lost *all* of the wealth that can be used for investment purposes" (1990, p.2). The authors show that the optimal policy for the manager is to hold risky assets in proportion to the *surplus* of wealth above $(1-\delta)m_t$ where m_t is the maximum level of wealth previously achieved. As wealth falls towards $(1-\delta)m_t$, he should sell equity and move into cash.

The behavior described is rather like that of the stop-loss traders discussed in the text *if* we choose to specify the exit trigger as $s_{sell} = s_m + \delta$ where s_m is the previous market high for the value of domestic currency (i.e., a previous *low* for the price of foreign currency); so stop-loss traders continue to hold domestic currency so long as it does not fall by more than 100 δ percentage points below its previous peak. When it does, they quit. This is how we make the exit trigger endogenous.

Endogenous but Irreversible Exit of Stop-loss Traders

Consider first market equilibrium when stop-loss traders are in the market, but are expected to exit irreversibly at a trigger point $s_x = s_m + \delta$, where s_m is the previous high for domestic currency (low for foreign currency). When s_x was fixed exogenously, as in Figure 3 of the text, then market equilibrium was defined by the convex curve shown there, intersecting the line XX at the predetermined exit point T, and approaching asymtotically the line NN.

When exit is determined by the drawdown rule, however, there will be a series of curves (one for each value of s_m), each with a vertical extension of δ. One of these is shown as TY in Figure A1. It is pinned down by two boundary conditions that it intersects XX at $s_x = s_m + \delta$; and it has a slope of 45^o where $s = s_m$.

Note that TY is tangent to the schedule labelled PP in the figure, where PP gives the value of the exchange rate whenever the fundamental sets a new peak for domestic currency (i.e., a new low for foreign currency). The reason for smooth pasting is analogous to that applied at the edge of a currency band, since the rate can either fall along PP if fundamentals drop below the previous low, or rise above PP as the "drawdown" rule begins to operate and the anticipated exit of traders affects the rate. How these boundary conditions determine the shape of TY, and the position of PP can be shown as follows.

When stop-loss traders are holding domestic currency but are expected to exit, the exchange rate function can be expressed as

$$s_{IN} - s_x = k - k_x + A_1(1 - e^{\lambda_1(k-k_x)}) + A_2(1 - e^{\lambda_2(k-k_x)}) \qquad \text{(A1)}$$

where λ_1 and λ_2 are the negative and positive roots of

$$\frac{\gamma\sigma^2}{2}\lambda^2 - \gamma\beta\lambda = 1 \tag{A2}$$

and s_x denotes the selling point and k_x the corresponding value of the fundamental. By inspection one can see that the boundary conditions imposed in Figure 3 of the text require $A_1 = 0$ and $-A_2 = \gamma(\beta - \beta_x)$. When exit is governed by a drawdown rule however, A_1 is no longer zero and the restriction that the solution lies on XX at s_x becomes

$$-(A_1 + A_2) = \gamma(\beta - \beta_x) \tag{A3}$$

The second boundary condition for the drawdown case (that the solution has a unit slope at $s_m = s_x - \delta$) implies

$$-A_1\lambda_1 e^{-\lambda_1\Delta} - A_2\lambda_2 e^{-\lambda_2\Delta} = 0 \tag{A4}$$

where $\delta = s_x - s_m$ and $\Delta = k_x - k_m$.

Together with equation (A1) this yields

$$\delta = \Delta - [A_1(1 - e^{-\lambda_1 \Delta}) + A_2(1 - e^{-\lambda_2 \Delta})] \qquad \text{(A5)}$$

Since δ is exogenous, (A3) (A4) and (A5) determine A_1, A_2 and δ. So for any point on XX (cf. point T in Figure A1), one can construct the "drawdown" curve shown as TY in the figure. The line shown as PP is the locus of points where these drawdown curves have a slope of unity.

The key feature to note about this solution for the exchange rate is that for $s > s_m$, the slope of TY is *everywhere greater than unity*, i.e., the presence of stop-loss traders makes the exchange rate more volatile than otherwise.

Endogenous Exit and Reentry

To allow for re-entry we postulate that funds are reallocated to stop-loss traders *once domestic currency has recovered by* ρ *from its previous trough* (and usually we will assume $\rho = \delta$). Because re-entry is now anticipated, domestic currency will command a higher prices and the boundary BB at which exit takes place will lie *below* XX. The solution is constructed using two switching boundaries AA, BB; these are connected by an infinity of *convex* curves portraying market equilibrium when exit is anticipated; and connected also by an infinity of *concave* curves for the exchange rate when re-entry is anticipated (see Figure A2). While the former smooth paste against AA and rise by δ to meet BB, the latter smooth paste against BB and fall by $\rho = \delta$ to intersect AA. The formulae for AA (the set of all possible troughs for s) and BB (the set of all possible peaks) are given below. Note that the connecting curves are not simple mirror images of one another because the market for foreign currency is more risk averse with stop-loss traders "in" domestic currency than when they are not.

When stop-loss traders are in the market then the exchange rate function will be as in (A1) above; and, as there should be a unit slope at the lower switching boundary AA in Figure A2, the boundary condition imposed in equations (A4) and (A5) still applies.

Similarly when the stop-loss traders are out, but are expected to return after a run-up of $\rho = \delta$, one obtains the exchange rate function

$$s_{OUT} - s_r = k - k_r + B_1(1 - e^{\xi_1(k-k_r)}) + B_2(1 - e^{\xi_2(k-k_r)}) \quad \text{(A6)}$$

where ξ_1 and ξ_2 are the negative and positive roots of the equation

$$\frac{\gamma\sigma^2}{2}\xi^2 - \gamma\beta_x\xi = 1 \tag{A7}$$

where s_r denotes the reentry point for stop-loss traders. The boundary condition that the run-up curve have a unit slope at its peak implies

$$-B_1\xi_1 e^{\xi_1\Delta} - B_2\xi_2 e^{\xi_2\Delta} = 0 \tag{A8}$$

where

$$\delta = \Delta + A_1(1 - e^{\xi_1\Delta}) + A_2(1 - e^{\xi_2\Delta}) \tag{A9}$$

To determine the five unknown parameters A_1, A_2, B_1, B_2 and Δ we need another equation (in addition to equations (A4), (A5), (A8) and(A9) above). The requisite restriction is implied by the "matching conditions", that the exit boundary and the re-entry boundary satisfy both the s_{IN} and s_{OUT} equations.

To obtain this restriction we note first that, when stop-loss traders are in,

$$s_x - k_x - (A_1 + A_2) = -\gamma\beta \tag{A10}$$

and second that, when they are not,

$$s_\tau - k_\tau + (B_1 + B_2) = -\gamma\beta_x \tag{A11}$$

Subtracting (A11) from (A10), and noting $s_x - s_\tau = \delta$, $k_x - k_\tau = \Delta$, implies

$$\delta - \Delta + (A_1 + A_2) - (B_1 + B_2) = \gamma(\beta - \beta_x) \tag{A12}$$

which is the required restriction.

The drawdown curve TY and the run-up curve YT are illustrated in Figure A2, tangent to the switching boundaries AA and BB respectively. The relationship between these switching boundaries and the free float loci XX and NN is given by equations (A10) and (A11) above.

Equation (A10) defines that the exit boundary BB

$$s = k - \gamma\beta + (A_1 + A_2) \tag{A13}$$

i.e., it lies $(A_1 + A_2)$ above line NN, see Figure A2. Similarly the switching boundary for re-entry is

$$s = k - \gamma\beta_x - (B_1 + B_2) \tag{A14}$$

from (A11) above. Thus it lies $(B_1 + B_2)$ below XX as indicated in figure A2.

From the construction of the figure it is easy to see that between AA and BB the slopes of TY and YT are always greater than unity. So the comings and goings of stop-loss traders add to exchange rate volatility.

Staggered Exit and Entry

In Figure 4 in the text there is an exit trigger for one group of stop-loss traders who are currently holding domestic currency assets, and an entry trigger for a group which has yet to move in. Here we discuss briefly how the analysis of endogenous triggers and reversible exit might be extended to handle two equal sized groups of stop-loss traders.

Let us assume that the same sort of "drawdown" and "run up" rules operate as before, but that ρ differs from δ, in particular $\rho_1 > \delta_1$ for group

1 and $\rho_2 < \delta_2$ for group 2. (Specifically $\rho_2 = \delta_1 = \delta$ and $\rho_1 = \delta_2 = 2\delta$.) Thus group 1 is first out and last in, while group 2 is last out and first in. In Figure A3 we sketch the case of reversible exit with these two groups. The two switching boundaries are labelled AA and BB, as in Figure A2. Between T and Y they are connected by two S-shaped curves with labels showing show which groups are holding domestic currency. Note that the inverse-S shaped curve YKT (shown in heavy outline) has the label 2 along its entire length. Evidently along YKT only group 2 holds domestic currency but the market expects it to be joined by group 1 at Y, or to quit at T. This inverse-S curve is therefore the analogue to the curve TT in Figure 5 of the text; but its location is endogenously determined by the history of the exchange rate.

Figures

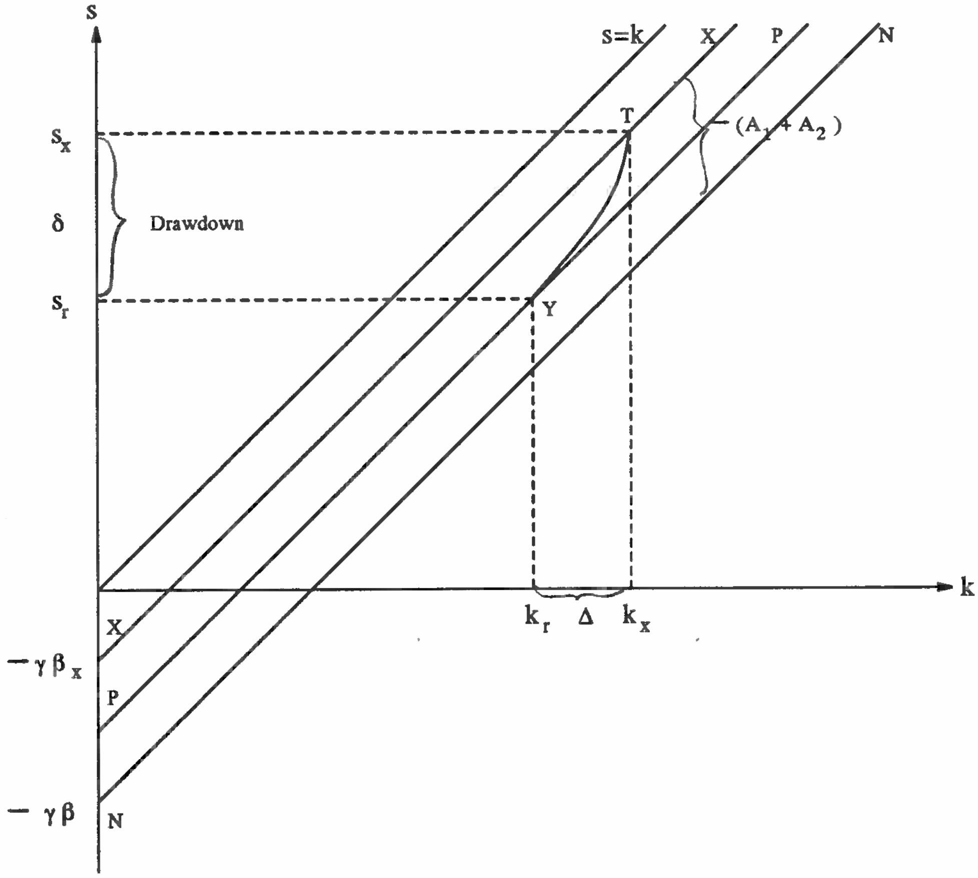

Figure A1: Endogenous Trigger Points for Irreversible Exit.

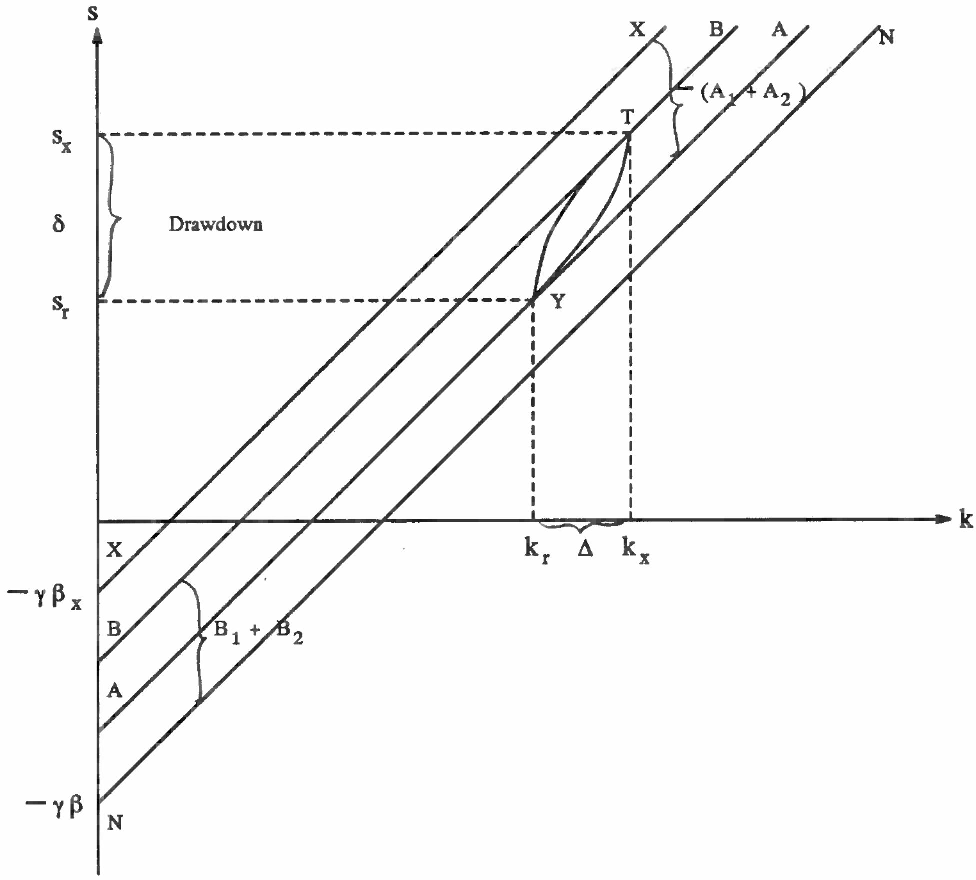

Figure A2: Endogenous Exit and Reentry Boundaries.

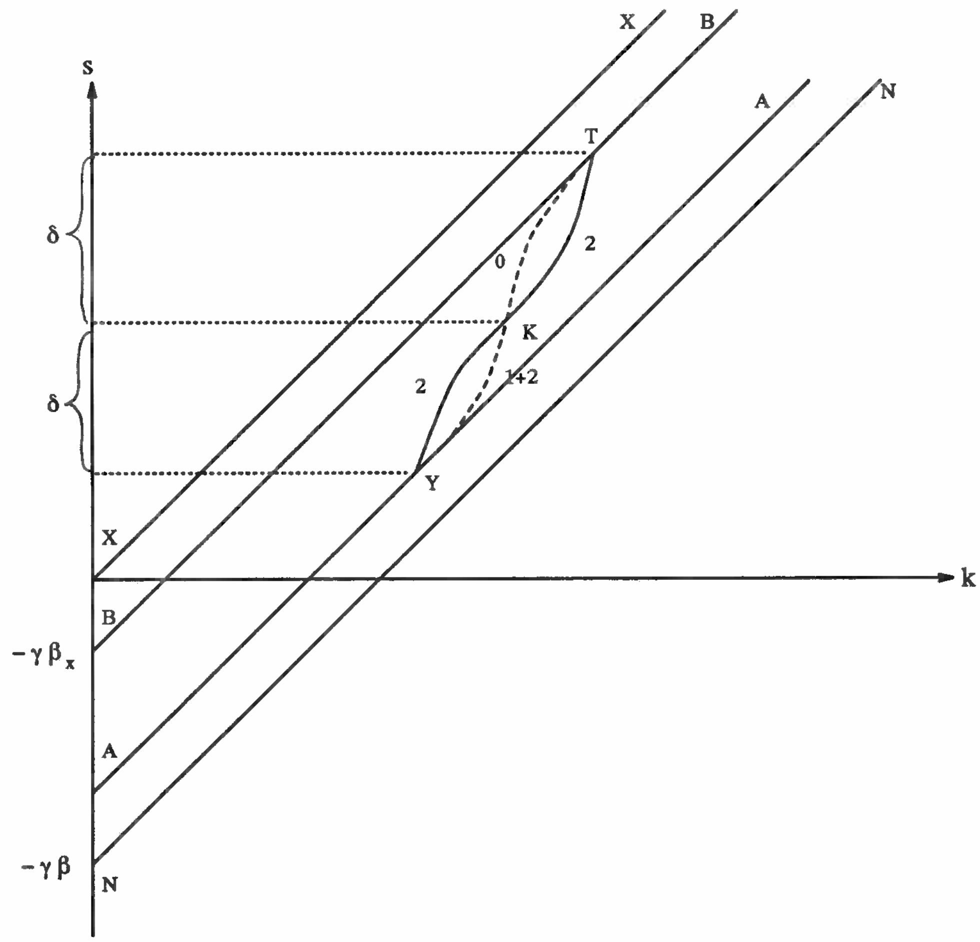

Figure A3: Endogenous Exit and Reentry—2 Groups.