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Exchange Rate Target Zones: A Survey of the Literature

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Abstract

This work selectively reviews the literature on exchange rate target zones and their theoretical and empirical methodologies and examines whether they can be used to clarify to what extent this type of exchange rate regime could contribute to greater exchange rate stability. We discuss the main contributions of the first and second generations of exchange rate target zone models. In an attempt to reconcile the poor empirical performance of the Krugman (1991) model with the reality of exchange rate target zone regimes, this line of research integrates target zones with alternative underlying economic models, such as imperfect credibility, intra-marginal interventions and sticky price models. It was thus possible to understand the correlations observed between the exchange rate, its fundamentals determinants and the interest rate differential, and to explain the fact that the statistical distribution of the exchange rate is hump-shaped rather than U-shaped. This implies that the initial emphasis of target zone models on nonlinearities, “honeymoon effect”, “smooth pasting” and marginal interventions has vanished. Exchange rate target zones are better described as similar to managed floating regimes with intra-marginal interventions, with some marginal interventions when the exchange rate reaches the edges of the floating band.

JEL Classification: F31, F41, G15.

Key Words: Exchange rate target zones, imperfect credibility, intra-marginal interventions realignments and sticky prices.

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1 – Introduction

After some initial theoretical research on the functioning of exchange rate target zones, with major contributions from McKinnon (1982, 1984), Williamson (1985), Williamson and Miller (1987) and Dumas (1989, 1992), the literature on the subject has seen a revival with the introduction by Krugman (1991) of the first model of a nominal exchange rate target zone in continuum time with rational expectations and flexible prices, using the structure of regulated Brownian motion.

The Williamson-type target zones are somewhat different from the narrow nominal exchange rate bands. Williamson (1985) and Williamson and Miller (1987) advocated a wider target zone, with a band of $\pm 10\%$ around a fundamental equilibrium exchange rate, as a method for international economic policy coordination. The Plaza Agreement and the Louvre Accord focus on that target zone proposal, despite being formulated in the context of a wider project to reform the International Monetary System².

Krugman (1991) develops a stochastic version of the monetary model of exchange rate determination in which he analyses the behaviour of this variable within an explicit target zone, concluding for its lower volatility vis-à-vis a floating exchange rate regime, especially when the exchange rate is near the edges of the band³.

Due to the innovative nature and relevance of the analysis, the model adopted by Krugman (1991) very quickly became the standard target zone model and the starting point for the emergence of a vast literature, both theoretical and applied. The general lessons of this literature are numerous and have created a new theoretical framework for the study of the relationship between the exchange rate and the monetary variables, different from what is used in fixed and floating exchange rates.

The model predicts a non-linear relationship (an S-shaped curve) between the exchange rate and its fundamental and a statistical distribution for the exchange rate that must be U-shaped or bimodal, with a greater number of observations lying close to the edges of the band. It also predicts that the exchange rate is much less variable the closer it is to the edges of the band and that there is a negative relationship between the

² Collapse of the gold block and increased concerns with the real exchange rate stabilisation of international currencies.

³ This model is essentially the same as that presented in Krugman (1987). The latest version, Krugman (1991) introduces new elements in the analysis such as the continuous-time formulation for the fundamentals' determination process and a different approach for the determination of the tangent point of the exchange rate to the edges of the floating band. For details, see Krugman (1988, 1992).

exchange rate and the interest rate differential. Therefore, we should find evidence of a trade-off between the volatility of the exchange rate and the volatility of the interest rate differential. These predictions can be tested against real world data in order to confirm the validity of the model and the credibility of the bands.

A first generation of exchange rate target zone models analysed the major implications of the basic model proposed by Krugman (1991) using data from the Nordic countries and the most important Member States of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS).

However, although the basic model leads to interesting predictions regarding exchange rate and the interest rate differential dynamics these were rejected by empirical analyses of data. Examples can be found in Diebold and Nason (1990), Meese and Rose (1991), Flood, Rose and Mathieson (1991), Svensson (1991a, b), Frankel and Phillips (1992), Mizrach (1992), Lindberg and Soderlind (1994), Klaster and Knot (2002) and Duarte, Andrade and Duarte (2008). More recently, Lundbergh and Terasvirta (2005) provide a partial verification of the basic target zone model.

These empirical results gave rise to the development of a set of critical extensions, the second generation of exchange rate target zone models, that include Svensson (1991a, c), Froot and Obstfeld (1991), Bertola and Caballero (1992) and Bertola and Svensson (1993), just to name a few. In addition to these two new lines of research, whose critical extension was the assumption of imperfect credibility of the bands and the existence of intra-marginal interventions, there was the extension introduced by Miller and Weller (1991) and Sutherland (1994) in the context of target zone models with sticky prices.

Following the new elements added to the basic target zone model, a series of studies that tried to explore the main implications of this second generation of target zone models also began to emerge, combining, sometimes in the same formulation, characteristics so far analysed separately. It was thus possible to bring the basic model closer to the real functioning of the exchange rate target zones. Among the studies that contributed to this are Chen and Giovannini (1992), Lindberg and Soderlind (1992), Edin and Vredin (1993), Lindberg, Soderlind and Svensson (1993), Mizrach (1995), Rose and Svensson (1995), Bekaert and Gray (1998), Cornell (2003), Tronzano, Psaradakis and Sola (2003), Baghli (2004) and Driffill and Sola (2006)⁴.

⁴ See also the Appendix for a synthetic analysis of some of the most recent works on exchange rate target zones.

We will analyse some of that literature and present the main conclusions of the economic theory on exchange rate target zones. However, this will be a selective analysis of the literature, from which we will seek to clarify to what extent this type of exchange rate regime may allow greater exchange rate stability. Our contribution to the literature results thus from the fact that our research has focused not only on *normative issues* concerning the optimal choice of the exchange rate regime, as has been common in most of the surveys on exchange rate target zones, but also on *aspects of positive order*, associated with the explanation of the stabilising effect on exchange rates resulting from the presence of a target zone.

The paper is structured as follows. Section 2 presents the first generation of exchange rate target zone models focusing on the empirical performance of the three central testable predictions of the basic model. Section 3 analyses the theoretical and empirical developments of the second generation of exchange rate target zone models in the context of a set of critical extensions, which include the presence of imperfect credibility, intra-marginal interventions and sticky prices. Section 4 draws some conclusions.

2 – The First Generation of Exchange Rate Target Zone Models

The first generation of exchange rate target zone models was initiated by Krugman (1988, 1991), under a stochastic monetary model in continuum time with rational expectations and flexible prices, based on which the author proposed a rigorous formalisation of the principles governing the functioning of an exchange regime with bands. His model allows us to examine to what extent the behaviour of the exchange rate can be changed by the presence of a credible government commitment to defend the edges of a target zone.

Examination of the basic model reveals the existence of a stabilising effect on exchange rates, a direct consequence of the presence of a floating band. This phenomenon of stabilisation, which results in an S-shaped non-linear relationship between the exchange rate and its fundamental determinants, has important implications for exchange rate and interest rate differential dynamics, which allows tests to be implemented on the model and the credibility of the bands.

Despite the interesting conclusions arising from the basic model, the first empirical work did not allow the confirmation of the model's predictions for the majority of the currencies.

2.1 – The Basic Target Zone Model

According to the basic target zone model proposed by Krugman (1991), the behaviour of the exchange rate within the band depends on an aggregate fundamental and its expected rate of change, as described in the following equation:

$$s(t) = f(t) + \alpha E_t [ds(t)] / dt, \quad \forall t \text{ and } \alpha > 0, \quad (1)$$

where $s(t)$ is the log of the nominal exchange rate at time t , $f(t)$ is the fundamental at time t , α is the absolute value of the semi-elasticity of the exchange rate with respect to its expected rate of change, and E_t is the expectations operator conditional on the available information at time t according to the rational expectations hypothesis.

The fundamental is the sum of two components,

$$f(t) = m(t) + v(t), \quad (2)$$

the domestic money supply, $m(t)$, and a term representing a composite money demand shock, usually referred to in the literature on target zones as “velocity”, $v(t)$ ⁵. The model assumes that “velocity” is an exogenous stochastic process, whereas the money supply is a stochastic process controlled by the monetary authorities. The question is then how the presence of a credible floating band may affect the behaviour of the exchange rate.

In the absence of any intervention, a situation common in a free floating regime, it is assumed that the money supply $m(t)$ is kept constant. As a consequence, the

⁵ The interpretation of $f(t)$ depends on the specific model for exchange rate determination one decides to adopt. It is possible to distinguish alternative target zone models by the way that the fundamentals are modelled. $f(t)$ may represent monetary variables, but it may also include other factors. Zhu (1996) develops a target zone model where the movements in exchange rates are mainly explained by non-economic fundamentals or psychological factors. In a similar line of research, Flood and Rose (1995) find a reduced explanatory power for the economic variables, suggesting the introduction of some non-economic factors in the explanation of the behaviour of the exchange rate. We can also take into account microeconomic factors such as heterogeneous expectations. See Torres (2000a) and Bauer, De Grauwe and Reitz (2008).

fundamental is simply equal to “velocity”, $f(t) = v(t)$. It is thus assumed that “velocity” follows a Brownian motion with drift μ and instantaneous standard deviation σ :

$$dv(t) = \mu dt + \sigma dz(t), \quad \mu \text{ and } \sigma \text{ positive parameters and } v(0) > 0, \quad (3)$$

where $z(t)$ is a Wiener process with $E_t[dz(t)] = 0$ and $E_t[(dz(t))^2] = dt$, that is, $f(t)$ is the equivalent of a continuous random walk⁶.

This assumption implies that the exchange rate under a free floating regime is also a Brownian motion. Therefore, changes in the fundamental will translate into equal changes in the exchange rate, $ds(t) = df(t)$.

In a target zone, it is assumed that the intervention rule is based on a specific floating band for the fundamental, $f_L \leq f(t) \leq f^U$, and that, if necessary, the fundamental will be regulated to remain within the band. This implies that the fundamental follows a regulated Brownian motion with constant drift and instantaneous standard deviation⁷:

$$df(t) = \mu dt + \sigma dz(t) + dL(t) - dU(t), \quad (4)$$

where $L(t)$ and $U(t)$ are the lower and upper regulators, defined as continuous and increasing functions of t , so that $dL(t)$ represents increases in the money supply, positive only if $f(t) = f_L$ and $dU(t)$ represents decreases in the money supply, positive only if $f(t) = f^U$. It is thus necessary to assume that the probability distribution of the marginal interventions is determined by the current level of the fundamental, $s(t) = s(f(t))$, so that the exchange rate function in a target zone will be flat at the edges of the fundamental band and tangent to the edges of the exchange rate band:

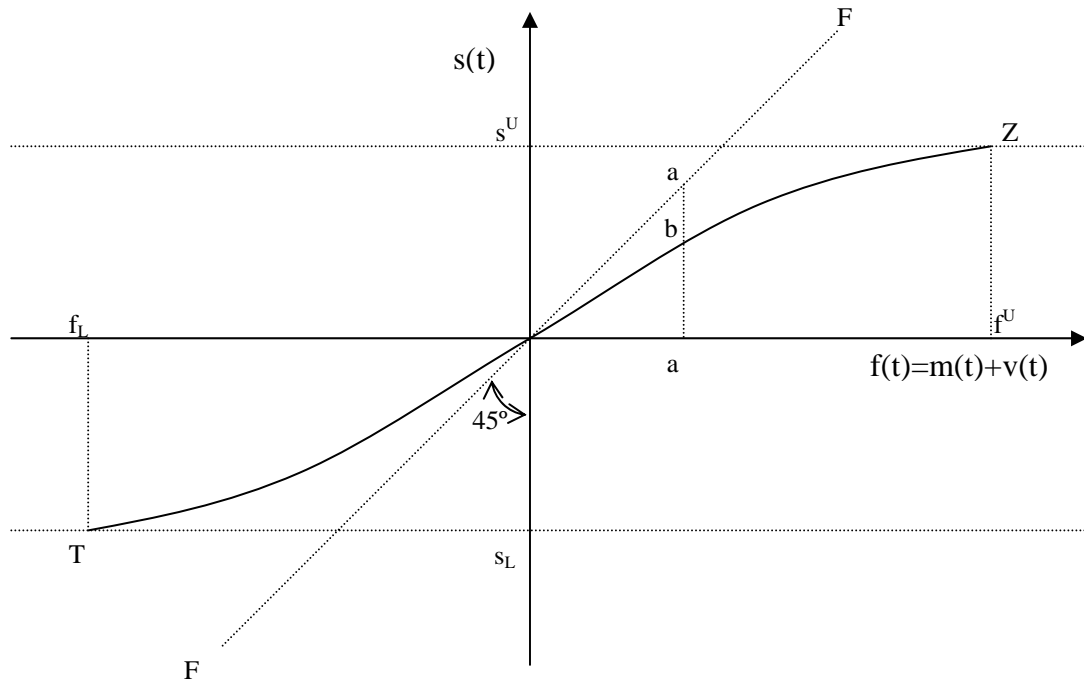
$$s'(f_L) = s'(f^U) = 0. \quad (5)$$

⁶ See Merton (1992), Campbell, Lo and Mackinlay (1997), Maddala and Kim (1999) and Demange and Rocher (2005).

⁷ Harrison (1985) and Karatzas and Shreve (1997) provide a formal presentation of these processes.

Under these circumstances, the exchange rate function establishes a non-linear relationship (an S-shaped curve) between the exchange rate and its fundamental, as illustrated in Figure 1.

Figure 1: Exchange Rate in a Perfectly Credible Target Zone



The straight-line FF represents the equilibrium exchange rate in the free floating case. A shock in $v(t)$ leads to a proportional change in $f(t)$ and $s(t)$. According to equation (5), the exchange rate target zone function is tangent to the edges of its floating band, where $s_L = s(f_L)$ and $s^U = s(f^U)$, represented by the curves TZ, non-linear, and S-shape, respectively.

The behaviour of the exchange rate in a target zone with perfect credibility leads to two main results. First, the slope of the curve TZ is always less than one. This feature is called “the honeymoon effect”, a reference by Krugman (1987: 19) to a “target zone honeymoon”. The exchange rate function thus appears less sensitive to changes in the fundamental than the corresponding free floating exchange rate. Moreover, the part of the adjustment supported by the exchange rate in a target zone is not constant, but decreases as the exchange rate moves away from the central parity.

The “honeymoon effect” thus implies that a perfectly credible target zone is inherently stabilising⁸.

Second, the curve TZ becomes flatter, reaching a zero slope at the edges of the band. At the edges of the target zone, the exchange rate function is tangential to the horizontal dashed lines that represent the edges of the exchange rate band. This result, represented by equation (5), is known as “smooth pasting”, and it corresponds to the continuity conditions for the solution of the basic model⁹. Given these conditions, the basic model has very interesting implications for the behaviour of exchange rate and the interest rate differential, which allows the implementation of tests to the model and the credibility of the bands.

2.2 – Main Predictions of the Basic Model: The Poor Performance of the Krugman Model

The model predicts that the statistical distribution of the exchange rate will be U-shaped or bimodal. Taking into account the “smooth pasting” conditions and assuming the uncovered interest rate parity, a negative relationship between the exchange rate and the interest rate differential is also expected. The Krugman model also predicts an S-shaped non-linear relationship between the exchange rate and its fundamentals¹⁰. These implications have been tested extensively using data from the European Monetary System, Scandinavia, especially Sweden, the Bretton Woods system and the gold standard. Although the basic model provides important results on the behaviour of the exchange rate, the main predictions of the model have been consistently rejected by the data.

⁸ Returning to Figure 1, if we consider that a positive random shock in $v(t)$ increases the fundamental from the origin to point a , under a free floating regime the exchange rate increases by the same amount. In a target zone, however, agents recognize that there is a high probability of a future contraction in the money supply. Thus, agents expect the future appreciation of the exchange rate. This results in an equilibrium exchange rate that is less than a , at point b . But it should be noted that the stabilising mechanism inherent to the “honeymoon effect” derives from the bias in expectations. As noted by Flandreau and Komlos (2001), although a credible floating band reduces uncertainty it improves the quality of expectations, thereby increasing the stabilising characteristic of the target zone. The announcement of and compliance with a target zone is thus stabilising. Some exchange rate stability is “free”, representing a free benefit as a result of the announcement of a perfectly credible target zone. See Svensson (1992a) and Anthony and MacDonald (1998).

⁹ See Dumas (1991), Flood and Garber (1991), Froot and Obstfeld (1991) and Dixit (1991, 1992).

¹⁰ Svensson (1992a) presents a survey of the main empirical implications of the basic model.

2.2.1 – The U-Shaped or Bimodal Distribution of the Exchange Rate

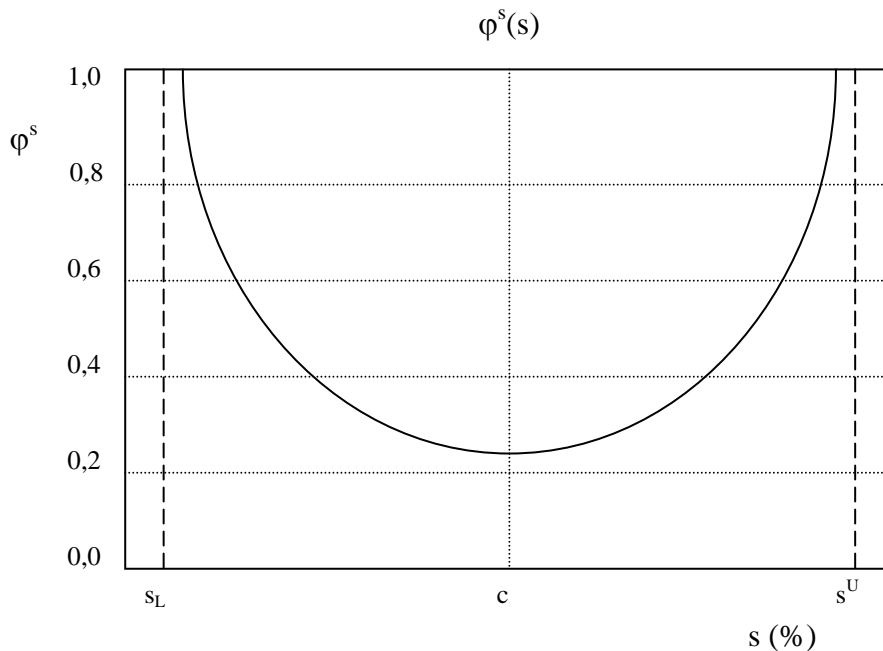
Based on the work of Harrison (1985), Svensson (1991a) and Bertola and Caballero (1992) tried to analyse the asymptotic distribution of the exchange rate within the band. Since the exchange rate function, $s(f)$, is strictly increasing and invertible only inside the band, the asymptotic density function of the exchange rate, $\varphi^s(s)$, is given by:

$$\varphi^s(s) = \frac{\varphi^f(f(s))}{|s'(f(s))|}, \quad (6)$$

for $s_L < s < s^U$, where $f(s)$ denotes the inverse of $s(f)$. Since the fundamental is uniformly distributed, the exchange rate will change slowly near the edges of the band. The exchange rate will thus tend to fix itself in the region where it changes more slowly and $\varphi^s(s)$ should present a peak near s_L and s^U .

The density function of the exchange rate is represented in Figure 2.

Figure 2: Density Function of the Exchange Rate within the Band



It follows from the basic target zone model that in the long run the exchange rate will spend most of the time near the edges of the band rather than at the central parity, where its presence should be relatively low.

The model also implies that the exchange rate will be much less variable near the edges of the band. According to the model, the instantaneous variability of $s(t)$ is directly proportional to the slope of the curve TZ:

$$V(t)[ds(t)] = [s'(f(t))\sigma]^2 dt, \quad (7)$$

where $V(t)[ds(t)]$ is the conditional variance of the changes in the exchange rate. The variability of the exchange rate thus reaches a maximum at the centre of the exchange rate band and decreases as the exchange rate gets closer to the edges of the band.

The U-shape of the exchange rate's density is clearly rejected by the data. The results of empirical work show that the statistical distribution of the exchange rate is hump-shaped, with most of the probability mass in the interior of the band and very little near the edges of the band¹¹.

Honohan (1998) assigns the poor empirical performance of the Krugman model to the fact that most of the work has neglected the multilateral character of the target zone of the ERM of the EMS, focusing instead on the relationship between each of the currencies and the deutschmark. However, Member Countries have an obligation to intervene with regard to all the participating currencies and not just against the deutschmark¹².

When the multilateral distance of the currencies in relation to the edges of the band is introduced, it is possible to confirm, at least in some cases, the U-shaped or bimodal distribution. Taking the ECU as the reference currency, Honohan (1998) find evidence, for example in the case of Denmark, for the distribution of the exchange rate being less concave when measured on a multilateral basis. In the case of Holland, the difference between the two analyses is even more evident since the bilateral distance suggests a distribution within the band with a very concave form, while the multilateral distance approaches a uniform distribution. For the Belgian franc, the multilateral distance clearly shows a U-shaped distribution, thus confirming the predictions of the

¹¹ See Flood, Rose and Mathieson (1991), Bertola and Caballero (1992), Magnier (1992), Lindberg and Soderlind (1994), Duarte, Andrade and Duarte (2008) and Lai, Fang and Chang (2008).

¹² Given the multilateral nature of the real world of target zones, it is possible to reconcile the model with the empirical characteristics of the behaviour of the exchange rate. See Serrat (2000).

basic model and contradicting the initial empirical results of Flood, Rose and Mathieson (1991) and Bertola and Caballero (1992), for example, for whom the exchange rate in the EMS had a concave distribution with most probability mass in the middle of the band.

The results confirm the theory predictions, particularly in the turbulent EMS period, from March 1979 to March 1983, and during consolidation and convergence, from April 1983 to January 1987, when there were several realignments of central parities in the majority of the currencies. This situation shows that exchange rates mostly remain near the edges of the bands¹³. The results are contrary to the theory in the post-1987 period. The presence of an effective interior band in the ERM of the EMS and the regular existence of intra-marginal interventions help to explain why the U-shaped distribution of the exchange rate disappears from February 1987 until early 1992. Since the intra-marginal interventions limit the amount of time spent by exchange rates near the edges of the band, they take exchange rates near to central parity. It is thus not possible to confirm empirically the first prediction of the basic model, especially for the period that became known as the “new EMS”¹⁴.

The importance of multilateral order aspects is also evident when we analyse the volatility of the exchange rate, but in this case to reinforce the empirical rejection of the basic model. Indeed, starting from a range of multilateral parities for all the currencies of the EMS, Engle and Gau (1997) conclude that the conditional volatility of the exchange rate tends to increase the closer the exchange rate is to the edges of the band, contrary to the prediction of the basic model. Several other studies, such as Flood, Rose and Mathieson (1991), Rose and Svensson (1995), Bekaert and Gray (1998), Duarte, Andrade and Duarte (2008) and Fidrmuc and Horváth (2008) also failed to detect the presence of a lower volatility of the exchange rate near the edges of the target zone, thus concluding for the poor empirical performance of the Krugman model with respect to this first implication.

¹³ See Honohan (1998).

¹⁴ Flandreau (1998) corroborates these latest findings. The existence of multilateral target zones leads to exchange rates not getting close to the edges of the floating band, but most of the time lying near the intra-marginal targets. As a consequence, the stationarity distribution of the exchange rate function is not U-shaped as predicted by the theory, exhibiting instead a unimodal nature. The history of repeated realignments and the predominance of intra-marginal interventions in the EMS, described by Giavazzi and Giovannini (1989), are also inconsistent with the basic model.

2.2.2 – The Negative Relationship between the Exchange Rate and the Interest Rate Differential

The basic model also has implications for the behaviour of the interest rate differential that emphasize the special features of the adjustment process in a target zone following a monetary shock. Svensson (1991c, 1992a, b) shows that in narrow target zones, with and without devaluation risk, the foreign exchange risk premium is likely to be very small. We thus assume that the foreign exchange risk premium is zero and that uncovered interest rate parity continually holds¹⁵, that is:

$$i(t) - i^*(t) = E_t[ds(t)]/dt, \quad (8)$$

where $i(t)$ and $i^*(t)$ are the domestic and foreign interest rates, respectively.

Letting $\delta(t)$ denote the interest rate differential, we can combine (8) with equation (1) in order to represent the interest rate differential:

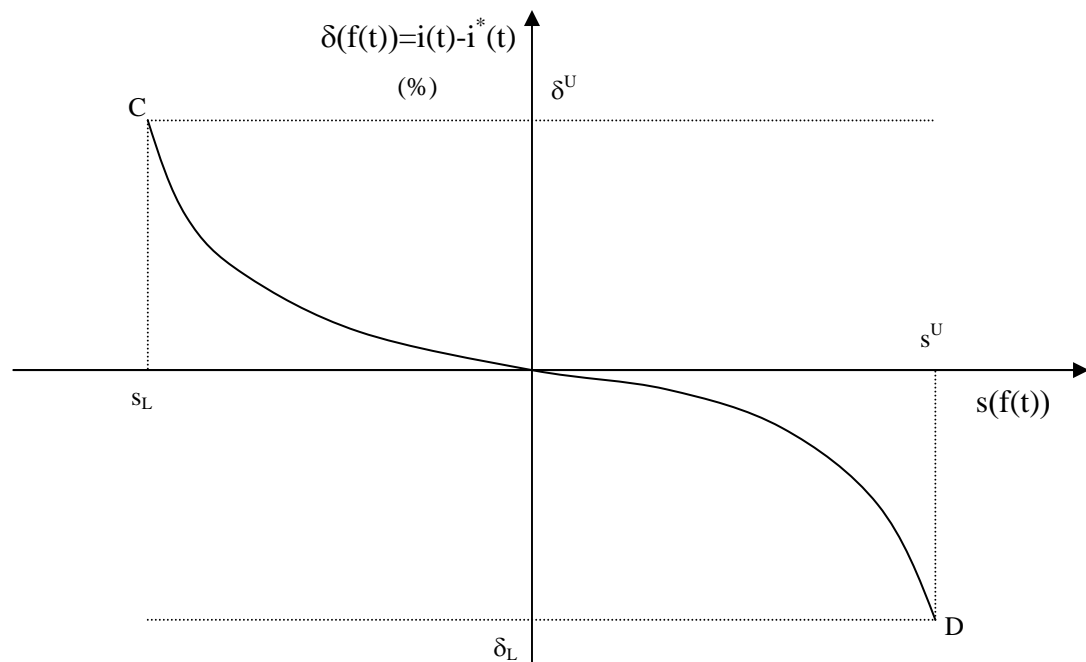
$$\delta(t) = \frac{s(t) - f(t)}{\alpha}. \quad (9)$$

In the case of a free floating regime it follows that the interest rate differential is constant and equal to the drift of the fundamental.

Since, under a target zone $s'(f(t)) < 1$, it follows that the interest rate differential will be decreasing in the fundamental, $\delta'(f(t)) < 0$. Furthermore, recalling that the exchange rate is an increasing function of the fundamental, the basic model implies a negative deterministic relationship between the exchange rate and the interest rate differential. This relationship can be represented by the CD curve in Figure 3.

¹⁵ We could incorporate an endogenous foreign exchange risk premium into the model, but, as shown in Svensson (1992a, b), for narrow bands with and without devaluation risk the foreign exchange risk premium is likely to be small. Consequently, it is assumed that the foreign exchange risk premium is zero and that uncovered interest rate parity is a good approximation. See Ayuso and Restory (1996) and Bekaert and Gray (1998) for an alternative point of view.

Figure 3: The Relationship between the Exchange Rate and the Interest Rate Differential in a Target Zone with Perfect Credibility



This negative relationship implies that the exchange rate within the band displays mean reversion. This mean reversion is an important general property of exchange rates in the context of a target zone because it is expected that the exchange rates are stationary around the central parity¹⁶.

Given the mean reversion property of exchange rates and assuming that the agents are rational, it is then understandable that they should easily accept a lower interest rate for a currency that is momentarily weaker because they expect foreign exchange gains from the future exchange rate appreciation. Similarly, agents should adopt a higher interest rate for a currency that is temporarily stronger, as agents expect foreign exchange losses due to future exchange rate depreciation¹⁷.

In this context, the expected mean reversion of the exchange rate around the central parity gives the monetary authorities a degree of autonomy in the execution of

¹⁶ Duarte, Andrade and Duarte (2009) analysed this natural property of an exchange rate target zone regime in the case of Portugal. The empirical analysis of mean reversion in the Portuguese exchange rate shows that most of the traditional unit root and stationarity tests point to the nonstationarity of the exchange rate within the band. However, using a set of variance-ratio tests, it was possible to detect the presence of a martingale difference sequence. In this context, the authors conclude that the Portuguese foreign exchange market has functioned efficiently and that the adoption of an exchange rate target zone regime has contributed decisively to the creation of the macroeconomic stability conditions necessary for the participation of Portugal in the euro area.

¹⁷ See Svensson (1992a, 1994), Pansard (1997) and Flandreau and Komlos (2001).

monetary policy. Monetary authorities should be able to control interest rate levels by acting on the position of the exchange rate within the band. This autonomy would be the main reason for the adoption of a target zone regime. Indeed, we can find here the main difference between a free floating regime and a target zone. In a free floating regime, the exchange rate is responsible for the whole adjustment process. In a target zone, the exchange rate and the interest rate “share” that responsibility between them. The volatility spillover from the exchange rate to the interest rates can be analysed through the instantaneous variability of the interest rate differential. The variability of $\delta(t)$ is computed using Ito’s lemma:

$$d\delta(t) = \frac{\delta(f(t))}{\alpha} dt + \delta'(f(t))\sigma dz(t), \quad (10)$$

where $[\delta'(f(t))\sigma]^2 dt$ represents the conditional variance of the changes in the interest rate differential. It follows that the interest rate differential’s volatility reaches a minimum at the centre of the band and increases near the edges where it replaces the exchange rate as the main variable in the adjustment process. There is thus a trade-off between the instantaneous variability of the exchange rate and the instantaneous variability of the interest rate differential¹⁸.

The deterministic negative relationship and the set of specific properties associated with this second implication are rejected by the data in most cases. The results of the empirical works show a wider scatter of observations. The correlation between the exchange rate and the interest rate differential is often positive or zero, and only occasionally negative, depending on the currencies that compose the sample and the sample period.

Based on data from the Swedish economy, Svensson (1991c) finds that the exchange rate and interest rate differential have a significant relationship that confirms the prediction of the basic model, but only for the period from February 1986 to October 1989, corresponding to the more stable functioning of the Swedish target zone, after the unstable period of 1985, with the switching of the band from $\pm 2.25\%$ to $\pm 1.5\%$, and before the disturbances in the monetary market in the winter of 1989-90. The author also finds a high variability in the interest rate differential, whose average should in theory be equal to zero, in the absence of any devaluation risk, but which in

¹⁸ See Svensson (1991a, 1994).

practice presents positive values between 1.2 and 2 for all terms of interest rate structure, suggesting the possibility of a devaluation risk.

Flood, Rose and Mathieson (1991) examined the predictions of the basic model using data for all countries participating in the ERM of the EMS from its creation in March 1979 until January 1990, decomposing the sample into 13 different periods according to the intervals between realignments. Using graphical analysis and correlation coefficients, the authors did not find a clear relationship between the exchange rate and the interest rate differential. The trade-off between the volatility of these two variables is not confirmed¹⁹. There are also large differences between countries in the variability of interest rates, which are less volatile for the more recent periods.

Based on the parities of the French franc and Italian lira against the deutschmark, Bertola and Caballero (1992) show that in the first eight years of the ERM, the behaviour of the interest rate differential is inconsistent with the predictions of the basic model. The graphical analysis does not lead to a deterministic negative relationship between the exchange rate and the interest rate differential. The data indicate that the interest rate differential tends to predict an additional depreciation of the French franc when the exchange rate is closer to the upper edge of the band. The depreciation of the currency is linked to high domestic interest rates, in a clear contrast with the predictions of the model. This happens because in the ERM depreciation in the direction of the upper edge of the band was interpreted as a sign that devaluation could be anticipated. Based on these results, the ERM appears to have rapidly lost the crucial element of credibility.

Using similar analytical techniques for data from the Swedish economy, Lindberg and Soderlind (1994) observed the existence of a positive relationship between the interest rate differential and the position of the exchange rate within the band.

More recently, Hallwood, MacDonald and Marsch (1996) and Bordo and MacDonald (1997, 2003, 2005) provide a partial verification of the exchange rate target zone model, while reinforcing the idea of lack of credibility associated with ERM. An examination of the functioning of the exchange rate regime in the core countries during the gold standard and interwar period, when policies were associated with less frequent devaluations, was more encouraging in terms of the viability of the target zone regime.

¹⁹ See Figures 4, 27 and 28 in Flood, Rose and Mathieson (1991).

However, the substitution between stability of the exchange rate and policy autonomy still remains modest. For example, the research of Bordo and MacDonald (2003) on the relationship between the exchange rate and the interest rate differential before the First World War only confirms the theory for two out of three cases analysed. As for the parities between sterling, the deutschmark and the French franc a negative relationship between the variables is observed, while for the exchange rate between the French franc and deutschmark the relationship is positive. Based on the parities of the Portuguese escudo against the deutschmark, Duarte, Andrade and Duarte (2008) also rejected this prediction. Using an M-GARCH model however the authors confirm that there is a trade-off between exchange rate volatility and interest rate differential volatility. These results express the increased credibility of the Portuguese monetary policy, due mainly to the modernisation of the banking and financial system and to the progress made in terms of the disinflation process under an exchange rate target zone policy. In accordance to these results we can say that a participation in an exchange rate target zone can be crucial to create the conditions of stability, credibility and confidence necessary, for example, for the adoption of a single currency.

2.2.3 – The Non-Linear Relationship between the Exchange Rate and its Fundamental

Since the basic target zone model predicts a non-linear S-shaped relationship between the exchange rate and the aggregate fundamental, with “smooth pasting” at the edges of the band, some authors tried to test this relationship directly by plotting the exchange rate against the fundamental. However, the empirical verification of this third implication of the Krugman model immediately raises the problem of how to interpret the fundamental, given that it is an aggregate of many different determinants of the exchange rate and it is not directly observable. The fundamental can be estimated, however, from observed variables²⁰. For example, Flood, Rose and Mathieson (1991) tried to confirm the existence of that relationship in six countries in the ERM basing its study on an explicit measure of the fundamental²¹.

²⁰ In most cases the interest rate differential is used as a proxy for the aggregate fundamental.

²¹ The work of Flood, Rose and Mathieson (1991) is taken by different authors to encompass the main methods used in the empirical analysis of the functioning of exchange rate target zones regimes.

Remember that on the assumption of uncovered interest rate parity, the expected rate of depreciation of the national currency is given by the interest rate differential, $E_t[ds(t)]/dt = i(t) - i^*(t)$, as can be easily deduced from relationship (8). In this context, if equation (1) is verified, we obtain the following expression for the fundamental:

$$f(t) = s(t) - \alpha(i(t) - i^*(t)). \quad (11)$$

Therefore, given an estimate or a guess of the value of α , the fundamental can be estimated by subtracting the product of the estimated α and the interest rate differential from the exchange rate²².

The choice of the parameter α remains one of the main difficulties of the study. Two methods are used to determine it. Initially, Flood, Rose and Mathieson (1991) tried to estimate it from the data. The authors note that in accordance with equation (3), the evolution of the fundamental in discrete time must meet the following relationship:

$$f(t) - f(t-1) = \mu + \varepsilon(t), \quad (12)$$

where μ represents the drift of fundamental and $\varepsilon(t)$ is an error or residual corresponding to a shock in the money demand²³. Taking into account the exchange rate equation (1), we can get α by estimating the model:

$$s(t) - s(t-1) = \mu + \alpha \left\{ E_t[ds(t)] / dt - E_{t-1}[ds(t-1)] / dt \right\} + \varepsilon(t), \quad (13)$$

since it is necessary to replace in the previous relationship the changing expectations in the exchange rate, $E_{t-j}[ds(t-j)]/dt$, by the interest rate differential, $i(t-j) - i^*(t-j)$.

The estimates of α obtained by Flood, Rose and Mathieson (1991: 16a) are generally small, although they differ considerably between countries and different periods of analysis. Except for some estimates for Denmark and France, there is little statistical evidence that α exceeds 0.25. Moreover, many estimates of α are negative.

²² See Svensson (1992a).

²³ The unit of time used corresponds to the range of observation. If it is a day, μ must be interpreted as the daily growth rate of the fundamental and $\varepsilon(t)$ as the daily disturbance of the fundamental process (3). For more details see Flood, Rose and Mathieson (1991: 17-20).

Given the unsatisfactory values obtained for α , in most cases small and often negative, the authors focus exclusively on the monetary interpretation of the parameter α using, in a second phase of their research, the estimates of α arising from the empirical literature on money demand²⁴. In this context, the parameter α is interpreted as the semi-elasticity (negative) of the money demand with respect to the interest rate. Therefore, Flood, Rose and Mathieson (1991) considered $\alpha=0.1$ and $\alpha=1$ as reasonable, although somewhat arbitrary, values.

Given a value for α , we can then plot the exchange rate as a function of the fundamental value, determined from relationship (11). This analysis is made by Flood, Rose and Mathieson (1991) for each of the currencies in the ERM against the deutschmark in the period 1979 to 1990. Although the study concentrates on the countries in the ERM, some comparisons for countries not participating in the ERM and countries outside the ERM were also carried out.

The results of the study are once again contradictory, and do not allow a simple general characterisation of the relationship between the exchange rate and fundamentals. Nevertheless, it is possible to enumerate a few characteristics resulting from the graphical analysis of this relationship. First, in the case of Member Countries, there is a very small number of non-linearities between the exchange rate and its fundamentals' determinants, while the parities for the currencies of countries outside the EMS, or not participating in ERM, lead to a greater number of linear relationships. Second, and somewhat surprisingly, it was found that the non-linearities are not readily apparent in the bands considered as more credible or in the more recent periods. For example, there is no clear confirmation of a non-linear relationship for the parity between the Dutch guilder and the deutschmark, although the Netherlands is generally regarded as a country that has maintained a credible band for the exchange rate. Third, although there may be some non-linearities, it is observed that the curves representing the relationship between the exchange rate and the fundamental tend not to exhibit an S-shaped behaviour as suggested by the theory. Finally, it is found that the small stabilising effects detected (weak evidence of "honeymoon effect") are strongly dependent on the value selected for the parameter α . A value of $\alpha=1$ indicates non-

²⁴ Goldfeld and Sichel (1990) provide an excellent survey on this subject.

linear effects of substantially greater importance. As the value of α is reduced, relations closer to the linear shape emerge²⁵.

Several other authors have tried to empirically test the non-linearity of the exchange rate function suggested by the Krugman model using different methodologies. In general, the non-linear relationship between the exchange rate and its fundamentals also proved to be very difficult to detect. Diebold and Nason (1990), Meese and Rose (1990, 1991), Chinn (1991) and Mizrach (1992), using non-parametric techniques, predominantly observe the presence of a random walk in the behaviour of the exchange rate. Ma and Kanas (2000) test the presence of a non-linear relationship in the exchange rate behaviour between the French franc and deutschmark using the non-linear Granger causality test modified by Hiemstra and Jones (1994). In an attempt to achieve conclusions more conducive to the Krugman model they use two measures for the fundamentals, the money supply and output. The results of the empirical work suggest that there is strong confirmation of the non-linear Granger causality between the relative money supply and the exchange rate, but this relationship disappears when output is taken as a fundamental determinant of the exchange rate. The basic target zone model has also been tested using the method of simulated moments, which includes choosing the parameters of the model so that its simulated moments (mean, variance, and covariance) meet the empirical moments. Once again, the empirical results strongly reject the implication predicted by the basic model²⁶.

²⁵ See Figures 6 to 19 in Flood, Rose and Mathieson (1991). Lindberg and Soderlind (1994) support many of the conclusions of Flood, Rose and Mathieson (1991) in their analysis of the Swedish krona.

²⁶ See Smith and Spencer (1992), Svensson (1992a), De Jong (1994) and Lindberg and Soderlind (1994). In the sequence of the application of the method of simulated moments to data on the French and German economies, Taylor and Iannizzotto (2001) conclude, contrary to earlier empirical work, that the non-linearity predicted by the basic model is present in reality, but applies only near the edges of the exchange rate band. Although the target zone model finds support in the data, the theoretical "honeymoon effect" may have such a small outcome that ultimately it has no practical effect. The literature on target zones may have overestimated the size of the "honeymoon effect", so the consistent failure to empirically detect a strong non-linear relationship between the exchange rate and its fundamentals' determinants may have led to an unjustified dismissal of the basic model. Based on a more general model with probability of realignment, Bekaert and Gray (1998) found evidence of non-linearity in the behaviour of the exchange rate between the French franc and the deutschmark.

3 – The Second Generation of Exchange Rate Target Zone Models: The Extensions

The poor empirical performance of the Krugman model motivated the development of a set of critical extensions, leading to a second generation of exchange rate target zone models. The extensions involve removing the three main assumptions of the basic target zone model by incorporating imperfect credibility, intra-marginal interventions and sticky prices. These three new features seem to solve the empirical difficulties raised by the basic model, allowing reconciliation of theory with the data. These include contributions from Bertola and Caballero (1992) and Bertola and Svensson (1993), which introduce into the model the risk of realignment, from Froot and Obstfeld (1991), which includes the possibility of interventions within the band in the analysis, and from Miller and Weller (1991) and Sutherland (1994) who developed a model with sticky prices.

3.1 – Imperfect Credibility

Bertola and Svensson (1993) extend the basic target zone model by including a time-varying realignment risk in the model. This means that we can have stochastic jumps in the central parity. Several works, including that of Krugman (1991), had considered the possibility of imperfect credibility in the form of realignments at the edges of the floating band, but not inside it. This is the case, for example, of Bertola and Caballero (1992), who develop a model where realignments can only occur when the exchange rate reaches the edges of the target zone. But in Bertola and Svensson's (1993) model the realignments are independent of the exchange rate's deviation from central parity²⁷.

The central parity jumps at realignments and remains constant between them. Economic agents are uncertain as to when realignments will occur and how large they will be, and they form expectations regarding the possibility of changes in the central parity based on the available information. Contrary to the basic model, this means that

²⁷ Empirically, perfect credibility has been rejected in periods when the exchange rates have been a long way from the edges of the band. This result supports the presumption that realignment risk is also relevant when exchange rates are away from the edges of the band. See Svensson (1992a).

we can express the expected rate of (total) currency depreciation as the sum of two components: the expected rate of change of the exchange rate relative to central parity or expected rate of currency depreciation within the band, and the expected rate of change of the central parity or expected rate of realignment. The second component should be interpreted as the product of two factors viz., the probability per unit of time of a realignment and the expected size of the realignment.

A more formal treatment of the Bertola and Svensson (1993) model is immediate. For this purpose it is useful to define the central parity as $c(t)$ and the exchange rate's deviation from central parity, also called the exchange rate within the band, as $x(t)$. Since the log of the exchange rate is the sum of the log of the exchange rate within the band and the log of the central parity, $s(t)=x(t)+c(t)$, then, defining the expected rate of currency depreciation within the band as $E_t[dx(t)]/dt$ and the expected rate of realignment by $E_t[dc(t)]/dt$, the expected rate of (total) currency depreciation can be written as follows:

$$E_t[ds(t)] / dt \equiv E_t[dx(t)] / dt + E_t[dc(t)] / dt^{28}. \quad (14)$$

Replacing the earlier relationship in equation (1), and subtracting $c(t)$ from both sides, we get a new exchange rate equation for the exchange rate within the band:

$$x(t) = h(t) + \alpha E_t[dx(t)] / dt, \quad (15)$$

where the new composite fundamental is $h(t)=f(t)-c(t)+\alpha E_t[dc(t)]/dt$.

The representation of Bertola and Svensson's (1993) model is similar to the basic target zone model suggested by Krugman (1991). This implies that there may be a relationship, an exchange rate function, between the exchange rate within the band and the new composite fundamental that is similar to the relationship between the exchange rate and the "old" aggregate fundamental²⁹.

Despite the similarity with the Krugman model, however, there are now two sources of exogenous exchange rate variation behind the new composite fundamental: the "velocity" shocks, described by the "old" aggregate fundamental, and the changes

²⁸ Recall that in the basic model, as a result of the assumption of perfect credibility, the expected rate of currency depreciation is exactly equal to the expected rate of currency depreciation within the band, $E_t[ds(t)]/dt \equiv E_t[dx(t)]/dt$.

²⁹ See Svensson (1992a).

in the central parity, represented by the expected rate of realignment, which in turn may depend on other variables. In these circumstances, it no longer makes sense to plot the exchange rate against only one of the stated variables, since it omits the expected rate of realignment.

This could explain why the initial plots of exchange rate against estimates of the aggregate fundamental, proposed by, for example, Diebold and Nason (1990), Meese and Rose (1990, 1991) and Flood, Rose and Mathieson (1991), do not result in a well-behaved exchange rate function as predicted by the theory. Rose and Svensson (1995) instead offer plots of exchange rate against estimates of the new composite fundamental that includes the expected rate of realignment³⁰. Those plots lead to an exchange rate function with a slope less than one, that is, they confirm the “honeymoon effect”, but do not seem to offer the correct flat slope near the edges of the target zone. The “smooth pasting” property is not confirmed³¹.

We can identify three main predictions arising from the model of Bertola and Svensson (1993). First, as with the basic target zone model developed by Krugman (1991), the model of Bertola and Svensson (1993) predicts that, within a target zone, the exchange rate displays reversion towards the central parity. Second, an exchange rate target zone with imperfect credibility may have destabilising features in some instances, such as where economic agents do not believe in the commitment of the monetary authorities to the defence of the band. Thus, in contrast to the “honeymoon effect”, we can talk about a “divorce effect”. Finally, Bertola and Svensson’s (1993) model predicts that the negative relationship between the expected deviation of the exchange rate from central parity and the interest rate differential is subject to stochastic changes in central parity. This clearly differs from the negative deterministic relationship predicted by the basic model.

The inclusion of a time-varying risk in the target zone model can help to understand the correlations observed between the exchange rate and the interest rate differential. On the assumption of uncovered interest rate parity, the interest rate differential equals the expected (total) rate of currency depreciation, which in turn, with imperfect credibility, is also equal to the sum of the expected rate of currency

³⁰ Galindo (1998) also finds evidence suggesting that Colombia’s exchange rate target zone is properly described by a model with imperfect credibility. Similar results are obtained for the Chilean, Israeli and Mexican exchange rate target zones by Fontes, Arbex and Almeida (2000).

³¹ Werner (1995) develops an alternative realignment model where the probability of realignment is an increasing function of the exchange rate’s deviation from central parity. The author concludes that the stabilisation properties associated with the target zone are inversely related to the band width.

depreciation within the band and the new component, the expected rate of realignment, $i(t)-i^*(t)=E_t[ds(t)]/dt=E_t[dx(t)]/dt+E_t[dc(t)]/dt$.

In this context, even though the expected rate of currency depreciation within the band is negatively correlated with the exchange rate within the band, depending on how the expected rate of realignment varies over time and is correlated with the exchange rate, any correlation pattern between the exchange rate and the interest rate differential is possible. For example, Lindberg and Soderlind (1994) estimate a model with imperfect credibility and intra-marginal interventions for Sweden. The authors argue that the positive correlation between the exchange rate and the interest rate differential can be explained by expected changes in central parity. The introduction of time-varying realignment expectations can thus help reconcile the theory with the data.

3.2 – The Intra-Marginal Interventions

As we have seen previously, most of the empirical work that tried to analyse the main implications of the basic model concluded that the statistical distribution of exchange rate within the band is hump-shaped, with most of the observations placed near the central parity, in contrast to the U-shape predicted by the theory.

The explanation for these results (see, for example, Edison and Kaminsky (1990), Dominguez and Kenen (1991) and Svensson (1992a)) seems to have been that the exchange rate is kept in the middle of the band by intra-marginal interventions, that is, central bank interventions that occur within the floating band³².

Taking into account the real world of target zones, it appears that central banks' intervention behaviour tends to shift over time³³. In this context, an approximation to this behaviour is to propose that in addition to infinitesimal marginal interventions at the edges of the band there can also be intra-marginal "leaning-against-the-wind"

³² Among the studies that take intra-marginal interventions into account, the works of Lewis (1990) and Klein and Lewis (1991) are particularly important. The authors allow the central bank a probability of intervention anywhere in the floating band for the fundamental, assuming that the probability of intervention is greater if the fundamental is away from its central value. In these circumstances, intra-marginal interventions increase the stabilising features of a target zone. However, this result is obtained on the assumption of perfect credibility. The mean reversion of the fundamental, and therefore of the exchange rate within the floating band, is also discussed in Froot and Obstfeld (1991) and Delgado and Dumas (1992). Its empirical importance was established by Lindberg and Soderlind (1992). The authors show that intra-marginal interventions play an important role in the process of stabilising the exchange rate within the band.

³³ Remember the functioning of the gold standard, Bretton Woods system and ERM of the EMS.

interventions³⁴, that is, interventions that aim at returning the exchange rate to a specified target level within the floating band. Thus, the central banks try to carry out a counter-cyclical monetary policy against the fundamental.

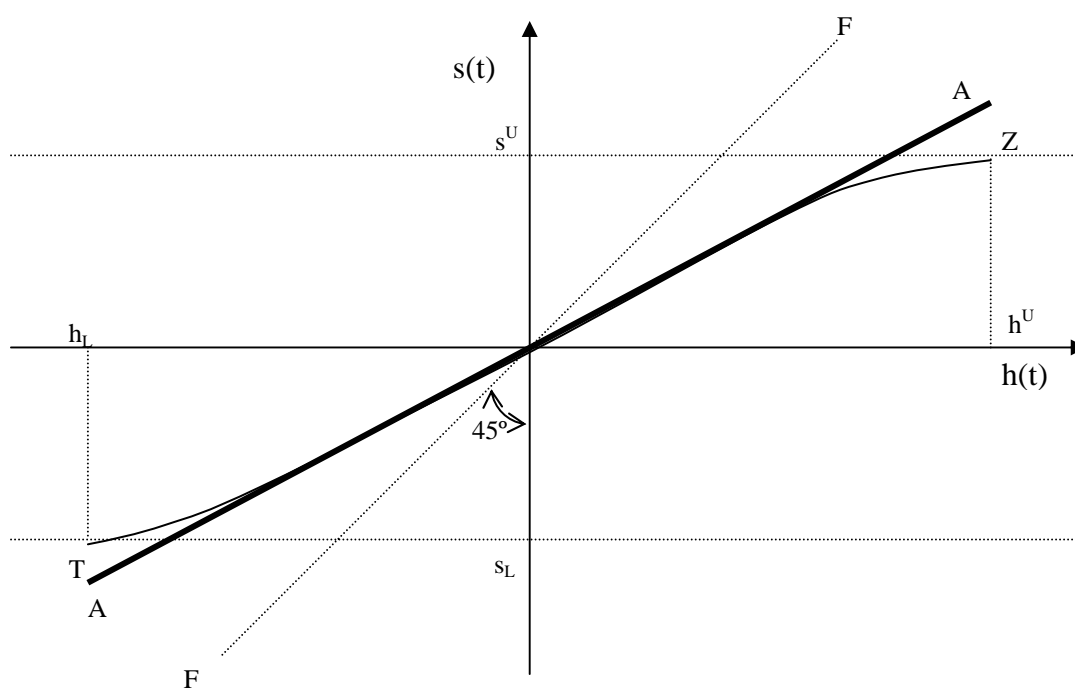
A simple way to model such interventions, in terms of an exchange rate target zone model with imperfect credibility, is to specify that their effect on the expected rate of change, the drift, of the composite fundamental towards central parity is proportional to the deviation from central parity. So it is assumed that the drift of the composite fundamental fulfils the following relationship:

$$E_t [dh(t)] / dt = -\phi h(t), \tag{16}$$

where ϕ , the rate of mean reversion, is a positive constant³⁵.

The result of this adjustment is illustrated in Figure 4.

Figure 4: The Behaviour of the Exchange Rate in a Target Zone with Intra-Marginal Interventions



³⁴ See Svensson (1992a: 134).

³⁵ See Froot and Obstfeld (1991), Delgado and Dumas (1992) and Svensson (1992a).

Again, the 45-degree line marked FF characterises the behaviour of the exchange rate in a free floating regime, when no interventions are undertaken by the monetary authorities.

Let us first consider a managed floating regime, when the intra-marginal interventions are mean reverting towards the central parity, but where there is no specific floating band, or marginal interventions. The result can be represented by the straight line AA, that fulfil equation $x(t)=h(t)/(1+\alpha\phi)$, which is less sloped than the straight-line FF representing the free floating regime. This means that there is also a “honeymoon effect” under a managed floating regime, even without the presence of an exchange rate band. This effect stems from the fact that the intra-marginal interventions imply that when the exchange rate is above the central parity, a situation in which the currency is weak, the currency is expected to appreciate, which by itself lowers the exchange rate towards central parity. The opposite is true when the exchange rate is below the central parity.

Suppose now that the intra-marginal interventions are carried out under an explicit target zone regime. This implies specifying a floating band and marginal interventions in case the exchange rate reaches the edges of the band. This situation is plotted as curve TZ in Figure 4. As we can see, the exchange rate function in a target zone with intra-marginal interventions is close to the AA line, corresponding to the managed floating regime, except that it is slightly S-shaped and there is “smooth pasting” at the edges of the floating band. We can thus observe an additional “honeymoon effect” relative to the managed floating regime. But the S-shaped is much less pronounced than the exchange rate function arising from the Krugman model. In this context, target zones are better described as being similar to managed floating regimes with intra-marginal interventions³⁶.

Based on a target zone model with intra-marginal interventions, Lindberg and Soderlind (1992) confirm that the distribution of the exchange rate is hump-shaped³⁷. Furthermore, the authors show that with sufficiently strong mean reverting interventions added, the relationship between the exchange rate and the fundamental is almost linear, and very close to the exchange rate function for a managed floating regime.

³⁶ For a detailed analysis of the reasons that could explain these results see Svensson (1992a).

³⁷ Dominquez and Kenen (1992), Beetsma and Van Der Ploeg (1994) and Torres (2000b) reach similar results.

The incorporation of intra-marginal interventions can thus explain the fact that the exchange rate observations tend to be located more frequently around the central parity, allowing us to understand the empirical difficulties encountered by Flood, Rose and Mathieson (1991) in detecting the presence of non-linearities in the case of the ERM. The first generation of exchange rate target zone models appears to have overestimated the importance of marginal interventions. Thus, the resulting difficulty of confirming the implications arising from the Krugman model empirically may have led to an unjustified rejection of the model.

3.3 – The Sticky Prices

The third path for reconciling the basic model with the data incorporates the possibility of price inertia. Miller and Weller (1991) diverge from the flexible price monetary approach, relying instead on a model where prices respond slowly to current demand shocks³⁸.

The advantages of the sticky price target zone model over the basic model are that it describes the behaviour of both real exchange rates and output as well as nominal exchange rates. Additionally, the sticky price approach allows one to distinguish between the effects of imposing real and nominal exchange rate bands.

In the sticky price model the exchange rate equation is given by:

$$s(t) - p(t) + p^*(t) = e(t) = \alpha_1 M(t) + \alpha_2 E[de(t)]/dt \quad (17)$$

where $M = m - p$ and $dM(t) = (\omega_1 M(t) + \omega_2 e(t))dt + \sigma dz$.

As we can see, equations (1) and (17) are basically identical. The difference comes from the process driving the money supply. In the basic model, the money supply, $m(t)$, is used as a regulator by the monetary authorities whereas in the sticky price target zone model, the money supply, $M(t)$, is a function of an endogenously determined drift term that is dependent upon both its own current value and the real exchange rate. Therefore, within the sticky price approach the monetary authorities can impose a real exchange rate target zone by announcing suitably chosen upper and lower limits for $M(t)$ at which discrete adjustments may $m(t)$ occur.

³⁸ A stochastic version of Dornbusch's (1976) overshooting model is used.

This is particularly interestingly since, under these circumstances, Miller and Weller (1991) achieve the same type of stabilising effect as Krugman (1991). However, the implications for policy actions are somewhat different. In the basic model, to generate mean reversion in exchange rate it is necessary to assume that the monetary authorities undertake intra-marginal interventions that push the exchange rate towards central parity³⁹. On the other hand, in the sticky price target zone model, mean reversion in exchange rate is generated by the price adjustment process, so there is no need to make assumptions about policy actions.

Unfortunately, in terms of empirical literature, there is very little work testing the implications of the sticky price target zone model. There is, however, some evidence which suggests that the sticky price model performed better with the data than the basic model. Sutherland (1994) finds that, to a limited extent, the sticky price target zone model can lead to a statistical exchange rate distribution with a central hump, whereas the simplest flexible price model is unable to generate such a distribution⁴⁰. This result is not very surprising, since Sutherland (1994) shows that, in terms of nominal variables, the sticky price and flexible price models are observationally equivalent when the latter are extended to include intra-marginal intervention and realignments⁴¹.

4 – Conclusion

The literature on exchange rate target zones has undergone a remarkable development since Krugman (1991) presented a stochastic version of the monetary model of exchange rate determination, using the structure of regulated Brownian motion. The model assumes that the bands are perfectly credible, that monetary authorities undertake only marginal interventions and that prices are flexible.

³⁹ Recall that with strong enough mean reverting interventions added, the exchange rate function is almost linear, and very close to the exchange rate function for a managed floating regime. As a consequence, the unconditional statistical distribution of the exchange rate will be hump-shaped, possibly with some small extra probability mass at the edges of the band. In this context, given the structure of the Krugman model, it is essential to suppose that the interventions are unsterilized, otherwise, there would be no impact on the money supply or the exchange rate. See Svensson (1992a).

⁴⁰ Similar results were reported by Kempa and Nelles (1999) and Baghli (2004).

⁴¹ For example, as with the case of imperfect credibility, the model also generates a noisy relationship between interest rate differential and the exchange rate.

According to the Krugman model, the exchange rate behaviour in a target zone ensures two main results. The first main result is called the “honeymoon effect”, implying that a perfectly credible target zone is inherently stabilising. The second result is called “smooth pasting”, implying that the exchange rate in a target zone is a non-linear function of its fundamentals’ determinants and completely insensitive to changes in these fundamentals at the edges of the band.

The basic target zone model has very interesting empirical implications for both the exchange rate and the interest rate differential. The model predicts that the statistical distribution of the exchange rate within the band must be U-shaped. A negative deterministic relationship between the exchange rate and the interest rate differential is also expected. The model also predicts an S-shaped non-linear relationship between the exchange rate and its fundamentals determinants.

Although the basic target zone model yields interesting insights with respect to the dynamics of exchange rates and the interest rate differential, resulting in mean reversion of the exchange rate within the band, the main predictions of the model have been strongly rejected by an empirical analysis of the data.

The empirical difficulties raised by the Krugman model motivated the development of a set of critical extensions that involved removing its three crucial assumptions, thus reconciling the theory with the data.

Introducing time-varying realignment expectations into the model may help to understand the correlations observed between the exchange rate and the interest rate differential. On the other hand, the inclusion of sticky price and intra-marginal interventions may explain the fact 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. Such interventions also imply the presence of a strong “honeymoon effect”. However, “smooth pasting” and non-linearities seem insignificant. Target zones are better described as very similar to a managed floating regime, with a central parity target, but without an explicit floating band. The official exchange rate bands should thus be seen as a practical way of expressing a verifiable general commitment to stabilise exchange rates near the central parity and not just a commitment to marginal interventions.

The literature on exchange rate target zones has been particularly focusing on the functioning of this type of exchange rate regime in the floating bands of the ERM considered to be most stable and credible, or on Scandinavia, especially Sweden, and

has almost always ignored the countries on the periphery of the system. Furthermore, most studies have focused primarily on normative issues relating to the optimal choice of exchange rate regime, leaving aside aspects of positive order, associated with the description of the stabilising effect on exchange rates resulting from the presence of a target zone. In this work we have tried to remedy these important deficiencies of the literature on target zones.

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Appendix

A Synthetic View of Some of the Most Recent Studies on Exchange Rate Target Zones

Authors	Country	Period	Methodology	Variables	Conclusions
Fidrmuc and Horváth (2008)	Czech Republic, Hungary, Poland, Romania and Slovakia	1999 – 2006	GARCH model TARCH model	Exchange Rates	The low credibility of exchange rate management implied higher volatility of exchange rates when it substantially deviated from the implicit target rates and significant asymmetric effects of the volatility of exchange rates in all analyzed countries.
Duarte, Andrade and Duarte (2008)	Portugal and Germany	January 1987 – December 1998	M-GARCH model	Nominal Exchange Rates Interest Rates Foreign Exchange Reserves	Hump-shaped distribution of the exchange rate and trade-off between exchange rate volatility and interest rate differential volatility.
Klaster and Knot (2002)	Belgium and Netherlands	13 March 1979 – 30 July 1993	GARCH model	Exchange Rates Interest Rates Inflation Foreign Exchange Reserves	An S-effect can only be observed for the Belgian franc, while mean reversion can be assert for both the Belgian franc and the Dutch guilder. Volatility for both currencies depends on previous observations and there is a clustering of extreme values.

Lai, Fang and Chang (2008)	Several economies in Latin America and Eastern Europe	1966 – 1992: Eastern Europe 1970 – 1994: Latin American Countries	Fleming-type stochastic macro model	Nominal Exchange Rates Interest Rates	When capital mobility is relatively low, exchange rate variability exhibits a positive relationship with the interest rate differential.
Bordo and MacDonald (2005)	France, Germany and United Kingdom	January 1880 – December 1913	Univariate Root Tests Johansen Method VECM models Impulse response functions	Spot Exchange Rates Interest Rates Money Supply Industrial Production Consumer Price Index Unemployment	The classical gold standard represented a credible, well-behaved, target zone system and did confer some independence in the operation of monetary policy for participating countries.
Driffill and Sola (2006)	France and Germany	1979 – 1992	Stochastic regime-switching Monetary model of exchange rate determination Drift-adjustment approach Sensitivity analysis	Exchange Rates Interest Rates	Expected changes in the process that drives fundamentals may have dramatic effects on the sustainability of the exchange rate. Depending on the original state of the economy, these changes may result in either a significant gain in the stabilizing effects of the exchange rate band, or an attack-type crisis where the government is forced to conduct a discrete intervention to sustain the band. Movements in the exchange rate which have the appearance of speculative attacks on a currency may be associated with market perceptions of a policy regime switch having taken place.

Tronzano, Psaradakis and Sola (2003)	France	June 1991 – September 1998	Markov switching model Hodrick Prescott filter Granger Causality tests	Interest Rates Industrial Production Trade Balance Real Exchange Rate Unemployment Rate Foreign Reserves Growth Rate of M1 and M2 Inflation Rate	Expected devaluation is significantly influenced by foreign reserves and the deviations of the exchange rate from the EMS.
Lundbergh and Terasvirta (2005)	Swedish and Norway	1 July 1985 – 17 May 1991 (Swedish) 1 October 1986 – 22 October 1990 (Norway)	STARTZ model	Exchange Rates	For the Swedish krona the behaviour of the currency index within the target zone is in line with what theory suggests for a currency when the central bank intervenes intramarginally. In the case of the Norwegian krone 1986-88, where the Central Bank intervened only at the edges of the band, the behaviour of the estimated model is in harmony with the results implied by the basic target zone model. For the remaining period of the Norwegian krone, consisting of observations in 1989-1990, the estimated model suggests that the implicit band maintained by the Central Bank during this period was not strictly enforced.

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