E C O N O M I C S B U L L E T I N

Exchange rate dynamics in crawling-band systems

M. Isabel Campos
Universidad de Valladolid

José L. Torres
Universidad de Málaga

Abstract

In this note we show that an exchange rate crawling-band system can borrow a portion of those aspects of a target zone that lead to its stabilizing effects on the exchange rate, depending on the relationship between the crawl rate and the drift of the fundamentals process. If the crawl rate is sufficiently high (with respect to the drift), the crawling-band is similar to a free float regime. As the crawl rate decreases, the crawling-band system collapses to a standard target zone.

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1 Introduction

Both target zones and crawling bands are exchange rate regimes which have been recently implemented by a large number of countries, as a compromise between fixed and floating exchange rates. The Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) is probably the most well-known example of a target zone. Currently, the New State Members of the European Union have to join the so-called ERM-II as a previous stage before joining the Euro. On the other hand, crawling-band regimes have been adopted by some developing countries which experience high inflation, such as Chile, Colombia, Israel, Indonesia, Ecuador, Russia and Venezuela, with a bandwidth that ranges from the ±5.5 percent of Ecuador to the ±15 percent of Chile and Russia. In these countries, the crawling-band was used as an inflation stabilization strategy while providing the exchange rate with some flexibility.

Following Williamson (1996), an exchange rate crawling-band can be defined as a system in which the exchange rate is forced to move inside a band with the band being adjusted in small steps with a view to keeping it in line with the fundamentals. Essentially, the only difference between a target zone and a crawling-band is the fact that, whereas in the former the fluctuation band for the exchange rate is constant over time, in the case of a crawling-band, the fluctuation band increases over time at a pre-announced constant rate, i.e. the crawl rate.

In this note we extend the Krugman (1991) target zone model to explain exchange rate dynamics in a crawling-band regime. We show that an exchange rate crawling-band system can borrow a portion of those aspects of a target zone that lead to its stabilizing effects on the exchange rate, depending on the relationship between the crawl rate and the drift of the fundamentals process. If the crawl rate is sufficiently high, the system is similar to a free float regime. As the crawl rate decreases, the system collapse to a standard target zone. Therefore, a crawling-band system is an intermediate regime between free-floating and a target zone.

2 Crawling bands versus target zones

In the past few decades, target zones have been adopted by a number of European countries as a mechanism to stabilize exchange rate fluctuations. The main characteristic of target zone models is the fact that agents firmly believe the declared policy of keeping the exchange rate within a fluctuation band. As a main consequence the target zone stabilizes exchange rate behavior as a function of its fundamentals. This is the so-called honeymoon effect. However, the maintenance of a constant fluctuation band can be a very restrictive mechanism for countries which experience high inflation and where fundamentals continuously deviate from their equilibrium value. For this reason, several developing countries have adopted a crawling-band system, in which the exchange rate is restricted to moving inside a fluctuation band (as in a target zone), and where central parity is not constant but increases continuously through time. The question of interest then is whether crawling-band systems present stabilizing properties as occurs in target zones.

In order to study the behavior of the exchange rate in a crawling-band system, we depart from the standard target zone model developed by Krugman (1991). Using the standard monetary model of exchange rate determination, the log of the exchange rate, s_t, is,

$$s_t = f_t + \alpha \frac{E_t(ds_t)}{dt} \tag{1}$$

where the exchange rate is equal to the fundamentals, f_t, plus the expected change in the exchange rate, $E_t(ds_t)/dt$, and where α is the interest rate semi-elasticity. It is assumed that the fundamentals follow Brownian motion, with drift μ_f and a standard deviation of σ

$$df_t = \mu_f dt + \sigma dZ_t \tag{2}$$

where Z_t is a Weiner process.

We solve the model for three exchange rate regimes: free float, target zone and crawling-band. In order to compare both the target zone solution and the crawling-band solution, and following Bertola and Svensson (1993), we solve the model in terms of deviations with respect to central parity. We define:

$$s_t = x_t + c_t \tag{3}$$

$$f_t = h_t + c_t \tag{4}$$

where $x_t = s_t - c_t$ denotes the exchange rate within the band, i.e., the exchange rate's log-deviation from central parity, and $h_t = f_t - c_t$ denotes the fundamental deviation from central parity. Note that in a target zone c_t is constant whereas in a crawling-band it is an increasing trend, i.e., the so-called crawl rate, $\delta > 0$. The expected change in the exchange rate, $E_t(ds_t)/dt$, can be defined as:

$$\frac{E_t(ds_t)}{dt} = \frac{E_t(dx_t)}{dt} + \frac{E_t(dc_t)}{dt} \tag{5}$$

where $E_t(dx_t)/dt$ is the expected exchange rate deviation from central parity and $E_t(dc_t)/dt$ is the expected change in central parity. The key point in our model is that whereas in a target zone the expected change in central parity is zero, i.e., $E_t(dc_t)/dt = 0$, under the assumption of perfect credibility of the fluctuation band, in a crawling-peg the expected change in central parity is a positive value, equal to the crawl rate, i.e., $E_t(dc_t)/dt = \delta > 0$.

Assuming that the exchange rate function has second derivatives, and applying Ito's lemma, the expected change in the exchange rate deviations from central parity can be defined as:

$$\frac{E_t(dx_t)}{dt} = x'(h)\frac{E_t(dh_t)}{dt} + \frac{1}{2}x''\frac{E_t(h_t)^2}{dt} = \mu_f x'(h) + \frac{\sigma^2}{2}x''(h) \tag{6}$$

2.1 Free float

In a free float regime, under the no-bubble assumption, the exchange rate is:

$$x_t^{FF} = \alpha\mu_f + h_t \tag{7}$$

that is, the standard 45 degree line between the exchange rate and the fundamentals, given that $x'(h) = 1$ and $x''(h) = 0$.

2.2 Target zone

Second, we consider a target zone in which the exchange rate is restricted to moving in the space $(\underline{x}, \overline{x})$, defining the lower and the upper limits of fluctuation, respectively. Given these limits, there is a unique solution to the target zone problem, characterized by the smooth pasting conditions. The general solution for the exchange rate in this scenario is the standard solution (see Krugman, 1991):

$$x_t^{TZ} = \alpha\mu_f + h_t + A_1^{TZ}\exp(\lambda_1^{TZ}h_t) + A_2^{TZ}\exp(\lambda_2^{TZ}h_t) \tag{8}$$

where $\lambda_1^{TZ} > 0$ and $\lambda_2^{TZ} < 0$ are the roots of the characteristic equation,

$$\lambda_{1,2}^{TZ} = -\frac{\mu_f}{\sigma^2} \pm \sqrt{\frac{\mu_f^2}{\sigma^4} + \frac{2}{\alpha\sigma^2}} \tag{9}$$

and where A_1^{TZ} and A_2^{TZ} are constants of integration which must be solved, using the boundary conditions which require the first derivative of x to be zero at the boundaries, implied by the exchange rate policy, $A_1^{TZ}, A_2^{TZ} = A^{TZ}(\underline{x}, \overline{x})$.[1] We obtain the following solution for the exchange rate in a target zone:

$$x_t^{TZ} = \alpha\mu_f + h_t + \frac{\lambda_1^{TZ}(e^{(\lambda_1^{TZ}\underline{h}+\lambda_2^{TZ}h_t)} - e^{(\lambda_1^{TZ}\overline{h}+\lambda_2^{TZ}h_t)}) + \lambda_2^{TZ}(e^{(\lambda_1^{TZ}h_t+\lambda_2^{TZ}\overline{h})} - e^{(\lambda_1^{TZ}h_t+\lambda_2^{TZ}\underline{h})})}{\lambda_1^{TZ}\lambda_2^{TZ}(e^{(\lambda_1^{TZ}\underline{h}+\lambda_2^{TZ}\overline{h})} - e^{(\lambda_1^{TZ}\overline{h}+\lambda_2^{TZ}\underline{h})})} \tag{10}$$

where $\underline{h}$ and $\overline{h}$ are, respectively, the lower and upper bounds of the fundamentals deviation. This solution gives the standard S-shape relationship between the exchange rate and the fundamentals deviations.

2.3 Crawling-band

Finally, let us take into account the case of a crawling-band system. As in a target zone, there are upper and lower bounds for the exchange rate in a crawling-band system. However, the fluctuation band is not constant but increases each period. In this case, the announced target is to maintain the exchange rate inside a band during each period:

$$\underline{s}_t < s_t < \overline{s}_t \tag{11}$$

where

$$\underline{s}_t = \underline{s}_0 + \delta t \tag{12}$$

$$\overline{s}_t = \overline{s}_0 + \delta t \tag{13}$$

and where $\underline{s}_0$, $\overline{s}_0$ are the initial lower and upper limits, respectively, and $\delta > 0$ is the crawl rate. This is a pre-announced, constant crawl rate of central parity, i.e., $c_t = c_0 + \delta t$. This means that central parity continuously depreciates at a constant

[1] The boundary conditions given by the upper and lower bounds on the exchange rate are:

$$1 + A_1\lambda_1 e^{\lambda_1\overline{h}} + A_2\lambda_2 e^{\lambda_2\overline{h}} = 0$$
$$1 + A_1\lambda_1 e^{\lambda_1\underline{h}} + A_2\lambda_2 e^{\lambda_2\underline{h}} = 0$$

rate, in small steps. Note that this system implies that the band width is constant over time but the lower and upper limits both increase in time. As above, we solve the exchange rate solution in terms of deviations with respect to the central parity. In this case, h_t is a Brownian motion process with differential:

$$dh_t = \mu_h dt + \sigma dZ_t \tag{14}$$

where

$$\mu_h = \mu_f - \delta \tag{15}$$

In a crawling-band the drift of the fundamentals deviation from central parity has two components: the drift of the fundamentals process and the crawl rate. We can observe that as the crawl rate increases, this reduces the drift of the fundamentals deviation. In fact, if $\delta = \mu_f$, this is equivalent to a Brownian motion process without drift. Therefore, in the case of a fundamentals process with a positive drift, the existence of a positive crawl rate reduces the long-run deviations of the fundamentals with respect to central parity.

Assuming perfect credibility, the general solution for the exchange rate in a crawling-band is similar to the standard target zone with constant band of fluctuation. Substitution of expression (5) in (1) and consideration of (3) and (4), yields:

$$x_t^{CR} = \alpha\delta + h_t + \alpha\frac{E_t(dx_t)}{dt} \tag{16}$$

The general solution for the exchange rate deviations in a crawling-band is:

$$x_t^{CR} = \alpha\mu_h + \alpha\delta + h_t + A_1^{CR}\exp(\lambda_1^{CR}h_t) + A_2^{CR}\exp(\lambda_2^{CR}h_t) \tag{17}$$

where $\lambda_1^{CR} > 0$ and $\lambda_2^{CR} < 0$ are the roots of the characteristic equation,

$$\lambda_{1,2}^{CR} = -\frac{\mu_f - \delta}{\sigma^2} \pm \sqrt{\frac{(\mu_f - \delta)^2}{\sigma^4} + \frac{2}{\alpha\sigma^2}} \tag{18}$$

Assuming perfect credibility, the general solution for the exchange rate in a crawling-band is similar to the standard target zone with a constant fluctuation band but smooth pasting conditions, reflecting expectations, are different. In fact, the constants A_1^{CR}, A_2^{CR}, reflecting the so-called honeymoon effect, are different from the ones corresponding to the target zone case.

The solution for the exchange rate in a crawling-band, similar to expression (10) for a target zone, is,

$$x_t^{CR} = \alpha\mu_h + \alpha\delta + h_t + \frac{\lambda_1^{CR}\left(e^{(\lambda_1^{CR}\underline{h} + \lambda_2^{CR} h_t)} - e^{(\lambda_1^{CR}\overline{h} + \lambda_2^{CR} h_t)}\right) + \lambda_2^{CR}\left(e^{(\lambda_1^{CR} h_t + \lambda_2^{CR}\overline{h})} - e^{(\lambda_1^{CR} h_t + \lambda_2^{CR}\underline{h})}\right)}{\lambda_1^{CR}\lambda_2^{CR}\left(e^{(\lambda_1^{CR}\underline{h} + \lambda_2^{CR}\overline{h})} - e^{(\lambda_1^{CR}\overline{h} + \lambda_2^{CR}\underline{h})}\right)} \tag{19}$$

In the crawling-band expectations behave as follows: as fundamentals deviate from their equilibrium value, the probability of interventions increases. Therefore, as in a target zone, we obtain expectations of appreciation in the upper side of the band. However, the probability of intervention is lower in the case of a crawling-band, compared to a target zone, due to the fact that the upper limit increases with time. Hence, it is reasonable to think that stabilizing effects in a crawling-band will be lower than in a target zone.

3 Stabilizing effect of a crawling-band

The question we want to solve is whether the stabilizing effects on the exchange rate derived from a target zone are also present in the case of a crawling-band. In order to solve this question we conduct a numerical simulation of the exchange rate behavior in both regimes.

In simulating the model, we use the standard values for the parameters. We consider a bandwidth of ± 7.5 percent for both the target zone and the crawling-band systems (as in the Venezuela exchange rate crawling-band). If time is measured in years, $\alpha = 1$ year and $\sigma = 5$ percent per square root of year.

We consider the existence of positive drift in the fundamentals process, as this is the main reason to establish a crawling-band system. In general, the drift reflects inflation differential. In fact, as pointed out by Williamson (1996), the main cause of changes in parity (the crawl) is typically the inflation differential, ensuring that high domestic inflation does not lead to progressive erosion in international competitiveness. Exchange rate crawling bands are used as an inflation stabilization strategy, providing some monetary flexibility while creating an anchor for the price level. In our simulation we consider a drift value of 5 percent per year ($\mu = 0.05$), which is equivalent to a 5 percent inflation differential. In the target zone the central parity is set to zero. In the crawling-band system, central parity increases according to $c_t = \delta + c_{t-1}$. The crawl rate is $\delta = \mu/2$. Note that the target zone case corresponds to $\delta = 0$.

Figure 1 shows the relationship between the fundamentals and the exchange rate deviations for the three exchange rate regimes: free float, target zone and crawling-band. The free float solution corresponds to the 45 degree line. The curve on the right corresponds to the target zone solution and the curve on the left corresponds to the crawling-band solution. The existence of a positive drift in the fundamentals process shifts the relationship to the left, reducing the upper bound of the fundamentals and increasing (in absolute value) their lower limit.

In general, as we increase the crawl rate, the relationship between the fundamentals and the exchange rate becomes steeper, and the non-linear effect is reduced. The intuition for the result is straightforward. In the case of a crawling-band system, as fundamentals deviate from the equilibrium value, the exchange rate market knows that the future upper limit for the exchange rate will be larger than the actual one, whereas in a target zone the upper limit is constant. Therefore, the probability of intervention is lower in a crawling-band compared to a target zone. This means that in the upper side of the band, expectations of appreciation will be lower in a crawling-band and also the stabilizing effect (honeymoon effect). Assuming the existence of a determined positive drift in the fundamentals process, as we increase the crawl rate, the stabilizing effects of the band will be lower.

4 Conclusions

The main conclusion of this analysis is that a crawling-band system can borrow a certain honeymoon effect and therefore, it stabilizes the exchange rate as a function of the fundamentals. Countries which face a large positive drift in the fundamentals have to adopt a crawling-band instead of a target zone to avoid repeated realignments (devaluations). It is assumed that the adoption of this regime is done in order to gain some stability in exchange rate targeting. However, the stabilizing effect of such an exchange rate regime depends on the relationship between the crawl rate and the drift of the fundamentals process. In order to gain exchange rate stability, the crawl rate must be significantly less than the drift of the fundamentals.

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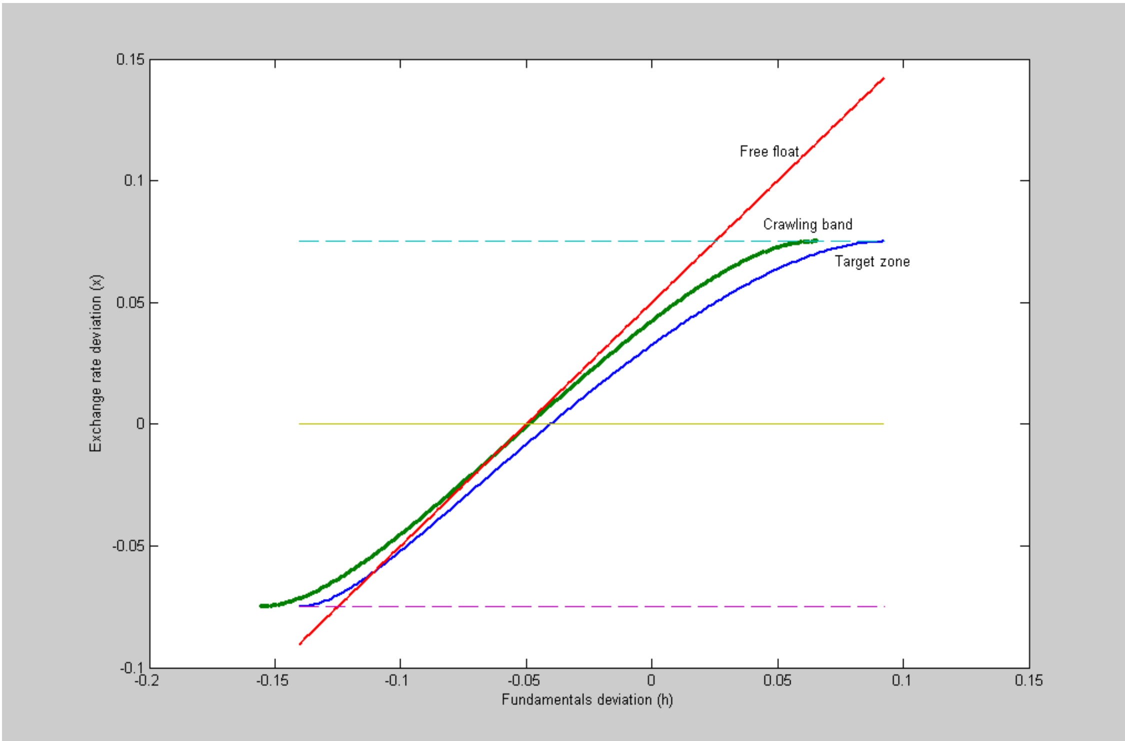

Figure 1: Exchange rate as a function of the fundamentals