"ESPECULATIVE ATTACK ON EXCHANGE RATE TARGET ZONE REGIME: THE UNCERTAINTY CASE"

Nilson Teixeira

Universidade da Pensilvânia

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Speculative Attacks On Exchange Rate Target Zone Regimes: The Uncertainty Case

Eduardo Levy-Yeyati and Nilson Teixeira
Department of Economics
University of Pennsylvania
Philadelphia, PA 19104-6627
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Abstract

We present a continuous time target zone model of speculative attacks. Contrary to most of the literature that considers the certainty case, i.e., agents know for sure the Central Bank behavior in the future, we build uncertainty into the model in two different ways. First, we consider the case in which the level of reserves at which the central bank lets the regime collapse is uncertain. Alternatively, we analyze the case in which, with some probability, the government may change its policy reducing the initially positive trend in domestic credit. In both cases, contrary to the case of a fixed exchange rate regime, speculators face a cost of launching a tentative attack that may not succeed. Such cost induces a delay and may even prevent its occurrence. At the time of the tentative attack, the exchange rate moves either discretely up, if the attack succeeds, or down, if it fails. The results are consistent with the fact that, typically, an attack involves substantial profits and losses for the speculators. In particular, if agents believed that the government will control fiscal imbalances in the future, or alternatively, if they believe the trend in domestic credit to be temporary, the attack is postponed even in the presence of a signal of an imminent collapse. Finally, we also show that the timing of a speculative attack increases with the width of the target zone.

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1. Introduction

In recent years we have observed remarkable crises on the exchange rate regimes across a very large and diverse group of countries. The common characteristic of such crises was that they were accompanied by intense speculative attacks. Some of these attacks, such as on the English and Swedish currencies, were successful. Others, e.g. on the Argentinian and Brazilian currencies, turned to be unsuccessful. An exchange rate crisis is characterized by a sharp speculative attack on central bank holdings of foreign exchange reserves. Agents attack the currency to hedge against either a discrete devaluation of a controlled exchange rate or a switch to a floating rate. A speculative attack, i.e., a run on the currency, is the agents' attempt either of avoiding capital losses or of obtaining capital profits by purchasing the remainder available reserves. The dynamics of the exchange rate regime collapse are rooted in domestic money market conditions: when there is excess domestic credit creation, money market equilibrium can be achieved through offsetting reductions in central bank foreign exchange reserves or by exchange rate adjustment. Although with political and economic costs, under a fixed exchange rate regime, as long as foreign exchange reserves remain in positive supply, monetary authorities can succeed at sustaining the exchange rate through the purchase of domestic currency and sale of foreign exchange reserves.

In this paper we concentrate ourselves on the study of the consequences of the uncertainty that agents face with respect to the government policy. We consider a small open economy with an exchange rate target zone regime. We do not intend to survey the whole literature in this subject. There are already a few papers that provided such survey\(^1\). Here we simply discuss some papers that are related to our study on attacks occurring when there is uncertainty of the minimum level of reserves or when an alternative post attack regime is possible. The first one is Flood and Garber(1984). They develop a discrete time stochastic fixed exchange rate regime model of collapse, which endogenously predicts the timing and probability of speculative attacks and forecasts lower bounds for the post-collapse exchange rates. In each period, the probability of regime change in the next period is found by evaluating the probability that domestic credit in the next period is sufficiently large to result in a discrete depreciation should

\(^1\)Complete surveys on speculative attacks on exchange rate regimes are available in Agenor and Flood(1994), Bertola(1994), Svensson(1994a) and Svensson(1994b).
a speculative attack take place. In a stochastic model with a random collapse time, agents' behavior will produce a forward discount on a weak currency even when the exchange rate remains fixed. In their framework, a fixed rate regime will collapse whenever agents find it profitable to attack the currency. In other words, after a period during which the central bank's foreign exchange reserves are gradually depleted, the decrease in confidence over the maintenance of the regime precipitates a speculative attack.

In a seminal paper Krugman(1991) develops a new approach for the treatment of target zone regimes. He was the first to explicitly analyse the effects of exchange rate bands on exchange rate behavior. He argues that if the regime is a target zone with marginal interventions, reserves are constant within the band and decrease (increase) each time the exchange rate hits the upper (lower) border of the zone. In the long run, the regime reaches a point at which the central bank can not hold a speculative attack and the regime collapses. Krugman and Rotemberg (1991) extend the argument to the analysis of a regime collapse. In these, as in most of the literature in continuous time, the condition on the fundamentals in order to get a speculative attack is obtained by imposing a continuity condition on the path of the exchange rate, which equivalent to ruling out arbitrage opportunities.

Typically, the government rule for the exchange rates collapse takes the form of a minimum level of reserves below which the government stops purchasing domestic currency and lets the regime change to a float. We consider that it is common knowledge that when the central bank runs out of its minimum level of reserves the new regime is a free float one. In this paper we avoid the issue of the central bank's objective function. Instead, we provide a known and credible policy rule. Most of the literature on exchange rate regimes do not consider any sort of uncertainty either on the domestic credit path or on the government's commitment to the target zone's bands. An exception is the discrete time fixed exchange rate model of Willman(1989), where he shows that depending on whether this threshold level of foreign reserves is stochastic or fixed but unknown to agents, currency speculation reveals itself as, respectively, a speculative outflow distributed over several periods of time or a sudden speculative attack on the currency. Still, there is a final speculative attack that succeeds. His model can readily be extended to continuous time without change in the results. Nevertheless, it is intuitively

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2The main difference between the discrete and the continuous time approach is that the first allows for jumps in the exchange rate. In particular, at every period there is a positive probability of depreciation that produces a forward discount on the domestic currency, i.e. the so called "peso problem".
clear that, in both cases, since there is no cost in attacking tentatively, i.e., the government is willing to repurchase the reserves previously sold at the same rate, his model predicts that agents attack the currency regime whenever there is a positive probability of success.

Contrary to Willman (1989), we focus, as already mentioned, on exchange rate target zone regimes. We intend to show how the implicit cost of attacking the domestic currency modifies the standard results to make them consistent with the fact that, depending on the outcome, speculative attacks often come with very large losses and profits for the speculators. We also show that the attacks' timing can usually be associated with credibility in the government. We discuss our results in the three remaining sections. In section 2, we present a continuous time one-sided target zone model of speculative attacks. We study the effects of uncertainty in two different ways. First, we consider the case in which the level of reserves at which the central bank lets the regime collapse is not known. Alternatively, we analyze the case in which, with some probability, the government may change its policy reducing the initially positive trend in domestic credit. In both cases, contrary to the case of a fixed exchange rate regime, speculators face a cost of launching a tentative attack that may not succeed, which induces a delay and even may prevent its occurrence. At the time of the tentative attack, the exchange rate moves either discretely up, if the attack succeeds, or down, if it fails. In addition, in the second case, if agents believed that the government will control fiscal imbalances in the future, or alternatively, if they believe the trend in domestic credit to be temporary, the attack is postponed even in the presence of an imminent collapse signal. In section 3, we develop a two-sided target zone regime. There, we show that the timing of a tentative attack increases with the width of the band. Finally, in the last section we conclude and point out possible extensions.

3The main difference between the discrete and the continuous time approach is that the first allows for jumps in the exchange rate. In particular, at every period there is a positive probability of depreciation that produces a forward discount on the domestic currency, i.e., the so called "peso problem".
2. A one-sided upper bound target zone model

2.1. Comments on Krugman's Model

As pointed out in Svensson (1994a), the seminal Krugman model of exchange rate target zone delivers two main results. First, exchange rates depend on fundamentals according to a nonlinear "S-shaped" curve, i.e., when fundamentals follow a Brownian motion with drift, the solution for the exchange rate is a S-shaped function of fundamentals. Second, credible target zones stabilize exchange rates more than fundamentals, i.e., the credible commitment of the central bank to defend the exchange rate exerts a stabilising influence on the exchange rate, even before intervention at the boundaries of the band takes place⁴. Krugman considers that the central bank defends the target zone up to a specific level of reserves. He assumes that the central bank's interventions in the foreign exchange market occur only when the exchange rate reaches the bounds of the target zone. The center and the width of a target zone are defined by, respectively:

\[
\left(\frac{s + g}{2}, \frac{s - g}{2}\right)
\]

where \(s\) is the upper bound and \(g\) is the lower bound of a target zone⁵.

Essentially, most of the target zone regime literature follows Krugman's approach. Krugman's basic model is represented by the following reduced form:

\[
m_t = \log\left(\frac{M_t}{P_t}\right) = \phi y - \alpha i_t
\]

\[
m_t = \gamma D_t + (1 - \gamma) P_t
\]

\[
p_t = s_t + p^*_t
\]

\[
i_t = i^* + \frac{E(ds_t)}{dt}
\]

where \(m_t\) is the logarithm of the nominal money demand, \(p_t\) is the logarithm of the price level at time \(t\), \(y\) is the logarithm of the output, \(\alpha\) is the semi-elasticity of interest rate, \(i_t\) is the nominal interest rate at time \(t\), \(D_t\) represents the level of domestic credit at time \(t\), \(R_t\) is the level of foreign reserves at time \(t\), \(s_t\) is the level of the exchange rate at time \(t\), \(p^*_t\) is the level of foreign prices at time \(t\),

⁴Expectations of future monetary contractions to defend the target zone strengthens the currency today.

⁵Notice that if \(s = g\) we are in a fixed exchange rate regime. If \(s = \infty\) and \(g = -\infty\) we are in a free float regime. When we consider a one-sided upper bound target zone we make \(g = -\infty\).
$i^*$ is the constant foreign interest rate, and $E[.]$ is the mathematical conditional
expectations operator. The reserves stock can be changed ad libitum for the pur-
pose of supporting the bands of the target zone regime. Equation (6.1) represents
the money demand function. Equation (6.1) gives the definition of money supply.
Equation (2.4) represents the Purchase Power Parity identity. Equation (2.5) rep­
resents the uncovered interest rate parity. Rearranging equations (6.1) to (2.5)
we get:

$$s_t = f_t + \alpha \frac{E(ds_t)}{dt}$$

where

$$f_t = m_t - \phi y + \alpha i^*_t + p^*_t$$

$$= \gamma D_t + (1 - \gamma) R_t - \phi y + \alpha i^* + p^*$$

$$= \gamma D_t + a$$

The value of $a$ is given by:

$$a = (1 - \gamma) R_t - \phi y + \alpha i^* + p^*$$

Following the standard approach, e.g., Krugman(1991), there is a term in $f_t$
that follows a Brownian motion with a non-zero drift, $\mu$. Then, the solution for
$s_t$ is given, using Ito's lemma, by

$$s_t = f_t + \alpha \mu + C_1 e^{\beta_1 f_t} + C_2 e^{\beta_2 f_t}$$

where $\beta_1$ and $\beta_2$ are the (positive and negative) roots of the characteristic quadratic
function defined by the process $f_t$, and $C_1$ and $C_2$ are constants to be determined
by the border conditions. Typically, in a two-sided target zone model, the value
matching condition is imposed at the thresholds. If there is only one threshold,
$i.e., a one-sided target zone regime, the other coefficient is set to zero to keep the
exchange rate function bounded when the fundamental $f_t$ gets arbitrarily large.
If the regime is a fixed exchange rate, $s_t = \bar{s}$ and the fundamental has to be
constant, $i.e., any change in, say, domestic credit has to be compensated by a
change in the stock of reserves. There is a point at which the post-attack rate,
which takes into account a lower level of reserves, the level of reserves at which the

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$^6$In the next section we explain in details how to obtain such solution.
government gives up with the plan, plus an expected depreciation proportional to the long run trend in the fundamental, exceeds the fixed rate, and an attack is launched successfully.

2.2. Uncertainty about the domestic credit path

Our model follows the Krugman approach discussed in the previous section and is represented by equations (6.1) to (2.7). In this case we consider that agents are uncertain about the path of domestic credit. It is common knowledge that the government is committed to defend the one-sided upper bound target zone up to a minimum level of reserves \( R_{\text{min}} \) is reached\(^7\). In such regime it is stipulated that the intervention of a central bank in the exchange rate market leads to a reduction of its money supply by the purchase of its currency with foreign reserves. The intervention, which is repeated as many times as the exchange rate hits the upper bound, is performed over an infinitely small period of time. It remains infinitesimal in size but takes place at an infinite speed. According to some ad hoc rule; the intervention may also take place continuously. Although ultimately it should be considered, we do not incorporate intramarginal interventions.

**Proposition 2.1.** Suppose an economy represented by the reduced form system (6.1) to (2.5) and that the uncertainty about the path of domestic credit is given by:

\[
dD_t = \mu dt + \sigma dw_t \tag{2.10}
\]

where \( D_0 > 0 \), \( \mu \) is the drift, \( \sigma^2 \) is the variance, and \( dw_t \) is the increment of a standard Wiener process. Moreover, it is common knowledge that the government will defend the one-sided upper bound target zone up to the level of reserves \( R_{\text{min}} \). Within the band, the government does not intervene in the market. Then, the exchange rate follows the process

\[
s^c = \gamma D + a + \alpha \mu \gamma^2 - (1 - \gamma) (R - R_{\text{min}}) e^{\beta_t(D - D^*)}. \tag{2.11}
\]

where \( D \) is the level of domestic credit when agents are certain, and \( D^* \) is the level of domestic credit agents launch an attack when they are certain about the minimum level of reserves,

\[
a = (1 - \gamma)R_t - \phi_y + \alpha i^* + p^*
\]

\(^7\)Although something is lost when we consider that the policy rule is given exogenously, there is no loss of generality by not considering the government ability of borrowing abroad.

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\[ \beta_1 = \frac{-\mu + \sqrt{\mu^2 + 2\sigma^2/\alpha}}{\gamma \sigma^2}. \]

**Proof.** Notice that the only variable that drives the behavior of \( s_t \) is the domestic credit \( D_t \). Then, let us solve for the general case where it is common knowledge that the government's rule is to defend the band until the reserves level falls to a minimum \( R_{\text{min}} \). Using Itô's lemma and dropping time indexes, we can express (6) as

\[ \frac{\alpha}{2}(\gamma \sigma)^2 s_{DD} + \alpha \gamma \mu s_D - s + \gamma D + a = 0. \]  

(2.12)

where \( a \) is defined by (2.8).

From (2.9), we get that the solution is given by:

\[ s(D) = \gamma D + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 D} + C_2 e^{\beta_2 D}, \]  

(2.13)

where \( \beta_1 \) and \( \beta_2 \) are, respectively, the positive and negative roots of the characteristic quadratic equation for the homogeneous part of (2.12)

\[ \frac{\alpha}{2}(\gamma \sigma)^2 \beta^2 + \alpha \gamma \mu \beta - 1 = 0, \]

\[ \beta_{1,2} = \frac{-\mu \pm \sqrt{\mu^2 + 2\sigma^2/\alpha}}{\gamma \sigma^2}, \]

and \( C_1 \) and \( C_2 \) are constants to be determined by the border conditions. It is immediate to check that \( \beta_1 > 0, \beta_2 < 0 \) and since \( \beta_1 - \beta_2 = \frac{-2\mu}{\gamma \sigma^2}, \) \( |\beta_2| > |\beta_1| \). This property will be useful later. For simplicity here we assume a one sided target zone, i.e., the government intervenes marginally whenever the exchange rate hits an upper bound \( \delta \) but imposes no lower bound to the exchange rate \( \delta \). Therefore, to keep \( s_t \) bounded for arbitrarily small values of the fundamental, we need to set \( C_2 = 0 \).

To solve for the remaining constant \( C_1 \) we imposed the standard value matching condition at the threshold. Given that in the certainty case the attack is known to be successful, the condition is equivalent to saying that there is no discrete jump in the value of \( s_t \) at the time of the attack. If the outcome of the attack is uncertain, however, a failed attack is not without cost for the speculators.

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\[ \text{We follow the same method as in Froot and Obstfeld (1991).} \]

\[ \text{All the results can be readily extended to the case of a two-sided target zone.} \]

\[ \text{Otherwise the no arbitrage condition would be violated.} \]
The solution for the exchange rate within the regime is

\[ s^c = \gamma D + a + \alpha \mu \gamma^2 + C_1^c e^{\beta_1 D} \]  \hspace{1cm} (2.14)

where, from now on, the superscript \( c \) represents the case where agents are certain about the minimum reserve level.

Absent any possibility of intervention after the collapse of the target zone regime, the post-attack level of reserves are kept constant at \( R_{\text{min}} \). The post-attack exchange rate behavior is determined solely by the behavior of domestic credit. To rule out bubbles we need to set \( C_1^c = 0 \). The expression for the expected post-attack exchange rate is given by

\[ s_+^c = \gamma D + a + \alpha \mu \gamma^2 \]  \hspace{1cm} (2.15)

where the subscript \( + \) represents the expected post-attack exchange rate. The value matching condition yields the following equation:

\[ \bar{s} = \gamma \bar{D}^c + a + \alpha \mu \gamma^2 + C_1^c e^{\beta_1 \bar{D}^c} = \gamma \bar{D}^c + a_+ + \alpha \mu \gamma^2 \]  \hspace{1cm} (2.16)

where \( \bar{D}^c \) is the value of domestic credit that launches the attack in the certainty case. Since both domestic credit and the exchange rate are continuous, the change in expected depreciation has to be matched by a change in the other variable component of the fundamental, i.e. \( a - a_+ = (1 - \gamma) (R - R_{\text{min}}) \), where \( R_{\text{min}} \) denotes the level of reserves where the Central Bank will give up the target zone regime and will shift from the target zone exchange rate regime to the floating regime. Such minimum level of reserves may be interpreted as the limit below which the government cannot keep its guarantees in the foreign trading transactions.

Using (2.14), (2.15), and (2.16), we get:

\[ C_1^c = -(1 - \gamma) (R - R_{\text{min}}) e^{-\beta_1 \bar{D}^c} \]

\[ \bar{D}^c = (\bar{s} - \alpha \mu \gamma^2 - a_+) / \gamma \]

and

\[ s^c = \gamma D + a + \alpha \mu \gamma^2 - (1 - \gamma) (R - R_{\text{min}}) e^{\beta_1 (D - \bar{D}^c)} \]

and this concludes the proof. \( \blacksquare \)

\[ ^{11} \text{Later on, we will let the agents be uncertain about this minimum level of reserves.} \]
Notice that the current stock of reserves as well as the minimum level up to when the government defends the band are relevant to forward looking exchange rate determination. As expected, the value of $\overline{D}$ at which the attack is launched depends negatively on the committed reserves$^{12}$. Moreover, the slope of the exchange rate function becomes flatter as the available reserves increase, i.e. $\partial C_1^i / \partial R < 0$.$^{13}$

2.3. Uncertainty about the government commitment to the target zone regime

We focus here in the case where there is uncertainty about the level of minimum reserves at which the Central Bank stops defending the regime. If the attack is launched bearing in mind a positive expected value for the limit reserves and the true limit turns out to be zero, there will be a fall in $s$, and a loss for the speculators equal to $\overline{s} - s(\overline{D})$, where $\overline{D}$ is the level of domestic credit that induces an attack in the uncertainty case$^{14}$. Such case might be represented in Figure 1.

[Figure 1]

**Proposition 2.2.** Suppose an economy represented by the reduced form system (6.1) to (2.5) and that the uncertainty about the path of domestic credit is given

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$^{12}$For large enough reserves, the attack does not occur and we are back in the typical target zone case.

$^{13}$If we consider a two-sided target zone, we would get the following results:

\[
C_1 = \frac{1}{e^{-\beta D} - e^{\beta D}} \left( \gamma D + a + au \gamma^2 - \bar{s} + \frac{\gamma D}{e^{\beta(a+au-\bar{s})}} \right)
\]

\[
C_2 = \frac{1}{e^{-\beta D} - e^{\beta D}} \left( \gamma D + a + au \gamma^2 - \bar{s} + \frac{(a_+ - a) e^{\beta D}}{e^{\beta(a+au-\bar{s})}} \right)
\]

\[
\overline{D} = \frac{\overline{s} - a_+ - au \gamma^2}{\gamma}
\]

where $D$ satisfies

\[
C_1 \beta e^{\beta D} + C_2 \beta e^{-\beta D} = 0.
\]

Given that the qualitative results do not change we will continue working with the one-sided target zone.

$^{14}$Whenever the level of domestic credit reaches $\overline{D}$ agents will launch an speculative attack.
by:

$$dD_t = \mu dt + \sigma dw_t$$

where $D_0 > 0$, $\mu$ is the drift, $\sigma^2$ is the variance, and $dw_t$ is the increment of a standard Wiener process. Moreover, it is common knowledge that the government will defend the one-sided upper bound target zone up to the level of reserves $R_{\min}$. Within the band, the government does not intervene in the market. Due to the uncertainty, agents assign a probability distribution to two different minimum levels of reserves, i.e.,

$$R_{\min} = \begin{cases} R^o, & \text{with probability } \pi \\ 0, & \text{with probability } 1 - \pi \end{cases} \quad (2.17)$$

Then, the upper boundary of the target zone equals

$$\bar{s} = \gamma \bar{D} + a_+ + \alpha \mu \gamma^2 - (1 - \gamma)(1 - \pi)R^o e^{\beta_1(D - \bar{D})} \quad (2.18)$$

where $\bar{D}$ is the level of domestic credit agents launch an attack when they are certain about the minimum level of reserves, $\bar{D}$ is the value when agents are uncertain about $R_{\min}$, and

$$a_+ = a - (1 - \gamma)(R - R^o) \quad \beta_1 = \frac{-\mu + \sqrt{\mu^2 + 2\sigma^2/\alpha}}{\gamma \sigma^2}.$$

**Proof.** We follow the same procedure as in the first proposition. We adapt equation (2.11) to solve the problem under uncertainty. It is clear that the level of reserves if the attack fails is the level of reserves that reveals information about the government’s rule. In other words, the new initial level for the case in which agents learn that the speculative attack was not successful equals the higher minimum level of reserves, $R^o$.

The solution for this case is given by:

$$s = \gamma \bar{D} + a_+ + \alpha \mu \gamma^2 - (1 - \pi)(1 - \gamma)R^o e^{\beta_1(D - \bar{D})} \quad (2.19)$$

where $\bar{D}$ corresponds to the level of domestic credit that you launch an attack when you are sure that the minimum level of reserves is the lower one, i.e., zero, and $a_+$ equals:

$$a_+ = a - (1 - \gamma)(R - R^o) = (1 - \gamma)R^o - \phi y + \alpha \pi - \rho.$$

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Considering the mentioned cost in the value matching condition for the upper bound, we get:

\[ \gamma D + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 D} = \gamma D + a_+ + \alpha \mu \gamma^2 - (1 - \pi)(1 - \gamma) R^o e^{\beta_1 (\bar{D} - \bar{D}')} \]  

(2.20)

So, the target zone regime might be in place even after an attack. If the attack is unsuccessful, however, there will be a downward shift in the exchange rate curve, as represented in Figure 2.

[Figure 2]

Such shift happens because all the uncertainty in the market will be solved. Agents will learn the true minimum level of reserves. As a result of the attack the level of money demand will be lower. Moreover, the fall in the exchange rate leads to a higher domestic interest rate and a lower price level. Solving (2.20) for \( C_1 \), we obtain:

\[ C_1 = -(1 - \gamma) [(R - R^o) + (1 - \pi) R^o e^{\beta_1 (\bar{D} - \bar{D}')} e^{-\beta_1 D}] \]

Replacing in (2.19):

\[ \bar{s} = \gamma D + a_+ + \alpha \mu \gamma^2 - (1 - \gamma)(1 - \pi) R^o e^{\beta_1 (\bar{D} - \bar{D}')} \]  

(2.21)

We are ready to solve for the level of domestic credit \( D \) that triggers a tentative attack when the agents are uncertain about the true minimum reserves level. Using (2.16) and (2.21), we get:

\[ \gamma D^c + a_+ - (1 - \gamma) R^o + \alpha \mu \gamma^2 = \gamma D + a_+ + \alpha \mu \gamma^2 - (1 - \gamma)(1 - \pi) R^o e^{\beta_1 (\bar{D} - \bar{D}')} \]

After some algebra, we get:

\[ \gamma (D - D^c) - (1 - \gamma) [(1 - \pi) R^o e^{\beta_1 (\bar{D} - \bar{D}')} - R^o] = 0 \]

After a change of variable, \( z = (D - D^c) \), the equation becomes

\[ g(z) = \gamma z - (1 - \gamma) [(1 - \pi) R^o e^{\beta_1 z} - R^o] = 0 \]  

(2.22)

Note that we have:

\[
\begin{align*}
g(0) &= (1 - \gamma) [(1 - \pi) R^o - R^o] > 0 \\
g(-\infty) &= -\infty \\
g(\infty) &= -\infty
\end{align*}
\]
and the second order condition assures us that the function is strictly concave in $z$, i.e.,

$$\frac{d^2 g(z)}{dz^2} = -\beta^2(1 - \gamma)(1 - \pi)R^o e^{\beta z} < 0$$

so that equation (2.22) has always two roots, $z_1$ and $z_2$, such that $z_1 < 0 < z_2$, or alternatively, $D_1 < D_0 < D_2$. The negative root $z_1$ corresponds to a level of $D$ such that investors launch a speculative attack facing the risk of a drop in the value of the foreign currency they have purchased during the attack in the event that the real minimum reserves level is zero\(^{15}\). The second one corresponds to a value of $D$ higher than the $D_0$. This value is on the downward part of the $s$ curve and clearly can not be a solution to the speculator's problem: a speculative attack under the most conservative assumption, i.e., zero minimum reserves level, will be successfully launched before the domestic credit reaches this level. ■

It is quite intuitive that if instead of having only two possible minimum level of reserves as in our case we have more, it is possible to get a solution where agents unsuccessfully launch attacks to the target zone regime more than once. Given the probabilities agents assign to the reserves level committed by the government, agents will choose the level of domestic credit where they will launch the attack. If the attack is not successful agents update their probability distribution and choose a new level of domestic credit where they will launch a new attack. This process might go on until there is only one possible level: the agents are certain and the attack is successful.

To picture the situation in more realistic terms, think of the case of a currency board with the mandate to defend the zone until reserves are depleted. Chances are that if things get complicated and a collapse is imminent, the government might decide to abolish the board by decree before running out of reserves. If this happens, it is likely that the loss of reserves will not be so large. This case corresponds to a high ratio $\frac{R^*}{R}$, which makes it more likely that a tentative attack will occur. As expected, a higher probability of reversal on the part of the government leads to a higher chance of a tentative attack.

Our result also suggests that the uncertainty about the government's commitment is useful in postponing speculative attacks. Moreover, some policy makers defend the central bank secrecy as an instrument of postponing possible speculative attacks.

\(^{15}\)Remember that in the case of a fixed exchange rate regime such risk does not exist at all.
2.4. Uncertainty about the government domestic credit policy

In this section we consider the case where the government may decide to change its policy if faced with a possible speculative attack. Therefore, agents are uncertain about future policy changes. In other words, the government may adjust monetary policy to be consistent with the target zone regime. This type of endogenous switch in the policy was studied by Drazen and Helpman (1988) and Willman (1987) in a fixed exchange rate framework. They show that the collapse of the fixed exchange regime is delayed, even if the announcement switch is only partly credible. Using the same argument as they use, we generalize their analysis to the case in which there is uncertainty about future policy changes. We show that the timing of a speculative attack is affected by policy measures.

For simplicity, we might interpret $D$ as monetized fiscal deficit, and a policy change as a reduction of the level of current deficit, i.e., a fall in the drift parameter for $D$. Facing an imminent collapse, a government that cares about the regime may choose to cut expenditures. Contrary to the former section, it is common knowledge that the government is willing to defend the one-sided upper bound target zone up to the level of $R_{\text{min}}$.

**Proposition 2.3.** Suppose an economy represented by the reduced form system (6.1) to (2.5) and that the uncertainty about the path of domestic credit is given by:

$$dD_t = \mu dt + \sigma dw_t$$

where $D_0 > 0$, $\mu$ is the drift, $\sigma^2$ is the variance, and $dw_t$ is the increment of a standard Wiener process. Moreover, it is common knowledge that the government will defend the one-sided upper bound target zone up to the level of reserves $R_{\text{min}}$. Within the band, the government does not intervene in the market. Initially, the drift parameter $\mu$ equals $\mu_H$. In the case of a speculative attack against the currency, the drift $\mu$ may assume two possible post-attack levels of domestic credit growth, i.e.,

$$\mu_t = \begin{cases} 
\mu_H, & \text{with probability } \lambda \\
\mu_L, & \text{with probability } 1 - \lambda 
\end{cases} \quad (2.23)$$

Then, the upper bound exchange rate is defined by

$$\bar{s} = \gamma \overline{D} + a_t + \alpha \mu^e \gamma^2 - (1 - \gamma)(1 - \lambda)R_{\text{min}} e^{B(D - D')} \quad (2.24)$$

where

$$\mu^e = \lambda \mu_H + (1 - \lambda)\mu_L$$
\[
\beta_1 = \frac{-\mu^e + \sqrt{\left(\mu^e\right)^2 + 2\sigma^2/\alpha}}{\gamma \sigma^2}
\]
\[
a_+ = (1 - \gamma)R_{\text{min}} - \phi y + \alpha i^* - p^*
\]

**Proof.** We follow the proofs of the former theorems, adapting equation (2.11) to the assumption about the post attack drift of the domestic credit process. When the trend is known to decrease after the attack, the solution is given by:

\[
C_1^c = -(1 - \gamma)(R - R_{\text{min}}) e^{-\beta_1 D'}
\]
\[
\bar{D}' = (\bar{s} - \alpha \mu_L \gamma^2 - a_+)/\gamma
\]

and the value of the exchange rate path is given by:

\[
s^c = \gamma D + a + \alpha \mu_L \gamma^2 - (1 - \gamma)(R - R_{\text{min}}) e^{\beta_1 (D - D')}.
\]  

(2.25)

In particular,

\[
\bar{s} = \gamma \bar{D} + a + \alpha \mu_L \gamma^2 + (1 - \gamma)(R - R_{\text{min}}) = \gamma \bar{D} + a_+ + \alpha \mu_L \gamma^2
\]  

(2.26)

The value matching condition for the upper bound of the target zone \( \bar{s} \), when there is uncertainty about future government policy is given by:

\[
\gamma \bar{D} + a + \alpha \mu_H \gamma^2 + C_1 e^{\beta_1 \bar{D}} = \gamma \bar{D} + a_+ + \alpha \mu^e \gamma^2 - (1 - \lambda)(1 - \gamma)R_{\text{min}} e^{\beta_1 (\bar{D} - D')},
\]  

(2.27)

where \( \mu^e \) is the expected value of the trend

\[
\mu^e = \lambda \mu_H + (1 - \lambda)\mu_L,
\]

and \( a_+ \) equals:

\[
a_+ = (1 - \gamma)R_{\text{min}} - \phi y + \alpha i^* - p^*.
\]

Solving equation (2.27) for \( C_1 \) we obtain:

\[
C_1 = \left(-(1 - \gamma) \left[(R - R_{\text{min}}) + (1 - \lambda)R_{\text{min}} e^{\beta_1 (\bar{D} - D')}\right] - \alpha \gamma^2 (\mu_H - \mu^e)\right) e^{-\beta_1 \bar{D}}.
\]

\[
\bar{s} = \gamma \bar{D} + a_+ + \alpha \mu^e \gamma^2 - (1 - \gamma)(1 - \lambda)R_{\text{min}} e^{\beta_1 (\bar{D} - D')}
\]  

(2.28)
and combining (2.26) and (2.28):
\[
\gamma \bar{D}^* + \alpha + \alpha \mu_L \gamma^2 = \gamma \bar{D} + \alpha + \alpha \mu^* \gamma^2 - (1 - \gamma)(1 - \lambda)R_{\min}e^{\beta_1(D - \bar{D})}
\]
After some algebra, and defining as before \( z = \bar{D} - \bar{D}^* \), we get:
\[
\gamma(z) + \alpha \gamma^2(\mu^* - \mu_L) - (1 - \gamma) \left[ -R_{\min} + (1 - \pi)R_{\min}e^{\beta_1 z} \right] = 0 \tag{2.29}
\]
It is easy to check that:
\[
\begin{align*}
g(0) &= -(1 - \gamma)[(1 - \pi)R_{\text{min}} - R_{\text{min}}] + \alpha \gamma^2(\mu^* - \mu_L) > 0 \\
g(-\infty) &= -\infty \\
g(\infty) &= -\infty
\end{align*}
\]
and the second order condition guarantees that it is a strictly concave function in \( z \), i.e.,
\[
\frac{d^2 g(z)}{dz^2} = -\beta_1^2(1 - \gamma)(1 - \lambda)R_{\min}e^{\beta_1 z} < 0
\]
Therefore, there is only one strictly positive value for \( \bar{D} \) that triggers a speculative attack.

Our result in the previous section applies here: if agents believe that the government may give priority to the sustainment of the plan in case of an imminent collapse, they may postpone the attack\(^{16}\). Notice that setting \( \pi = 1 \) returns us to our previous results in section 2.2. The smaller is \( \pi \) the later is the collapse. Setting \( \pi = 0 \) implies that the speculative attack will be a function of \( \mu_L \). Moreover, if \( \mu_L \) equals zero, the speculative attack never occurs.

3. A two-sided target zone model

Following Delgado and Dumas(1991), we extend the previous model to the case in which there is also a lower bound \( g \) for the exchange rate such that the government intervenes buying reserves whenever \( s \) hits \( g \). We show that, if there is uncertainty

\(^{16}\)We can think of such case as of the trade-off between stabilization and government expenditures during an electoral year. The chances to win reelection increase with \( \mu \) but decreases strongly with the inflation rate (i.e., with the rate of change in \( s \)).
about the post-attack exchange rate as defined in the previous section, a wider band may induce a longer wait on the side of the speculators and give more time to the government. First, we show that there is a unique solution for a two-sided target zone for an economy as the one we have studied in the former sections.

**Proposition 3.1.** Suppose an economy represented by the reduced form system (6.1) to (2.5) and that the uncertainty about the path of domestic credit is given by:

\[ dD_t = \mu dt + \sigma dw_t \]

where \( D_0 > 0, \mu \) is the drift, \( \sigma^2 \) is the variance, and \( dw_t \) is the increment of a standard Wiener process. Moreover, it is common knowledge that the government will defend the two-sided target zone up to the level of reserves \( R_{\text{min}} \). Within the band, the government does not intervene in the market. Then, there is a solution for the two-sided target zone problem characterized by the upper and lower levels of the domestic credit, respectively, \( \overline{D} \) and \( \underline{D} \), that triggers the government intervention.

**Proof.** Starting from equation (2.13),

\[ s(D) = \gamma D + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 D} + C_2 e^{\beta_2 D}, \quad (3.1) \]

we get the following 4x4 system:

\[ \xi = \gamma \underline{D} + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 \underline{D}} + C_2 e^{\beta_2 \underline{D}}, \quad (3.2) \]

\[ 0 = \gamma + \beta_1 C_1 e^{\beta_1 \underline{D}} + \beta_2 C_2 e^{\beta_2 \underline{D}} \quad (3.3) \]

\[ \overline{\xi} = \gamma \overline{D} + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 \overline{D}} + C_2 e^{\beta_2 \overline{D}} \]

\[ \overline{D} = (\overline{\xi} - \alpha \mu \gamma^2 - a_+)/\gamma \quad (3.5) \]

where, as before, \( a - a_+ = (1 - \gamma) (R - R_{\text{min}}) \). Equations (3.2) and (3.4) are the value matching conditions at the lower and upper threshold, respectively. Since in the event of a drop in \( D \) the government can purchase as much foreign currency as it needs to keep the exchange rate from moving below the lower bound, the standard "smooth pasting" condition at \( \xi \) gives equation (3.3). The additional equation is given, as usual, by the post-attack exchange rate function

\[ s_+ = \gamma D + a_+ + \alpha \mu \gamma^2 \]
which, in particular, implies equation (3.5) at the upper threshold $\bar{D}$. From equation (3.4),

$$C_2 = \frac{\bar{s} - \gamma \bar{D} - a - \alpha \mu \gamma^2 - C_1 e^{\beta_1 \bar{D}}}{e^{\beta_2 \bar{D}}}$$ (3.6)

Equation (3.3) gives, after replacing for $C_2$,

$$\beta_1 C_1 e^{\beta_1 \bar{D}} = -\gamma - \beta_2 C_2 e^{\beta_2 \bar{D}}$$
$$= -\gamma + \beta_2 (\gamma \bar{D} + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 \bar{D}} - \bar{s}) e^{\beta_2 (\bar{D} - \bar{D})}$$

from which we get

$$C_1 = \frac{-\gamma + \beta_2 (\gamma \bar{D} + a + \alpha \mu \gamma^2 - \bar{s}) e^{\beta_2 (\bar{D} - \bar{D})}}{(\beta_1 e^{\beta_1 \bar{D}} - \beta_2 e^{(\beta_1 - \beta_2) \bar{D} + \beta_2 \bar{D})}}$$ (3.7)

Finally, from equation (3.2) and using equations (3.6) and (3.7):

$$s = \gamma \bar{D} + a + \alpha \mu \gamma^2 + C_1 e^{\beta_1 \bar{D}} + C_2 e^{\beta_2 \bar{D}}$$
$$= \gamma \bar{D} + a + \alpha \mu \gamma^2 + (\bar{s} - \gamma \bar{D} - a - \alpha \mu \gamma^2) e^{\beta_2 (\bar{D} - \bar{D})} + C_1 \left[ e^{\beta_1 \bar{D}} - e^{(\beta_1 - \beta_2) \bar{D}} e^{\beta_2 \bar{D}} \right]$$

which characterizes implicitly $\bar{D}$. Combining equations (3.5), (3.8) and (3.7) we can solve numerically for $\bar{D}$. Using equations (3.7) and (3.6), we obtain values for the rest of the parameters of the exchange rate curve. 

In the Appendix we solve for different set of parameters and present the respective graphs.

Now we are able to state the following:

**Proposition 3.2.** In a target zone exchange rate regime, the extent to which the tentative attack is postponed in the presence of uncertainty about the future policy, as measured by the difference between $D_0$ and $\bar{D}$, increases with the width of the band.
Proof. Note that since $\beta_1 > 0, \beta_2 < 0$ and $|\beta_2| > |\beta_1|$, it is easy to check that

\[
\left( e^{\beta_1 D} - e^{\beta_1 D} e^{(\beta_1 - \beta_2) D + \beta_2 D} \right) < 0
\]
\[
(\beta_1 e^{\beta_1 D} - \beta_2 e^{(\beta_1 - \beta_2) D + \beta_2 D}) > 0
\]
\[
(\gamma D + a + \alpha \mu \gamma^2 - \beta_1) > 0
\]
\[
(\beta_1^2 e^{\beta_1 D} - \beta_2^2 e^{(\beta_1 - \beta_2) D + \beta_2 D}) < 0
\]

and, as a result, $C_1 < 0$ and

\[
\frac{\partial C_1}{\partial D} = \frac{\beta_2^2 (\gamma D + a + \alpha \mu \gamma^2 - \beta_1) e^{\beta_1 (D - \bar{D})}}{(\beta_1 e^{\beta_1 D} - \beta_2 e^{(\beta_1 - \beta_2) D + \beta_2 D})} - \frac{C_1 (\beta_1^2 e^{\beta_1 D} - \beta_2^2 e^{(\beta_1 - \beta_2) D + \beta_2 D})}{(\beta_1 e^{\beta_1 D} - \beta_2 e^{(\beta_1 - \beta_2) D + \beta_2 D})} < 0.
\]

Differentiating equation (3.8) with respect to $D$ yields:

\[
\frac{\partial s}{\partial D} = \gamma - \beta_2 (\gamma D + a + \alpha \mu \gamma^2 - \beta_1) e^{\beta_1 (D - \bar{D})} + \frac{\partial C_1}{\partial D} \left[ e^{\beta_1 D} - e^{\beta_1 D} e^{\beta_2 (D - \bar{D})} \right]
\]
\[
+ \frac{\partial C_1}{\partial D} \left[ e^{\beta_1 D} - e^{\beta_1 D} e^{(\beta_1 - \beta_2) D} \right] > 0.
\]

From equation (3.6) we obtain:

\[
\frac{\partial C_2}{\partial C_1} = -e^{(\beta_1 - \beta_2) \bar{D}} < 0. \quad (3.9)
\]

Finally, differentiating equation (3.1), with respect to the lower bound of the target zone, $\bar{s}$,

\[
\frac{\partial s(D)}{\partial \bar{s}} = \frac{\partial C_1}{\partial D} \frac{\partial D}{\partial \bar{s}} \left( e^{\beta_1 D} + \frac{\partial C_2}{\partial C_1} e^{\beta_2 D} \right)
\]
\[
= \frac{\partial C_1}{\partial D} \frac{\partial D}{\partial \bar{s}} \left( e^{\beta_1 D} - e^{(\beta_1 - \beta_2) \bar{D} + \beta_2 D} \right) > 0, \quad (3.10)
\]

since $\beta_1 D < (\beta_1 - \beta_2) \bar{D} + \beta_2 D$.

We have proved that, everything else equal, lowering the lower bound of the target zone results in an exchange rate curve everywhere below the previous one. To complete the proof note that, in the uncertainty case, we need to replace the certain post-attack exchange rate by its expected value in equation (3.5) so that
\[ \bar{\pi} = \lambda (\gamma D + a + \alpha \mu \gamma^2 + \gamma D) + (1 - \lambda) (\gamma D + a + \alpha \mu \gamma^2 + C_1 e^{\delta_1 D} + C_2 e^{\delta_2 D}) \]

\[ = \gamma D + a + \alpha \mu \gamma^2 + \gamma D + (1 - \lambda) [(1 - \gamma)(R^s - R_{\min}) + C_1 e^{\delta_1 D} + C_2 e^{\delta_2 D}] \]

Since for a given \( D \), \( C_1 e^{\delta_1 D} + C_2 e^{\delta_2 D} \) is decreasing in \( s \), \( D \) must be increasing in \( s \) to satisfy equation (3.11).

In words, since now the exchange rate curve is steeper for a wider band, and the eventual drop increases with the distance to \( D \), the value of domestic credit at which the regime collapses with certainty, the attack will be launched at a point that comes closer to \( D \). This result is a simple generalization of the idea that whereas in a fixed exchange rate regime there is no cost involved in the attack and therefore it is launched whenever there some positive probability of success, in a target zone the possibility that the Central Bank defends the regime delays the tentative attack. The counterpart to this is, naturally, that the jumps that we observe after a failed attack are higher the wider the target zone is.

4. Further Comments

We show some interesting features of the model, usually overlooked. First, under uncertainty about the government policy function, unsuccessful attacks may be launched even in the presence of a cost of failing. More importantly, in contrast with the fixed exchange rate case treated by Willman (1989), the cost of failing induces a proportional delay in the attack. If the cost is too big the tentative attack may not occur. If there is a band instead of a one-sided target zone, the existence of a lower threshold make the exchange rate curve flatter and the drop after a failed attack smaller, reducing the cost. In other words, a wider band may have the benefit of postponing or even preventing a tentative attack. The decision of the width of the band should take this into account.

Several comment on our setup are in order. First, a trend is needed to induce a speculative attack. If there is a trend, the plan is sustainable only in the short run, if anything, and this implies either the government strongly discounts the future, i.e., using current reserves to moderate inflation in the short run, or there

\[^{17}A\ random\ domestic\ credit\ process\ is\ not\ enough\ for\ obtaining\ a\ speculative\ attack,\ since\ expected\ depreciation\ is\ then\ zero\ at\ every\ period\ for\ any\ current\ value\ of\ the\ fundamental.\]
is some subsidiary goal not explicit in the model. The assumption of a constant trend may be viewed also as an approximation of temporary and highly persistent increase to be reverted in the long run. We address this case in section 2. We were able to show that a speculative attack is postponed if the probability of a policy switch increases. Finally, the government sticks to the minimum level of reserves even though it knows that the plan will fail. Even in the case of uncertainty, with trend there is always a final attack that is successful. Once this attack is launched, it is clear that after selling reserves the government has to surrender to a float or to devalue\textsuperscript{18}. Then, if there is a positive cost of losing reserves, e.g., if there are real effects of a drastic reduction in money supply, the government will shift to a float without selling any amount of reserves, which makes the rule time inconsistent. On the other hand, if reserves have no value for the government, either selling all at time zero or using intramarginal interventions if there is a cost in deviating from a predetermined exchange rate target will dominate the announced rule.

If we consider heterogeneous agents we can get some sort of asymmetry in the trading results of different traders. Informed traders will never face losses. On the other hand, if non informed agents are uncertain about the minimum level of reserves and it turns to be the lower one, i.e., in our case equal to zero, they will attack the target zone earlier and will face a loss in their positions. If the minimum reserves turn to be positive, non informed traders may or may not get profits. They will get profits if the government do not let the exchange rate float before the reserves drop from its initial level to the minimum decided ex-ante by the government. Otherwise, if the government is able to predict that the attack will be successful, it might let it float before the reserves reach the ex-ante minimum level.

A possible extension to our work is to consider the suggestion of Garber and Svensson (1994). They argue that by incorporating imperfect credibility and intramarginal interventions to the original Krugman's model we can manage to resolve empirical difficulties\textsuperscript{19}. This is accomplished by expressing the expected rate of currency depreciation as the sum of two components. One is the expected rate of change of the central parity $g_t$, i.e., the expected rate of realignment, $\frac{\text{Ed}_{g\mid x}}{dt}\textsuperscript{20}$. The other component is the expected rate of currency depreciation within the

\textsuperscript{18}Such case has additional problems of credibility and deserves to be treated separately.

\textsuperscript{19}The likelihood of intramarginal intervention directly affects the relationship between exchange rates and fundamentals.

\textsuperscript{20}The realignment might be a function of additional variables.
band, $E[dz_t | \Gamma_t]$. So, instead of observing (2.6) we have:

$$s_t = f_t + \alpha E [dg_t | \Gamma_t] + \alpha E [dx_t | \Gamma_t]$$

A first approximation to this complicated behavior is to consider intra-marginal \textit{leaning against the wind} interventions. Such interventions aim at returning the exchange rate to a specific target level within the band. When the exchange rate is above the central parity, i.e., the currency is weak, the currency is expected to appreciate for two reasons. One reason is expected intra-marginal interventions to appreciate the currency towards central parity. The other is expected future marginal interventions to prevent the exchange rate moving outside the band. The probability of the future exchange rate ever reaching the edges of the band is smaller with mean reverting interventions than in the traditional Krugman model.

The exchange rate is kept in the middle of the band by intra-marginal interventions. Garber and Svensson (1994) suggest the drift of the composite fundamental following the process

$$E \left[ d \left( f_t - g_t + \alpha \frac{E[dz_t | \Gamma_t]}{dt} \right) | \Gamma_t \right] = -\rho \left( f_t - g_t + \alpha \frac{E[dg_t | \Gamma_t]}{dt} \right),$$

where $\rho \geq 0$ is the rate of mean reversion.

Another fruitful extension may focus on providing an objective function for the government to derive the minimum level of reserves endogenously. In the early literature, there seems to be a problem of time inconsistency. Generally we have that the government establishes \textit{ex ante} a minimum level of reserves below which it moves from a target zone regime to a floating regime. The time inconsistency comes when the exchange rate reaches the upper bound and agents launch an speculative attack. There is no reason why the government should commit to the former policy rule for the level of reserves. However if the Central Bank does not sell its reserves, there will be a jump in the exchange rate which is inconsistent with the agents behavior. In contrary to the early literature that considers such \textit{ad hoc} policy rule for reserves we may try to built a model where such decision is endogenous. By doing that we would eliminate one of the weakest features of those models. If we go forward and introduce uncertainty about the utility function of the government we might use a similar argument as above to show why several speculative attacks do not succeed.

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5. References


6. Appendix

From equation (6), we have:

\[
\left( \frac{\bar{s} + \bar{s}}{2} - \bar{s} - \bar{s} \right).
\]

From equations (6.1) and (6.1):

\[m_t - p_t = \phi_y - \alpha_t\]
\[m_t = \gamma D_t + (1 - \gamma)R_t.\]

From equation (6):

\[dd_t = \mu dt + \sigma dw_t\]

We also know that:

\[a = (1 - \gamma)R_t - \phi y + \alpha_t^* + p^*\]
\[a_+ = a - (1 - \gamma) (R - R_{\min}).\]

For our example, we consider the following values:

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<th>3rd Set</th>
<th>4th Set</th>
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<td>1</td>
<td>1</td>
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<td>0.5</td>
<td>0.5</td>
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<tr>
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<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>$(R - R_{\min})$</td>
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<td>0.03</td>
<td>0.06</td>
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</tr>
</tbody>
</table>

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Figure 1: Exchange Rate x Level of Domestic Credit
We represent the cases where the speculative attacks will take effect. In the uncertainty case agents will postpone the attack with respect to the upper bound of the minimum reserves interval.

Figure 2: Losses from attacking when the attack is not successful.
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N. Cham. P/EPGE SPE T26es
Autor: Teixeira, Nilson.
Título: Speculative (sic) attack on exchange rate target 20

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