Interest Rate Defense Against Speculative Attack as a Signal: A Primer

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I. Introduction

In the light of recent currency crises, two key policy questions are how to defend a currency against attack, and what are the effects of different avenues of defense. An oft-used (and even more often discussed) defense is to raise short-term interest rates sharply to deter speculation. Interest rate defense has had both successes and failures, some quite spectacular. For example, Hong Kong raised overnight rates to several hundred percent and successfully defended its currency in October 1997 against speculative attack. On the other hand, Sweden raised similarly raised its interest rate by several hundred percent in its currency defense in September 1992, but the success was short-lived. These are but two examples. In many countries raising very short-term rates to very high levels to defend the exchange rate appeared to have little effect in deterring speculation, while in others, moderate increases in the interest rate have seemed to dampen speculative pressures. In short, a first look at episodes leaves the question of the effectiveness of an interest rate defense very much open.

More formal empirical models are far from resolving this question. On the basis of probit estimation of the probability of over 300 successful and failed attacks as a function of short-term interest and other explanatory variables, Kraay (1999) argues that high interest rates are neither a necessary nor a sufficient condition for preventing a devaluation. Hubrich (2000), in a large-sample study similar to Kraay's, does identify significant effects of monetary policy during currency crises. He finds that the nominal discount rate is *perversely* related to the outcome of a speculative attack, but that the result is conventional when the monetary policy stance is identified through domestic credit. He also examines how these results are affected by country characteristics, finding, for example, that countries with low prior reserves are more likely to choose an interest rate defense than countries with high reserves.

The lack of empirical consensus is mirrored by a relatively small number of theoretical papers on the interest rate defense. In spite of the importance of the question, the role of interest rates in deterring a speculative attack is only beginning to receive attention.[1] Textbook models indicate with imperfect capital mobility high domestic currency interest rates are a tool to attract

[1]Formal models of an interest rate defense include Lall (1997), Drazen (1999), Lahiri and Végh (2000), Drazen (2000), and Flood and Jeanne (2000)

foreign capital and strengthen the domestic currency. From a more micro perspective, high interest rates deter speculation by increasing the cost of speculation. More precisely, when speculators borrow domestic currency to speculate against a fixed exchange rate (they "short" the domestic currency), high short-term interest rates makes such borrowing very costly.

However, in assessing how high interest rates can deter speculation, this argument runs into a simple "arithmetic problem." If the horizon over which a devaluation is expected is extremely short, interest rates must be raised to extraordinarily high levels to deter speculation when there is even a small expected devaluation. For example, even if foreign currency assets bore no interest, an expected overnight devaluation of 0.5 percent would require an annual interest rate of over 500% ($(1.005^{365} - 1)\times 100 = 517$) to make speculation unprofitable. (See, for example, the discussion in Furman and Stiglitz [1998, p. 75-6)]

This reasoning has been used to call into question how effective high interest rates can be in deterring an attack, suggesting, for example, why the Swedish defense failed. It suggests that sharply raising interest rates will have only marginal beneficial effects at best. Though the "arithmetic problem" suggests why spectacular defenses may have only limited effects, this reasoning leaves other questions unanswered. First, why, as seems sometimes to be the case, might an interest rate defense may lead to even greater spectacular pressures against the currency? That is, why would there be *perverse* feedback from raising interest rates to speculative pressures? Second, even in the absence of perverse feedback effects, the "arithmetic problem" raises the question of why they ever work. How can an effectively minor change in the cost of speculation have such significant, and one might say, *disproportional* effects? There is another sort of "disproportionality" as well, namely that short-lived increases in interest rates sometimes appear to have much longer-term effects. Something other than a simple cost of borrowing effect must be present.

One possibility, which has been the focus of my research in this area, is that both disproportional and perverse effects reflect the *information* that raising interest rates provides to market participants. Specifically, high interest rates may signal the commitment of policymakers to defend the currency. (Anecdotal evidence suggests that this was the message the Swedish Riksbank wanted to send.) If so, the direct cost implications of high interest rates for speculators are irrelevant relative to the signal they provide. The signal may be what makes interest rate defense successful.

By the same token, *increases* in speculative pressure in the wake of an interest rate defense may also reflect a signaling effect. Raising interest rates instead of letting reserves decumulate in order to defend the currency may signal weak fundamentals, such as low reserves. It may also be read as a sign of government panic by speculators. Such information would only encourage further speculation.

Our central argument is that a major effect of high interest rates is as a signal of the government's willingness or ability to defend the exchange rate. That is, there are unobserved characteristics of the government that affect the probability that a defense will be mounted or continued, with policy choices being correlated with these characteristics. Hence, given imperfect information about these government characteristics, speculators used observed policy choices to make inferences about them and hence form (that is, update) the probability they assign to a devaluation. "Signaling" is presented not as an esoteric theoretical point, but as what I hope will be seen as a very sensible view of what governments are doing.

The purpose of this paper is to summarize some of this research, concentrating on the underlying theory, but with some discussion of the empirical work supporting the argument that the effects of high interest rates are in part due to their signal content. The paper is meant as an introduction to the basic approach that I have used in a number of papers, rather than as a paper meant to break new ground. That is, it is meant as a simple "user's guide" to interest rate defense as a signal. As such the stress is on simple models meant to get the basic points across. The plan of the paper is as follows. In section 2 I discuss interest rate defense as a signal of commitment to defending the exchange rate. In section 3, I introduce an alternative way of defending and consider the information an interest rate defense conveys about the ability of a government to defend. A key result is that raising interest rates may send a negative signal, suggesting why there can be perverse effects. Section 5 contains conclusions.

2. A Basic Model of Signaling Commitment

I begin with a model of signaling commitment to keeping the exchange rate fixed by raising short-term interest rates. I want to keep the model extremely simple in order to highlight how this signaling of commitment might work, that is, how raising interest rates allows a government that is committed to defending the exchange rate to "separate" itself in the eyes of investors from one that is not. The model presented is a variant of the model in Drazen (1999).

2.1 *Basic Structure and Assumptions*

Consider a finite-horizon discrete time model of the defending the exchange rate or abandoning it. The timing of actions within a period is as follows. At the beginning of each period t a stochastic shock η_t is observed by both government and speculators. This shock may be to reserves, to the economy, *et cetera*; the key point is that it affects the cost of maintaining the fixed exchange rate, as modeled below. Speculators then choose how much to speculate against the currency, given η_t, the interest rate i_t, and the probability p_t they assign to a devaluation (of known size) at the end of the period. Specifically, speculators borrow domestic currency from the government at an interest rate i_t to be repaid at the end of the period, and use it to buy foreign currency reserves.

Maintaining the fixed exchange rate at t requires that reserves remain above some critical level. This determines a minimum interest rate i_t^H that must be maintained if the government is to defend the fixed parity, where i_t^H will depend on both p_t and η_t. On the basis of η_t and i_t^H, the government then decides in each period whether to defend the fixed exchange rate (denoted by choice of policy F) by holding the interest rate at i_t^H, or not to defend the parity and devalue (a policy N), consistent with a lower interest rate, call it i_t°.

A number of features allow this dynamic signaling model to be kept simple without sacrificing the robustness of the basic insights. First, I consider an irreversible decision to abandon the fixed parity (in a way that will be made clear below). The important assumption is that not defending has a discrete cost. Considering, for example, a return to a fixed rate at some point in the future makes the model too complicated, where my goal is to illustrate the analytics of interest rate defense as a signal as simply as possible. What is central to a signaling approach is that demonstrating commitment to not abandoning the fixed rate is costly, where this cost is unobserved. Second, I concentrate on the decision of whether to raise interest rates, rather than how much to raise them (that is, on the optimal path of interest rates and reserves in defense of a fixed rate). This is reflected in the modeling assumption of a reserve target and a minimum interest rate increase consistent with maintaining the fixed rate. I discuss below some implications of raising interest rates to even higher levels to signal even greater "toughness."

Third, for simplicity of exposition, I don't explicitly model the decision of speculators. (See Drazen [2000] for an explicit model.) For an interest rate defense to be possible, there must be some deviation from interest rate parity. Simple uncovered interest parity cannot hold if the central bank is to have the ability to raise the interest rate in order to increase the net cost of speculation. Different models of interest rate defense use different arguments in this respect. In Drazen (1999), I assumed that speculators face an upward-sloping borrowing schedule when they borrow to finance their speculation. Hence, the speculators' decision implies a well-defined demand curve for borrowing at each point as a function of the interest cost of borrowing and expectations about a devaluation over the immediate future. Combined with the previous assumption about a level of reserves consistent with not abandoning the fixed exchange rate, this implies that at any point in time there is some interest rate that chokes off speculation in the very short term. These assumptions allow me to focus on the government's decision problem in a signaling context, on the role of uncertainty about the government's commitment to fixed rates in driving these decisions, and on exogenous shocks in determining the dynamics of interest rate defense.

2.2 *The Government's Choice Problem*

We now consider the workings of the model in more detail. A standard model of interest rate defense has two actors: speculators who choose relative demands for currency given short-term interest rates and their beliefs about the likelihood of a devaluation in the near term; and, the government (or central bank) which must choose whether and how to defend the currency in the face of speculative pressure. .

Speculators' behavior may be summarized by decision of how large a position to take, given the probability they assign to the fixed exchange rate collapsing over the immediate horizon (call it p_t) and the interest cost of speculation (summarized as i_t). Speculator behavior implies, as indicated, that demand for reserves is a function of i_t, of the probability p_t, and of η_t, the variable summarizing the state of the economy, where η_t has a cumulative distribution $N(\eta_t)$, which we assume is unchanging over time. (We return to this assumption below.) As indicated above, this determines an interest rate consistent with defending the exchange rate in each period denoted i_t^H. Given i_t^H, we can then concentrate on the government's choice problem in period t, subject to the constraint that speculators' beliefs are rational given the government's behavior. This will be addressed below.

At time 0, the government announces a commitment to a fixed exchange rate, and at each subsequent date $t = 1, ..., T$, the government chooses either to maintain the fixed parity (policy F) or to devalue (policy N). In choosing whether or not to defend in a given period, the government minimizes a loss function, reflecting the costs it assigns to abandoning the exchange rate and the costs of defending. If the government is to maintain the fixed parity in period t, it must raise the interest rate to the level i_t^H. This implies a cost of high interest rates to the economy, denoted $\ell(i_t^H, \eta_t)$, where this cost reflects the now standard arguments on the costs of high interest rates: the negative impact on economic activity; the effect of high interest rates on the corporate and financial sectors, with a risk of destabilizing a fragile banking system; the negative impact on mortgage interest rates, especially when these rates are directly indexed to money market rates and defense of the exchange rate requires holding market rates high for significant periods; and the impact of interest rates on increasing the government budget deficit. We assume that increases in η represent a worsening of the economy, so that an increase in η_t implies that $\ell(\cdot, \eta_t)$ rises for any value of i_t.

If the government chooses not to maintain the fixed parity, interest rates can be kept lower, at a level i_t°. For simplicity it is assumed that $\ell(i_t^{\circ}, \cdot) = 0$, which is simply a normalization. However, abandoning the commitment to the fixed exchange rate has a cost x in the period of a devaluation and thereafter. This represents both social loss the government assigns to abandoning the fixed rate (that is, the value to the economy that the government had put on maintaining fixed rates) and the cost it assigns to having reneged on its commitment to a fixed exchange rate.[2] It is assumed that a fixed exchange rate has no other costs *per se*, that is,

[2] Models of abandoning fixed exchange rates typically do not model the value of fixed

costs associated with fixed rates themselves, rather than with the defense of fixed rates. (Alternatively, we could think of $\ell(\cdot,\cdot)$ as including such costs.) It is assumed that *x* is *not* observed by speculators, where governments can differ in their *x*, that is, in the cost they assign to abandoning the fixed exchange rate. A government that is more "committed" to defending the fixed rate is thus modeled as having a higher value of *x*. Whereas the policymaker knows his type, speculators know only the distribution of possible types *x*, as summarized by an initial distribution G(*x*), initially defined over $[\underline{x}, \bar{x}]$, where $\underline{x} > 0$ is the lowest possible type at the beginning of period one. This distribution will be updated over time as a function of observed actions in a way that will be made explicit below.

The decision of a government of whether or not to defend in any period *t* can then be represented as comparing the cost of abandoning the exchange rate to the cost of defending it. Given our assumptions on the irreversibility of the decision to abandon, so that *x* must be paid every period thereafter, the cost of abandoning the exchange rate at *t* can be represented as:

$$x + \beta x + \beta^2 x + \ldots + \beta^{T-t} \tag{1a}$$

The immediate cost of defending at *t* is the loss $\ell(i_t^H, \eta_t)$. Defending today gives the option of either defending or abandoning the exchange rate next period, depending on which has a lower cost. Defending next period in turn allows the option of defending or not the following period, and so on. Hence, the cost of defending today may be represented as (see the appendix):

$$\ell(i_t^H, \eta_t) + \beta\, \mathrm{E}_t \min\left[x + \beta x + \beta^2 x + \ldots + \beta^{T-t-1},\ \ell(i_{t+1}^H, \eta_{t+1}) + \beta\, \mathrm{E}_{t+1}\min(\cdots)\right], \tag{1b}$$

where $\ell(i_{t+1}^H, \eta_{t+1}) \equiv \ell_{t+1}$ is a random variable (due to the randomness of η_t) as of *t*, as are all values of $\ell(\cdot,\cdot)$ dated *t*+2 and higher, with a distribution $F(\ell_{t+1})$ that is induced by the distribution of η_t. (In other words, future cost of defending is uncertain because of uncertainty about the future state of the economy.) In period T the cost of defending is simply $\ell(i_T^H, \eta_T)$ which is compared to *x*. Equating (1a) and (1b) and assuming that a government that is indifferent defends, one can show that the condition in period *t* for defending the exchange rate is:

$$x \geq \ell(i_t^H, \eta_t) - \beta O_{t+1}, \tag{2}$$

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rates *per se*, so that this simple approach is consistent with the literature.

where O_{t+1} is defined by the recursive relation:

$$O_t = \int_{\ell_{t+1}=0}^{x+\beta O_{t+2}} (x+\beta O_{t+2} - \ell_{t+1}) \mathrm{dF}(\ell_{t+1}), \tag{3a}$$

and the terminal condition:

$$O_T = \int_{\ell_T=0}^{x} (x - \ell_T) \mathrm{dF}(\ell_T). \tag{3b}$$

(See the appendix). In (2), O_{t+1} can be interpreted as the "option" value of choosing to defend in the current period.

Note that (2) with equality determines a "cut-off" type x_t^* who is just indifferent between defending and not defending (conditional on having previously defended), given speculative pressures and η_t. Note that an increase in η, by raising the cost $\ell(i_t^H, \eta_t)$ of defending, will raise the cut-off value x_t^*. This observation will be important later on. A government's problem of whether or not to defend is easily represented. A government of "type" x will defend the exchange rate in period t as long as $x \geq x_t^*$. All types that satisfy this condition will defend; all types that do not and have previously defended will abandon the defense in period t.

2.3 *The Evolution of Beliefs over Time and the Nature of Equilibrium*

Using the above results, we can now consider the signal inherent in high interest rates. To do this, we must first consider how information about the government's commitment evolves over time. That is, how does information about the government's possible "type" x evolve as function of past observed policy? The key to answering this question is to note first that if a government chose to defend the exchange rate at t, it is known that its type is greater than or equal to x_t^*. Hence, observing a defense at time t implies that as of the beginning of time t+1, the lowest possible type is x_t^*, that is, $\underline{x}_{t+1} = x_t^*$. Hence the set of possible types as of the beginning of time t+1, is $[x_t^*, \bar{x}]$. Second, note that if the realization of η_t is sufficiently low, all possible types at t will defend, that is, $x_t^* < \underline{x}_t$, so that $\underline{x}_{t+1} = \underline{x}_t$.

We can summarize this discussion in terms of the type of equilibrium that prevails at t, and the evolution of beliefs about government type that it implies. If fixed rates had been maintained until t, then if $x_t^* \leq \underline{x}_t$ (that is, if η_t is sufficiently low), an equilibrium with no probability of devaluation prevails, that is, a "pooling" equilibrium. In this case, policy observed in t gives no new information about type and $\underline{x}_{t+1} = \underline{x}_t$. If instead, $x_t^* > \underline{x}_t$, then a "separating" equilibrium prevails: types in the range $[\underline{x}_t, x_t^*)$ devalue; types in the range $[x_t^*, \bar{x}]$ maintain fixed rates. Observing a defense provides new information about possible types that is used to update beliefs. That is, observing a defense at t when $x_t^* > \underline{x}_t$, speculators "truncate" the set of possible types for t+1, so that $\underline{x}_{t+1} = x_t^* > \underline{x}_t$. Formally, based on the policy action observed in t, speculators update the distribution of possible types and form a new distribution $\mathrm{G}(\mathrm{x} \mid \underline{\mathrm{x}}_{t+1})$ from the initial distribution G(x), defined by:

$$\mathrm{G}(x \mid \underline{x}_{t+1}) = \frac{\mathrm{G}(x) - \mathrm{G}(\underline{x}_{t+1})}{1 - \mathrm{G}(\underline{x}_{t+1})}, \qquad \textbf{(4)}$$

where $\underline{x}_{t+1}$ is defined as above. Updating of possible types provides information on the possible course of future policies that is the essence of the signaling argument.

On the basis of the evolution of $\underline{x}_t$ we can derive rational beliefs of speculators consistent with optimal government behavior. This "closes" the model, since government behavior in each period was based on speculative demand derived from p_t, the probability that speculators assigned to a devaluation. That is, we equate p_t to the probability of a devaluation based on optimal government behavior, where this probability reflects beliefs over possible government types. Given that speculators observe η_t before forming their expectation of p_t, the probability of a devaluation in the current period, conditional on no previous devaluation having been observed, is simply the probability that x lies in the interval $[\underline{x}_t, x_t^*)$ conditional on the cumulative distribution $\mathrm{G}(x \mid \underline{x}_t)$ as defined by (4). This is simply $\mathrm{G}(x_t^* \mid \underline{x}_t)$.

2.4 *High Interest Rates as a Signal*

The signal content of high interest rates follows from the nature of a separating equilibrium as described above. When there is a non-zero probability that a government would not defend (which is necessary for speculators to launch an attack), a defense leads to a discrete upward revision in $\underline{x}_t$. This implies a discrete upward revision in the probability of a future defense under any circumstances in which this probability was less than one. (That is, for any realization of η_t such that $x_t^* > \underline{x}_t$, an increase in $\underline{x}_t$ raises the probability of a defense.) An especially clear example is a defense under a given set of circumstances today (that is, for a specific realization of η_t) implies that the exchange rate will be defended in the future under the same circumstances.[3] (Remember that the distribution of η_t was assumed to be unchanging over time.) This example gives a clear illustration of a disproportionality effect, since the effect in choking off future speculation under identical circumstances is independent of the size of the interest rate increase needed to defend the exchange rate today.

Put another way, this formulation makes it possible to formalize the notion that it may be optimal to "hang tough to send a signal." A government with a relatively high value of x will find it optimal to defend a fixed exchange rate in circumstances in which weaker (that is, lower x) governments would not in order to "separate" itself. By "hanging tough" in difficult circumstances today, a government can induce speculators to raise their expectation of the government's x. This will be especially true when a high value of η_t is seen as transitory.

This model could be extended in several ways. Economic circumstances could be deteriorating over time, as in the basic first-generation model, so that the cost of defense is becoming progressively higher. (Formally, this could be represented by the distribution of η_t changing over time so that high realizations of η are becoming more likely.) Known deterioration would generally imply that there is a lower benefit from defending today. This case is studied in greater detail in Drazen (1999). This effect would be strengthened if deterioration is endogenous to tough defense, for example, when a defense weakens the reserve or the fiscal position of a country, thus making it more vulnerable for future attack. This general sort of argument was explored in a different context in Drazen and Masson (1994); we return to it in section 3.3 below, in the context of signals of the ability to defend the exchange rate.

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[3] Technically speaking, the finite horizon makes this statement inexact, as the same realization of η at a later date implies a different choice problem. It will be strictly correct for an infinite horizon and approximately correct if T is sufficiently far in the future. Conceptually, the point being made should be clear.

The discussion in the previous two paragraphs should shed light on the question of whether or not it is sensible to incur costs today to build a reputation, in the sense of increasing speculators' rational expectation of type. It depends on the government's beliefs about the evolution of η_t. If the government believes that the current ("speculation-inducing") state is transitory, then incurring high costs today to build a reputation is sensible. On the other hand, if the high values of η_t are believed to have a strong permanent component, then hanging tough to build a reputation not only makes little sense, but also implies a futile waste of costly resources. The latter scenario seems to describe the situation of many countries that vainly attempt to maintain a fixed parity, as in the case of the United Kingdom in the early 1990's.

Another extension is to consider the possibility of raising the interest rate even higher than what is necessary to deter current speculation (what we called i_t^H). One might argue that such action is the essence of sending a signal about commitment to defending the fixed exchange rate. I postponed discussion of this issue until now, since I think that the framework that has been set out and the discussion in the previous paragraphs make it easier to understand what is involved. Consider raising the interest rate to a level $i_t^{HH} > i_t^H$, that is, strictly above what is necessary to defend the exchange rate. The higher interest rate implies a higher economic cost $\ell(i_t^{HH}, \cdot)$, so that the associated cut-off level would be $x_t^{**} > x_t^*$. Hence, a "tougher" reputation could be obtained (in the sense of a lower value of $\mathrm{G}\,(x_t^{**} \mid \underline{x}_t)$) at the cost of a larger current economic loss from the interest rate policy used to defend the exchange rate. Allowing a choice of the level of the interest rate used to defend the exchange rate could then be analyzed in a signaling model in terms of considering this trade-off in an intertemporal context. I do not pursue the details here.

3. Signaling Ability to Defend the Exchange Rate

The above model does not allow for interest rate defense to send a *negative* signal. That is, there is no possibility that raising interest rates in the face of a speculative may not only fail to reduce speculative pressures over time, but may actually serve to increase them. Both specific episodes and the findings of Kraay (1998) suggest that this is a real possibility. Since there was only one way to defend the exchange rate in the model, defense signals commitment and thus has a positive effect. Hence, one may ask what signal might be sent by use of interest rate defense when it is used in place of another defense option. This is exactly the question posed in Drazen (2000), in which it is shown that depending on what government characteristics are unobserved, an interest defense may send a negative or mixed signal. In this section we explore this possibility more fully.

In the previous section we concentrated on signaling commitment to defend the exchange rate, with speculation being fueled by the belief that a government is not willing to bear too high costs of defending the exchange rate. Speculation against a currency may also reflect the belief that the government lacks the ability or the resources to defend the exchange rate. The most basic argument here is that a government lacks the reserves to defend the exchange rate, where neither the central bank's reserve position nor its commitment to fixed rates is fully observed by speculators[4], and governments may differ in both of these dimensions, that is, in their "type".

3.1 *Interest Rate versus Borrowing Defense*

The starting point is that in reality, a central bank has a number of actions available to it in meeting a speculative attack. It may intervene in either the forward or the spot market; if it intervenes in the spot market, intervention may be financed with either its own reserves or with borrowed reserves; it may restrict domestic credit to speculators or raise the interest rate at which they borrow; or may put controls on credit to specific borrowers or on other foreign exchange operations (such as foreign exchange swaps). Except for the strategy of imposing credit controls, active defense strategies come down to either letting interest rates increase to reduce speculative demand, or using its reserves to meet demand (or some combination of these), where this strategy often entails borrowing reserves to meet large outflows, hence the term "borrowing defense."

A borrowing defense has costs, though of a different nature than those of a high interest rate defense. If the fixed rate is successfully defended, then the reserve outflow associated with then attack will be reversed, so that borrowing can be easily paid back. The cost is the interest cost of borrowing, though this may not be large, especially if borrowing is from other central

[4] The idea is that published statistics on foreign exchange reserves do not give a fully accurate picture of reserves available to defend the exchange rate.

banks under existing short-term financing facilities. However, if there is a devaluation, then closing the short position in foreign currency can be quite costly. It is this which leads central banks to limit their short positions and which constitutes the principal direct cost of a borrowing defense.

The key point is that when both a borrowing and an interest rate defense are possible, these strategies have *different* costs, depending on whether or not there is a devaluation. To make this more specific, consider the following reasonable assumptions. An interest rate defense is costly (in terms of the costs of high interest rates) whether or not there is a devaluation, whereas a borrowing defense may have small effects on welfare if it is successful, but large effects if it is unsuccessful, given the capital loss the government suffers from a devaluation. Hence, the cost of a borrowing defense may be less than an interest rate defense if defense is successful, but greater if it is unsuccessful. It is this ranking of relative costs that is crucial for results in Drazen (2000). Given the oft-observed unwillingness of countries to engage in massive borrowing (or the very high costs they incur if they do borrow massively and then devalue), this ranking seems realistic. If borrowing defense was always less costly than an interest rate defense, the latter would never be observed.

Our assumptions about the menu of policy options means that current-period ℓ can take on a number of possible values, corresponding to: interest rate defense (with or without devaluation); successful borrowing defense; and unsuccessful borrowing defense. We denote these as $\ell^{H}, \ell^{ZS}, \ell^{ZU}$ respectively, with the ranking:

$$\ell^{ZU}(\cdot) > \ell^{H}(\cdot) > \ell^{ZS}(\cdot) \ , \qquad \textbf{(5)}$$

To summarize, a successful borrowing defense (with minimal increases in interest rates) is least costly defense. A defense via raising domestic interest rates will be costly for the reasons stressed in section 2 whether or not it prevents a devaluation. The inequality reflects the assumption that foreign currency borrowing does not drive up domestic interest rates in equilibrium to the same extent as the interest rate defense, that is, the interest rate defense, even if successful entails a larger social cost than a successful borrowing defense. The key assumption is that $\ell^{ZU} > \ell^{H}$, that is, an unsuccessful borrowing defense is seen by the government as more costly than an interest rate defense. That is, a borrowing defense is preferred if it is successful but not if it is unsuccessful. The source of this distinction is the significant capital loss on its short foreign currency position that a central bank will suffer if it borrows massively and then devalues.

3.2 *A Basic Model – Setup*

The role of these assumptions can be seen in a model that is a variant of the one presented in section 2. A full treatment may be found in Drazen (2000). A key change is that there must be a possibility that the government mounts a defense that subsequently fails. Abandoning the fixed exchange rate may reflect not only a policy decision even when reserves are sufficient to continue, but also the realization of an adverse reserve shock. For simplicity of exposition, we represent this as a probability $q(R_t)$, where R_t are reserves of the central bank at the beginning of the period, and where $q' < 0$. As indicated above, it is assumed that speculators do not observe the government's reserve position as of the beginning of the period, as well as not observing their x.

In this extended model, the sequencing of actions is as follows. At the beginning of each period speculators choose how much to speculate against the currency, on the basis of previously and currently observed variables, the distribution of unobserved variables, the probability they assign to a devaluation at the end of the period on the basis of those distributions, and the interest cost of speculation. The central bank then chooses whether or not to defend the fixed exchange rate, and if so, whether to do so via borrowing or raising interest rates. (If it chooses not to defend, it devalues at the beginning of the period.) After the central bank has chosen a defense, there is a shock to reserves that may force a devaluation, as represented in the previous paragraph. Hence, the model allows both devaluation as a policy choice, consistent with second-generation models of currency crisis, and devaluation as unavoidable due, for example, to running out of reserves, as in first-generation models of currency collapse. At the end of the period, speculators exchange their foreign currency for domestic currency and pay off their borrowing. In the case of no devaluation, speculators update the probability of a devaluation in the following period.

3.3 *Signaling Ability to Defend*

One may then ask how a government will behave when both its *x* and its *R* are not observed. A key result in Drazen (2000) is that a government that chooses an interest rate defense is one with a high *x*, but a low *R*, that is, with a strong commitment to fixed rates to defend, but with a relatively weak reserve position. The result and the intuition behind it may be illustrated by considering period *T*. With a probability *q* of a devaluation and using the fact that the loss from an interest rate defense is the same whether or not there is a devaluation, the expected loss from an interest defense is:

$$q(x+\ell^{\mathrm{H}})+(1-q)\,\ell^{\mathrm{H}}=qx+\ell^{\mathrm{H}}\,, \tag{6}$$

and the expected loss from a borrowing defense that implies the same level of reserves is:

$$q(x+\ell^{\mathrm{ZU}})+(1-q)\,\ell^{\mathrm{ZS}}\,. \tag{7}$$

Equating (9) and (10), we obtain a critical value of the devaluation probability, call it $q_T^*(\cdot)$ such that the government is indifferent between the two policies. This in turn implies a critical level of reserves, R_T^*, namely

$$R_T^*=q^{-1}(q_T^*[\cdot])\,. \tag{8}$$

For $R_T \geq R_T^*$, (5) implies that the expected loss from an interest rate defense in (6) exceeds the expected loss from a borrowing defense in (7), so that a borrowing defense is chosen, while for $R_T < R_T^*$, the ranking of the expected loss from the two policies is reversed, so that the interest rate defense is chosen.

In Drazen (2000) it is shown (in the context of a two period example that could be extended) that the government's decision in an earlier period is similarly characterized once the signal inherent in type of defense is taken into account, namely that a government with reserves below a critical level will choose an interest rate defense (if it chooses to defend), while one with a higher level of reserves will choose a borrowing defense. The intuition of these results is straightforward. Suppose that the fixed rate must be abandoned if the reserve position is too low and that the reserve position is also affected by exogenous reserve shocks, as discussed above.

Then, a central bank with a low level of reserves would have a greater incentive to hold onto its reserves than one with a high level of reserves, and hence would be more likely to use an interest rate defense than a reserve defense to try to maintain the fixed rate. (Of course in a separating equilibrium, low reserve governments find it optimal to choose the interest rate defense in spite of the negative signal it sends, due to the risks of either letting reserves run down or of borrowing reserves.) Hence, raising interest rates would signal low reserves and hence may only encourage further speculation.5 In terms of our earlier terminology, if raising interest rates is taken as a signal of low reserves, there may be a "perverse feedback" effect.

Conditional on the type of defense chosen, we can then ask the question of whether or not a defense is undertaken. This is the question address in section 2. Combining those results with the results here, one may argue that observing an interest rate defense indicates that $R_t < R_t^*$ and that $x \geq x_t^*$. Hence, observing an interest rate defense is a mixed signal, as it indicates a high degree of commitment to the fixed rate, but a low level of *R*, that is, weak fundamentals.

An alternative story is one where high interest rates signal strong fundamentals. Suppose that rather than reserves, the key fundamental that is not fully observed is the government's fiscal position. To see why this can be a positive signal when the fiscal position is unobserved, consider first the case where it is observed. High interest rates weaken the government's fiscal position, so that a tough defense today may actually lower the credibility of the fixed rate tomorrow due to the deterioration in the fiscal position it implies. (This is the effect stressed by Drazen and Masson [1994].) This is true both for weak fiscal fundamentals and for other structural weaknesses. It also suggests one reason why an interest rate defense is not mounted, as in the case of the United Kingdom in September 1992.

If the fiscal position is unobserved, than the willingness to raise the interest rate may signal a strong fiscal position, since the negative impact of high rates may be stronger the weaker is the fiscal position. That is, the worse the fiscal position, the less willing the government will

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5 In common parlance, a high interest rate defense might signal that the government is "panicking" due to a weak reserve position.

be to raise interest rates to defend the currency (and the more fragile is the fixed exchange rate if the government's fiscal position is important to its health). Hence, if, for example, the level of government debt that is not fully observed, raising interest rates in defense of the currency is a signal of fiscal health and may have a positive effect in deterring speculation beyond what the increase in the arithmetic cost of borrowing would imply.

To close the model, one calculates the probability that the fixed exchange rate collapses in a period, where this includes the possibility that the government chooses not to defend and that the fixed rate collapses due to an exogenous shock, and where this depends on the distribution of the unobserved fundamental. For example, in the case of unobserved reserves and commitment, the probability that speculators assign to collapse would be of the form:

$$p_t = \int_{R_t} (\mathrm{G}\,[x_t^*(R_t) \mid j_{t-1}] + (1 - \mathrm{G}\,[x_t^*(R_t) \mid j_{t-1}])\,\Omega(R_t))\,\mathrm{d}\Psi(R_t \mid j_{t-1}) \qquad \textbf{(9)}$$

where $\Omega(R_t)$ is the probability of a shock forcing devaluation conditional on R_t, $\mathrm{G}\,[x_t^*(R_t) \mid j_{t-1}]$ is the cumulative distribution of commitment types conditional on policy previously observed, , denoted j_{t-1}, and $\Psi(R_t \mid j_{t-1})$ is the cumulative distribution of reserves conditional on the policy previously observed. Lower reserves make a devaluation more likely both because a given *x* type is less likely to defend and because having chosen to defend he is more likely to be forced to devalue due to an exogenous shock.

4. Testing the Signaling Approach

In this section, we quickly review some evidence on whether the signaling approach is relevant, based on Hubrich (2000) and Drazen and Hubrich (20001).

4.1 *Country Characteristics*

Hubrich (2000a) considers whether the effectiveness of restrictive monetary policy during an attack actually differs according to certain characteristics, such as debt or prior reserves, and finds evidence that this is the case in a large, cross-country sample of speculative attacks on fixed exchange rates. Attacks are identified as large observations of an index aggregating reserve losses and exchange rate devaluations. The policy variables considered are domestic credit (the net domestic assets on the central bank's balance sheet) and the nominal discount rate. The stance of policy is determined as the policy during the attack relative to a prior average, where of course a contractionary policy refers to contractions in domestic credit or increases in the discount rate. The sample is then split into a 'high' and a 'low' subsample according to a certain characteristic, and the policy rule has been obtained separately for each subsample. Comparing the policy rule between the two subsamples, he examines whether the policy pursued during an attack is related to country characteristics in a way that, if the characteristic were unobserved, could signal crucial information. He finds that contractionary policies are more likely for countries characterized by low reserves or low public debt. The former is fully consistent with the 'perverse" signaling effect discussed above, whereby governments with low prior reserves are more likely to use an interest rate defense rather than a reserve-based defense. The latter finding is in line with the positive signaling argument presented for the case of unobserved fiscal fundamentals, whereby a country with high public debt is averse to an interest rate defense because of the impact on its fiscal position.

However, note that these findings are a rather weak test for the signaling hypothesis. If we found these characteristics did not matter (or mattered in the wrong direction), such a finding *would* have constituted strong evidence against signaling. However, finding that the policy rule *does* differ in the required manner is only the first step *towards* a signaling mechanism. In addition, signaling requires that these characteristics are not observed by investors, which is much more difficult to establish, and was not pursued in Hubrich (2000a).

4.2. *The Term Structure of Exchange Rate Expectations*

Since the signaling framework outlined above is based on policy providing information about exchange rate fundamentals otherwise unobserved, a natural direct test consists of relating exchange rate expectations to that policy. Signaling models suggest that 'temporary' policies have 'permanent' effects, in the sense that the signaling effect of high interest rates may outlast the high interest rate policy itself. This can be examined by looking at the 'term structure' of exchange rate expectations – does interest rate policy affect exchange rate expectations similarly at all horizons, or does it only have an impact on short-term expectations? The more the effect is spread out across the entire term structure, the more it would seem that something ‘fundamental’ is being signaled. Drazen and Hubrich (2001) present evidence using a set of survey data for exchange rate forecasts of different horizons to study the effect of interest rates on exchange rate expectations during the 1992/3 ERM crisis and in Brazil during the various crises between 1994 and 1998.

As far as signaling, there were two key findings. First, there is evidence of ‘disproportionality’, in that the effects are mostly smaller in absolute value the larger the total interest rate increase is. This suggests that much of the information effect is already triggered by comparatively small interest rate defenses, and that resorting to very high interest rates adds little information.

Second, there is a striking and pervasive difference between short-term and long-term effects. The typical picture is that short-term effects are negative (representing improved expectations) for the very short term, and then gradually increase as the term becomes longer, ending up in positive territory for the forecasts 12 months out or more (representing a deterioration of long-term expectations). Drazen and Hubrich (2001) suggested that this may reflect two signaling effects at work. First, there is a short-term effect in that high interest rates today signal high interest rates (or strong commitment) for a couple of months to come. This effect is skewed towards the short term and dominates the short term results, but dies out in the medium-to long term. The other effect is a ‘negative’ signaling effect where high interest rates signal bad news about the overall fundamentals of the peg, deteriorating expectations at all horizons alike. This negative effect is outweighed by the policy signal in the short term, but comes through dominantly in the medium-to long term as the policy signal dies out. This picture is consistent with the mixed signal of an interest rate defense discussed at the end of section 3.

Drazen and Hubrich find that that these results are remarkably consistent across countries the countries in their sample, including Brazil. This suggests that signaling effects are surprisingly similar among fixed exchange rate regimes, even when the countries behind them are fairly different.

A final note of caution. Some of these findings are also consistent with alternative hypotheses, such as the “revisionist” argument of Furman and Stiglitz (1998) that the effect of high interest rates on the banking sector leads to an increase in default risk. They are also in part consistent with first-generation models of interest rate defense (see Flood and Jeanne [2000] or Lahiri and Vegh [2000]) in which an interest rate defense may bring the crisis forward because of its impact on the very macroeconomic fundamentals (specifically, debt) underlying the peg.

5. Conclusions

In this paper I have set out some basic results on the signaling effect of high interest rates. As indicated in the introduction, the goal was neither to present a comprehensive or extremely technical exposition, nor to concentrate on new results. The aim was to present a fairly simple presentation of the main concepts and results, with the hope of making the ideas clear for a wider audience. My further aim was to try to convince readers of the usefulness of this approach in explaining the empirical findings about the effectiveness of interest rate defense. Towards this end, I also surveyed some econometric evidence consistent with the signaling approach. While the tests are open to alternative explanations, they provide significant evidence towards the importance of signaling.

Appendix

We here derive the condition (2) for an interest rate defense and the associated definition for O_t. In period T, the condition for a defense is obviously:

$$x \geq \ell(i_T^H, \eta_T) \quad . \qquad \textbf{(A1)}$$

As of period T-1, the central bank may devalue (at a present discounted cost of $x + \beta x$) or may defend, in which case it faces a cost of $\ell(i_{T-1}^H, \eta_{T-1}) \equiv \ell_{T-1}$ and then chooses optimally in period T according to (A1). Thus, the condition for a defense in period T-1 is:

$$x + \beta\, x \geq \ell(i_{T-1}^H, \eta_{T-1}) + \beta\, \mathrm{E}_{T-1} \min(x, \ell_T), \qquad \textbf{(A2)}$$

where ℓ_T is a random variable as of time T-1. The "min" operator implies that:

$$\mathrm{E}_{T-1} \min(x, \ell_T) = \int_{\ell_T=0}^{\ell_T=x} \ell_T \,\mathrm{dF}(\ell_T) + \int_{\ell_T=x}^{\ell_T=\infty} x \,\mathrm{dF}(\ell_T) \equiv x - \int_{\ell_T=0}^{\ell_T=x} (x-\ell_T)\mathrm{dF}(\ell_T), \qquad \textbf{(A3)}$$

so that (A2) becomes:

$$x \geq \ell_{T-1} - \beta \int_{\ell_T=0}^{\ell_T=x} (x-\ell_T)\mathrm{dF}(\ell_T), \qquad \textbf{(A4)}$$

with the second term on the right-hand side defining O_T. Similarly, in period T-2, we may write the condition for a defense as:

$$x + \beta\, x + \beta^2 x \geq \ell(i_{T-2}^H, \eta_{T-2}) + \beta\, \mathrm{E}_{T-2} \min[x + \beta\, x, \ell_{T-1} + \beta\, \mathrm{E}_{T-1} \min[x, \ell_T]], \qquad \textbf{(A5)}$$

where ℓ_T and ℓ_{T-1} are random variables as of time T-2. Working from the inside bracket outward, one obtains:

$$x \geq \ell_{T-2} - \beta \int_{\ell_{T-1}=0}^{\ell_{T-1}=x+\beta O_T} (x-\ell_{T-1})\mathrm{dF}(\ell_{T-1}), \qquad \textbf{(A6)}$$

with the second term on the right-hand side defining $O_{T\text{-}1}$. In this manner one can easily derive that the condition for a defense in period t is as given in (2).

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