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Interest Rate Defense against Speculative Attack as a Signal
A Primer

Allan Drazen

2.1 Introduction

In the light of recent currency crises, two key policy questions are how to defend a currency against attack and what the effects of different avenues of defense are. A commonly used 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 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, whereas 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 a sample of over 300 successful and failed attacks, 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

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The empirical work surveyed here is either from Stefan Hubrich's thesis or done jointly with him. The author owes him a large debt of gratitude for countless conversations on these issues. Financial support from the Yael Chair in Comparative Economics, Tel-Aviv University is also gratefully acknowledged.

currency crises. He finds that raising the nominal discount rate may *increase* the probability of a successful 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 is deterring a speculative attack is only beginning to receive attention.[1] Textbook models indicate that with imperfect capital mobility high domestic currency interest rates are a tool to attract 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 make 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 percent $[(1.005^{365} - 1) \times 100 = 517]$ to make speculation unprofitable. (See, e.g., the discussion in Furman and Stiglitz 1998, 75–76.)

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. Although 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 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.

1. Formal models of an interest rate defense include Lall (1997), Drazen (2001), Lahiri and Végh (2000), Drazen (2000), and Flood and Jeanne (2000).

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 policy makers 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 to signal 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 use 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, as it were, to interest rate defense as a signal. Thus, the stress is on simple models meant to get the basic points across. The plan of the paper is as follows. In section 2.2, I discuss interest rate defense as a signal of commitment to defending the exchange rate. In section 2.3, 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 2.4 presents some empirical evidence on the signaling hypothesis. Section 2.5 contains conclusions.

2.2 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 (2001).

2.2.1 Basic Structure and Assumptions

Consider a finite-horizon discrete time model of 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, and so on; 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, which we will call i_t^o.

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 later). 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, whereas 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 later some implications of raising interest rates to even higher levels to signal even greater "toughness."

Third, for simplicity of exposition, I do not 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 (2001), 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.

2.2.2 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 the decision of how large a position to take, given the probability they assign to the fixed exchange rate's 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 later.) As indicated above, this determines an interest rate consistent with defending the exchange rate in each period denoted i_i^H. Given i_i^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 later.

At time 0, the government announces a commitment to a fixed exchange rate, and at each subsequent date $t = 1, \ldots, T$, 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_i^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^o. For simplicity it is assumed that $\ell(i_t^o, \cdot) = 0$, 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 the 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, 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 policy maker knows his type, speculators know only the distribution of possible types x, as summarized by an initial distribution $G(x)$, initially defined over $[\underline{x}, \overline{x}]$, 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.

2. Models of abandoning fixed exchange rates typically do not model the value of fixed rates per se, so this simple approach is consistent with the literature.

Hence, the cost of defending today may be represented as (see the appendix)

$$\text{(1b)} \qquad \ell(i_t^H, \eta_t) + \beta E_t \min [x + \beta x + \beta^2 x + \ldots + \beta^{T-t-1}, \ell(i_{t+1}^H, \eta_{t+1}) + \beta E_{t+1} \min(\cdots)],$$

where E_t is the expectations operator and $\ell(i_{t+1}^H, \eta_{t+1}) \equiv \ell_{t+1}$ is a random variable as of t (due to the randomness of η_{t+1} and ℓ_{t+1} as of t), as are all values of $\ell(\cdot,\cdot)$ dated $t + 2$ and higher, with a distribution $F_{t+1}(\ell_{t+1})$ that is induced by the distribution of η_{t+1}. (In other words, the 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 equations (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

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

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

$$\text{(3a)} \qquad O_{t+1} = \int_{\ell_{t+1}=0}^{\ell_{t+1}=x+\beta O_{t+1}} (x + \beta O_{t+1} - \ell_{t+1})\, dF_{t+1}(\ell_{t+1})$$

and the terminal condition

$$\text{(3b)} \qquad O_T = \int_{\ell_T=0}^{\ell_T=x} (x - \ell_T) dF_T(\ell_T).$$

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

Note that equation (2) with equality determines a cutoff 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 cutoff value x_t^*. This observation will be important later. A government's problem of whether 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.

2.2.3 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 a 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 $[x_t^*, \overline{x}]$. 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 $[x_t^*, \overline{x}]$ 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 $G(x \mid \underline{x}_{t+1})$ from the initial distribution $G(x)$, defined by

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

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, because 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's having been observed, is simply the probability that x lies in the interval $[\underline{x}_t, x_t^*)$ conditional on the cumulative distribution $G(x \mid \underline{x}_t)$ as defined by equation (4). This is simply $G(x_t^* \mid \underline{x}_t)$.

2.2.4 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 nonzero 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 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 1. (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 that 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, because 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, as it were. 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's 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 (2001). 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 to future attack. This general sort of argument was explored in a different context in Drazen and Masson (1994); we return to it in section 2.3.3, in the context of signals of the ability to defend the exchange rate.

The discussion in the previous two paragraphs should shed light on the question of whether 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

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.

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 1990s.

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, because 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 cutoff level would be $x_t^{**} > x_t^*$. Hence, a tougher reputation could be obtained (in the sense of a lower value of $G(x_t^{**} \mid \underline{x}_t)$) 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 tradeoff in an intertemporal context. I do not pursue the details here.

2.3 Signaling Ability to Defend the Exchange Rate

The foregoing 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 attack not only may fail to reduce speculative pressures over time, but may actually serve to increase them. Both specific episodes and the findings of Kraay (1999) suggest that this is a real possibility. Because 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.

2.3.1 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 either with its own reserves or with borrowed reserves; it may restrict domestic credit to speculators or raise the interest rate at which they borrow; or it 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). This strategy often entails borrowing reserves to meet large outflows, hence the term *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 there is a devaluation. If the fixed rate is successfully defended, then the reserve outflow associated with the attack will be reversed, so that borrowing can be easily paid back. The cost is the interest cost of borrowing, although this may not be large, especially if borrowing is from other central 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 that leads central banks to limit their short positions and that constitutes the principal direct cost of a borrowing defense. Hence, the cost of a borrowing defense may be less than that of an interest rate defense if defense is successful, but greater if it is unsuccessful.

Denoting by ℓ^{H}, ℓ^{ZS}, and ℓ^{ZU} an interest rate defense (with or without devaluation), a successful borrowing defense, and an unsuccessful borrowing defense, we may represent relative costs by the ranking

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

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. In other words, 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.

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.

2.3.2 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 2.2. 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 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.

2.3.3 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 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

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

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

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

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

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

For $R_T \geq R_T^*$, equation (5) implies that the expected loss from an interest rate defense in equation (6) exceeds the expected loss from a borrowing defense in equation (7), so that a borrowing defense is chosen, whereas 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.

Drazen (2000) shows (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; that is, a government with reserves below a critical level will choose an interest rate defense (if it chooses to defend), whereas 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 borrowing reserves.) Hence, raising interest rates would signal low reserves and thus may only encourage further speculation.[5] To employ our earlier terminology, if the raising of 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 a defense is undertaken. This is the question addressed in section 2.2. 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, 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 in which 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

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

a positive signal when the fiscal position is unobserved, consider first the case in which 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 that an interest rate defense is not mounted, as in the case of the United Kingdom in September 1992.

If the fiscal position is unobserved, then the willingness to raise the interest rate may signal a strong fiscal position, because 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 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 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

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

where $\Omega(R_t)$ is the probability of a shock forcing devaluation conditional on R_t, $G[x_t^*(R_t)\,|\,j_{t-1}]$ is the cumulative distribution of commitment types conditional on policy previously observed, denoted j_{t-1}, and $\Psi(R_t\,|\,j_{t-1})$ 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.

2.4 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 (2002).

2.4.1 Country Characteristics

Hubrich (2000) 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, Hubrich 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 previously discussed, whereby governments with low prior reserves are more likely to use an interest rate defense 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 *toward* 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 (2000).

2.4.2 The Term Structure of Exchange Rate Expectations

Because 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 (2002) 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 1992–93 ERM crisis and in Brazil during the various crises between 1994 and 1998.

As far as signaling, there were several key findings. First, although there was generally little or no clear statistically significant effect of raising interest rates on next month's expected exchange rate, this result masks significant effects on different components of the expected exchange rate and at different horizons. There was some evidence of a positive (i.e., appreciating the exchange rate) short-term effect, coupled with a negative longer-term effect, at horizons of twelve months or longer. An increase in overnight interest rates often induces an increase in the n month ahead rate relative to the k month ahead rate ($n > k$), thus implying an appreciation of next month's exchange rate, but also an increase in risk premiums and the exchange rate forecast a year ahead, implying a depreciation.

Second, the effects of changes in overnight interest rates that are observed are clearly nonlinear, often significantly so, and these effects may be either concave or convex. This is in contrast to the simple "arithmetic" argument for the effect of raising interest rates, but it is consistent with the signaling explanation (as well as some other explanations). 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.

To summarize, the typical picture is that short-term effects are negative (representing improved expectations) for the very short term, and then they gradually increase as the term becomes longer, ending up in positive territory for the forecasts twelve months out or more (representing a deterioration of long-term expectations). Drazen and Hubrich (2002) 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 toward the short term and dominates the short-term results, but it dies out in the medium to long term. The other effect is a negative signaling effect, in which 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 it 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 2.3.

Drazen and Hubrich find that that these results are remarkably consistent across 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 Végh 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.

2.5 Conclusions

In this paper I have set out some basic results on the signaling effect of high interest rates. As was 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. To this end, I also reviewed some econometric evidence consistent with the signaling approach. Although the tests are open to alternative explanations, they provide significant evidence toward the importance of signaling.

Appendix

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

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

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 equation (A1). Thus, the condition for a defense in period $T-1$ is

$$\text{(A2)} \qquad x + \beta x \geq \ell(i_{T-1}^H, \eta_{T-1}) + \beta E_{T-1} \min(x, \ell_T),$$

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

$$\text{(A3)} \quad E_{T-1}\min(x, \ell_T) = \int_{\ell_T=0}^{\ell_T=x} \ell_T dF(\ell_T) + \int_{\ell_T=x}^{\ell_T=\infty} x dF(\ell_T) \equiv x - \int_{\ell_T=0}^{\ell_T=x} (x - \ell_T) dF(\ell_T),$$

so that equation (A2) becomes

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

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

(A5)
$$x + \beta x + \beta^2 x$$
$$\geq \ell(i^H_{T-2}, \eta_{T-2}) + \beta E_{T-2} \min\{x + \beta x, \ell_{T-1} + \beta E_{T-1} \min[x, \ell_T]\},$$

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

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

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

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Comment Robert P. Flood

The last time I commented on Allan Drazen's work on the interest rate defense of a fixed exchange rate was at the Spring International Finance and Macroeconomics meeting in Cambridge two years ago. I now think I got the interest rate defense issue almost half right at those meetings.

My discussion then was connected to Drazen's work at three points. First, both Drazen's work and my discussion took off from some kind of policy-exploitable wedge in the uncovered interest parity (UIP) relation. Without such a wedge, interest rate policy has no real-interest rate implications and is either a nonstarter—end of story—or it is really a nominal aggregates defense.

Second, in all of the work, beliefs about future policy actions determine, in part, market reactions to current policy moves. That's pretty standard. Drazen's emphasis has been on the rational formation of beliefs by private agents concerning some relevant information known only to the policy maker that cannot be revealed directly to the public in a completely convincing way.

Third, the two strands of work are "connected in the breach" in terms of fiscal policy. In, for example, Flood and Jeanne (2000; hereafter FJ), the real primary fiscal deficit/surplus is assumed invariant to the interest rate defense. This, plus perfect capital mobility, is the source of FJ's results. In Drazen's work, in contrast, feedback from the fiscal deficit is not modeled. I am fairly sure the only way he could be ignoring fiscal implications is if it is assumed implicitly that the primary deficit/surplus adjusts to pay the cost of the interest defense.

In my discussion today I want to do two things while keeping my eye on one other thing: First, as I said above, my previous discussion was almost half right. In later work (FJ), Olivier Jeanne and I got it completely half right. I would like to show the direction that I now think is more than half right. Second, I'll talk a little toward the end about adding aspects of signaling about future policy moves in this setup. Third, while I do the above, I will be clear about this fiscal deficit/surplus.

Here is a quick recap of the FJ-type results. FJ is a *shadow-rate* model (i.e., hypothetical flex rate with reserves exhausted). The FJ "money stuff" is suppressed presently.[1]

$$i_t = i^* + E_t e_{t+1} - e_t + \theta\left(\frac{N_t}{P_t}\right) \quad \text{portfolio balance}$$

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1. At the end of this comment I discuss some of the (not very important) shortcuts, for example, "money stuff," that I use for presentation purposes.

$$\left(\frac{N_{t+1} - N_t}{N_t}\right) = i_t + \left(\frac{P_t d}{N_t}\right) \quad \text{nominal deficit}$$

$$\ln(P) = e \qquad \text{PPP}$$

where N is nominal debt, P is the price level, d is the real deficit/surplus, $(g - t)$ *minus real seigniorage*, for simplicity. In FJ, after an attack, the real side of the model is fixed and $N/P = PV(d)$, where PV represents the present value operator.

These are the results:

1. Raising i before a potential speculative attack always depreciates the shadow currency and thereby brings the attack closer in time.
2. Raising i after a speculative attack can appreciate the shadow value of the currency before the attack (strengthen the currency) if the economy is on the upward-sloping part of seignorage "Laffer Curve;" that is, raising i post-collapse will increase d through seigniorage.

Although I'm sure FJ is logically correct, I'm just as sure that the seigniorage Laffer curve really can't be what's going on here. If the above is half right, which I think it is, what is (somewhat) more than half right?

Let's make the following changes:

$$i_t^s = i^{*s} + E_t e_{t+1} - e_t + \theta\left(\frac{N_t}{P_t}\right)$$

represents portfolio balance (watch for little s's). I am now using the portfolio balance condition for short-term debt, denoted s. Disaggregate government debt payments by term to maturity into

$$\frac{N_{t+1} - N_t}{N_t} = i_t^s\lambda + i_{t-1}^l(1 - \lambda) + \left(\frac{P_t d}{N_t}\right).$$

This is the nominal deficit again, but with debt shares. The short-term debt share is λ, with $0 \leq \lambda \leq 1$. Watch d. Remember too that i_{t-1}^l is contractual from last period.

Finally, make price (P) predetermined[2]

$$\ln(P_t) = E_{t-1}e_t \quad \text{sticky prices.}$$

The way I want to pay for the interest rate increase here is with N during period t and then for Pd to increase permanently next period by *just enough to service the new debt*. The budget was balanced before the interest rate defense, and it returns to balance in the period after the defense. This is needed just to keep the math simple. (Drazen must be doing something like this in the background, or else his fixed rate would explode. More on this later.)

2. This is the model of Flood and Engel (1985), with an as yet unspecified yield curve.

To see how the model works, let $\lambda = 1$, and suppose it is announced and believed that i_t^s is to be increased by, say, 10 percentage points (e.g., 0.10 to 0.20) for one period (one year) and then returned to its previous level and the budget rebalanced. Then, with N_t and P_t predetermined, N_{t+1} will increase by 10 percent as will other nominal variables. Since e_t+1 will rise by the full 0.10, the current level of e_t need not move. The defense is ineffective—worse, actually, in terms of next period.

Now suppose $0 < \lambda < 1$: not all debt is short-term. Holding i_{t-1}^l fixed by contract at $t-1$, N increases now by the proportion λ*0.10, and other nominal variables increase in the same proportion. Since i_t^s rose by the full 0.10, however, e_t must fall by $(1-\lambda)$*0.10.

The implication is simple, plausible, and pretty obvious: low short-term (ST) debt makes it possible to "stick it to" long-term (LT) debt owners in an effective surprise *temporary* defense. Basically, the unwary LT debt owners are being taxed with a capital loss that is passed on to money and ST debt owners.

That a temporary short-term interest rate increase can strengthen the (shadow) currency when prices are sticky is an "interest rate policy update" of the famous Dornbusch overshooting result. Recall Dornbusch's finding that a (surprise) once-and-for-all monetary increase results in a more than proportionate short-term currency depreciation. Presently, a (surprise) short-term interest rate increase results in an equal increase in expected currency depreciation and *future* nominal debt expansion. Positioning for the required expected depreciation may require an initial currency appreciation (the flip side of overshooting).

The following are some things to work on:

1. There is a long-term bond price that I have left out for simplicity. A term-structure theory will price new LT bonds. (Second-period LTs are priced at $[\{1 + i_{t-1}^l\}/\{1 + i_t^s\}]$, but first-period LT pricing needs a bit of modeling. For now I'm assuming 100 percent ST financing on the margin.)

2. There seems to be a government versus LT bond holder game that must be lowering the price of LT bonds and influencing deficit financing. This may be making countries move more toward ST debt financing, particularly in turbulent times.

3. The way we got the math to work out is if the private sector believes with probability 1 that the interest rate increase is temporary, one period. If it lasts longer (say it dies away at the rate ρ where $0 < \rho < 1$), then $E_t e_{t+1}$ will rise by more than λ*0.10, so e_t need not fall.

Somehow the government must convince the private sector about temporariness with reference to i^s and about the debt-service cleanup with future *Pd*. This is exactly the problem Drazen is addressing, but in a slightly different setting. He uses i^s to convey *both* the promise of an interest check to bond holders and information about likely future actions.

Models of the Krugman, Flood, and Garber (KFG) type were based on agents who use unlimited data to infer correctly average future policy actions—the standard rational expectations methodology of the 1970s and 1980s. The innovation of many more recent models is an apparent "taste change" by both policy makers and researchers. Agents in the newer models have more realistic data endowments and therefore cannot possibly determine perfectly average future government actions.

Complete models that have both signaling and (say) KFG fundamentals will have reduced-form coefficients on fundamentals with a KFG part and a signaling part. Model-constrained estimation will allocate the importance of the parts.

Finally, there are two more areas that warrant further work:

1. Although the interest rate defense may have worked this period, there is nothing we have done to indicate it did not set in motion events that will spell the fixed rate's demise next period.
2. When Drazen discusses his and Hubrich's key empirical findings he invokes a second signaling effect, which makes all this appear remarkably similar to the standard fundamentals story.

These are some places where I have cheated (a little):

1. The complete (in levels) UIP "wedge" is $\theta[(N - M)/P]$. I've left out the M/P term. It complicates things but does not change the argument fundamentally.
2. $d = g - t + i(M/P)$
3. In the disaggregated part, I've said that the wedge in ST UIP depends on real ratio aggregate debt N/P, where N is total debt.

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Discussion Summary

Michael P. Dooley remarked that if a successful interest rate defense depends on whether the incurred losses are imposed on the private sector, it is crucial whether the government is truly separated from the private sector.

Andrew Berg noted that Hong Kong conducted an interest rate defense without a large change in debt position.

Vince Reinhart remarked that a successful defense has implications for the term structure of interest rates and asked about the consequences of the endogeneity of interest rate defenses. He pointed to the question of whether the costs of a defense are hurting the government or the society as a whole and noted that in the discussant's model the costs are inflicted on the holders of consols.

Robert P. Flood remarked that the interest rate defense is factored into the long-run prices of debt.

John McHale made reference to the early stages of the Asian crisis and pointed to the importance of transparency.

Olivier Jeanne remarked that the presented model would benefit from the addition of two-sided imperfect information.

Allan Drazen acknowledged that two-sided imperfect information is desirable, but it also substantially complicates the model. He remarked that the economic costs of giving in to a speculative attack are not the only costs incurred; there is also the cost of losing face to be considered. Regarding the issue of whether the private sector or the government picks up the tab, he argued that a government will have an incentive for setting up an interest rate defense and inflicting the costs of borrowing on others, provided that there is time to readjust the fiscal position after the attack.