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ABSTRACT

Mixed Signals in Defending the Exchange Rate: What do the Data Say?*

High interest rates to defend the exchange rate signal that a government is committed to fixed exchange rates, but may also signal weak fundamentals. We test the effectiveness of the interest rate defense by disaggregating into the effects on future interest rates differentials, expectations of future exchange rates, and risk premia. While much previous empirical work has been inconclusive due to offsetting effects, tests that 'disaggregate' the effects provide significant information. Raising overnight interest rates strengthens the exchange rate over the short-term, but also leads to an expected depreciation at a horizon of a year and longer and an increase in the risk premium, consistent with the argument that it also signals weak fundamentals.

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1. Introduction

Raising the short-term interest rate is often used to defend a currency under attack. The interest rate defense has had both successes and failures, some quite spectacular. Hong Kong increased overnight rates to several hundred percent and successfully defended its currency in October 1997 against speculative attack. Sweden similarly increased its interest rate by several hundred percent in its currency defense in September 1992, but the success was short-lived. Other cases of both success and failure can be cited, so that even a first look at episodes leaves very much open the question of the effectiveness of an interest rate defense. Econometric tests of this question are similarly inconclusive. Hence, we still have no clear answer to the question: Is raising interest rates effective in defending a currency?

A closely related question is: Why do high interest rates deter speculation? The standard argument is that they increase the opportunity cost of speculation. 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, this argument runs into a simple "arithmetic" problem. If the horizon over which devaluation is expected is extremely short, interest rates must be raised to extraordinarily high levels to deter speculation even when the expected devaluation is small. 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% ($(1.005^{365}-1)*100=517$) to make speculation unprofitable. (See, for example, the discussion in Furman and Stiglitz [1998].)

This reasoning has called into question how effective very high overnight interest rates can be in deterring an attack, and has been used to explain why the interest rate defense may be ultimately unsuccessful. Though the "arithmetic problem" addresses the question of why "spectacular" defenses may have only limited effects, it raises other questions. On the one hand, why then is the interest rate defense sometimes successful, especially when the interest rate used to defend is *not* spectacularly high? And, why do short-lived increases in interest rates often appear to have much longer-term effects? On the other hand, why does an interest rate defense often appear to lead to even *greater* spectacular pressures against the currency, that is, generate an adverse feedback from higher interest rates to speculative pressures? The effects of raising interest rates must reflect more a simple cost-of-borrowing effect.

In this paper we investigate these specific questions with the more general aim of addressing the two questions raised at the beginning of the paper. Our focus is largely empirical, but one suggested by a specific theoretical approach to the effectiveness (or ineffectiveness) of interest rate defense. We argue that the effects of high interest rates may reflect the *information* that increasing interest rates provides to market participants. If so, the direct cost implications of high interest rates for speculators may be secondary to the signal they provide. Raising interest rates signals that a government is committed to fixed exchange rates, but also possibly weak fundamentals. Hence, a key empirical implication is that raising interest rates leads to the expectation that future rates will be high, but may also increase the probability speculators assign to collapse. This is the mixed signal.

If the effects of high interest rates reflect the expectations they engender about future policy (via the signal about unobserved government characteristics under asymmetric information), then these effects should appear in expectations of future exchange rates and forward interest rates. Hence, tests of the effectiveness of the interest rate defense looking at these forward-looking variables should be informative. Empirical testing along these lines is the focus of this paper.

Our main conclusion is that while tests looking at the effect of high interest rates on "summary measures" like the outcome of an attack (or the very short-term expected rate) are often inconclusive, tests that "disaggregate" these effects both across different time horizons and across different determinants of short-term expected exchange rates (interest differentials, risk premia, and long-term expectations) provide significant information. The inconclusiveness of tests using summary measures is due to *offsetting* effects, with tests on disaggregated measures displaying some clear regularities to explain these offsetting effects. Raising overnight interest rates strengthens the exchange rate over the short-term for most countries in our sample via its effects on short-term interest rate differentials, consistent with signaling commitment to defend. However, raising overnight interest rates leads to an expected depreciation at a horizon of a year and longer, consistent with the argument that it also signals weak fundamentals. High overnight rates also weaken the exchange rate via an increase in the risk premium, consistent with the argument that they increase the risk of default.

The plan of the paper is as follows. In the next section, we review standard empirical tests of the interest rate defense, in which probability of the fixed rate regime being maintained is related to the stance of monetary policy. Given the inconclusiveness of the tests, we argue that an alternative approach is required. To provide a basis for an alternative, in section 3, we set out the essential logic of the signaling approach to defense of a currency in a very simple model in order to show that the signal content of a policy such as raising interest rates may either strengthen or weaken a currency. In section 4, we consider tests of the effects of the interest rate defense via the term structure of exchange rate expectations and interest rates, using data from eight European countries. We show that disaggregating the effect of raising overnight interest rates in the way outlined in the previous paragraph provides significant information that is hidden in a test on a summary measure. These results are consistent with the signaling hypothesis, but also in part with other arguments, as we will outline. Section 5 presents a summary of our main empirical findings, as well as concluding comments.

2. Testing the Effectiveness of Interest Rate Defense in General

We begin by reviewing the evidence on tests of the effectiveness of raising the interest rate to defend against speculative attack. The most obvious test is to relate some measure of the level of interest rates to attack outcomes. Recent empirical literature has produced a number of empirical tests of the effectiveness of interest rate defense of this sort. Our main conclusion is that tests of this sort ultimately provide little information.

There are many papers presenting empirical tests of the effect of monetary policy on the survival of a fixed exchange rate. A well-known paper is that of Kraay (1999), who studies a large cross-country sample of fixed exchange rate crises, and relates the stance of monetary policy to the outcome of the crisis (collapse or survival of the peg) through an instrumental variable probit regression. He finds little significant relationship between monetary policy and attack outcomes one way or the other. Other studies of this sort include Goldfajn and Gupta (1998) and Dekle, Hsiao, and Wang (1999), who find more support for the conventional view. On the whole, the evidence is inconclusive.

There are a number of questions that may be raised about this methodology. To begin, there is the question of the choice of instrument used to measure monetary policy. Hubrich (2001a), looking at the same type of data but using simpler statistical methods, argues that Kraay's result is due mainly to how he defines the policy variable. Hubrich finds significant effects for monetary policy when using variations of Kraay's policy variables, but shows that the relationships break down when using Kraay's definition. Specifically, he shows that monetary policy has conventional effects when measured by the stance of the central bank's domestic credit. Conversely, he finds that the effect seems to be "perverse" when looking at nominal discount rates, which he attributes to biases attached to using a nominal interest rate measure that are not present in the domestic credit measure. Using Kraay's main policy variable, the real discount rate obtained by deflating with ex-post inflation, he finds no significant relationship (see Hubrich [2001a] for details as well as a survey of the empirical literature).

There are other questions besides simply how interest rates are measured. First, the relationship between observed interest rates and exchange rate outcomes suffers from a potential bias due to the endogeneity of the former. Both the degree to which a country raises interest rates and the probability that an attack succeeds (for given interest rates) are likely to depend on the amount speculative pressure it faces, as well as on specific country characteristics. Hence, heavy speculative pressure may lead a country to raise interest rates sharply but may also make failure likely, so that there is a correlation between interest rates and attack outcomes that has nothing to do with the effectiveness of interest rate defense *ceteris paribus,* that is, when speculative pressure or characteristics are controlled for.[1] One obvious, though less-than-perfect, way to deal with this bias is by using instrumental variables, as Kraay does.

There is, however, a more fundamental issue. In the very short-run, the interest rate defense *must* be effective, almost by definition. To see why, consider the following, very general interest parity condition:

$$i_t = i_t^* + S_{t+1,t} - S_t + P_t \qquad \textbf{(1)}$$

[1] For example, Hubrich (2001a) shows that high-inflation countries are more likely to face a successful speculative attack, *and* are more likely to resort to an interest rate defense when facing an attack. These two imply that high interest rates are associated with successful attacks in a cross-country study, even though interest rate defense may have been effective on a per-country basis, controlling for inflation.

i and i^* represent the domestic and international interest rate, respectively, and S is the (log of the) exchange rate in terms of domestic per foreign currency. $S_{t+k,t}$ denotes the expectation with respect to period $t+k$, formed in period t (so that $S_{t+1,t} - S_t$ is simply the one-period ahead devaluation expectation). P, the residual from uncovered interest parity, captures a currency and a default risk premium.

Hubrich (2001b) illustrates how most notions of speculative pressure in the currency crisis literature translate to positive shocks to the right-hand side components in (2) other than S_t itself. (For example, the gradual deterioration of fundamentals underlying the first-generation models is represented by a gradual increase of $S_{t+1,t}$, the expected future exchange rate.) The interest rate defense, then, can simply be understood as the policy of letting i increase along with pressure shocks on the right-hand side, so that S_t remains unchanged. Hence, for a given amount of speculative pressure, a high enough nominal interest rate will successfully defend the peg in the very short term, that is, it will ensure that interest rate parity holds. This is the sense in which, when everything else is controlled for, an interest rate defense *must* be successful.

If the interest rate defense fails,[2] it must therefore be because raising interest rates in fact increases speculative pressure against the exchange rates, what we termed above an "adverse" feedback effect. Hence, instead of relating interest rates to exchange rate outcomes, one really needs to examine whether there are *feedback effects* from interest rates back to pressure.[3] While an interest rate defense must always be successful *given* pressure, it can still be very ineffective if it in turn increases pressure over the short or medium term.

Why might raising interest rates have the effect of raising pressure? One argument is that

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[2] One must distinguish an attack that succeeds due to the failure of a defense from an attack that succeeds because the government chooses not to defend. If defense requires an extremely high interest rate maintained over some period of time, the government may find it too costly to defend.

[3] Hubrich (2001b) proposes to look not at the relationship between interest rates and exchange rate outcomes, but at that between interest rates and speculative pressure (as identified through a structural econometric model), and to estimate the *feedback* effects implied by a signaling model (as well as others). Using a specific simultaneous structure among those variables, he is able to isolate exogenous shocks to pressure, and study their dynamic effects in the system. In particular, he provides a parametric test for potential feedback effects from the interest rate i back to the pressure terms on the right-hand side of (1).

high interest rates cause the fundamentals themselves to deteriorate, an argument suggested by Drazen and Masson (1994). For example, if pressure against a currency reflects the belief that a weak fiscal position means that debt will have to be monetized, then raising interest rates only worsens the fiscal position, raising expectations of further monetization. This argument is explored in detail by Lahiri and Végh (2001). Another argument that put forward by Furman and Stiglitz (1998) and Radelet and Sachs (1998), by which higher interest rates destabilize an already weak banking system, leading to the belief that defense of the fixed exchange rate must soon be abandoned.

The argument that we stress in this paper is that of *signaling* of unobserved government characteristics – raising interest rates affects speculator's behavior because it serves 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, with 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. In the next section we sketch a basic approach, our main intent being to consider testable implications.

3. High Interest Rate as A Signal

In this section, we outline the signaling approach to interest rate defense of a fixed exchange rate. We present a very stylized example to show how "tough" policy sends an ambiguous signal. A fuller model is presented in Drazen (2003). As has been pointed out to us, the argument may be seen as more generally concerning exchange rate intervention.

The two basic actors in a model of speculative attack against a fixed exchange rate are speculators who attack the currency and the government that defends.[4] Consider first

[4] Speculators often take short domestic currency positions via short forward contracts with commercial banks, who will then try to offset their long domestic currency position by writing an offsetting forward contract (or equivalently, creating a synthetic forward contract), with the central bank being the effective counterparty. Hence, the role of financial intermediaries can be seen as netting out. Selling of domestic currency to purchase foreign currency may also reflect the behavior of hedgers or of investors simply wanting to "flee" the domestic currency. This does not materially change the basic story, as their

speculators. They choose positions against a currency based on the costs of speculation and on their beliefs about the expected gain from speculation. The cost to speculators of speculation against a currency is the interest cost of borrowing domestic currency in order to speculate. This is the arithmetic argument presented in the introduction, as expanded upon in footnote 6. The expected gain from speculation depends on the probability assigned to a collapse of the fixed exchange rate as well as the expected size of the devaluation if a collapse occurs. Central to the signaling approach is that these depend on possibly unobserved characteristics ("fundamentals") of the government, including both its "commitment" to the fixed rate and its ability to defend the exchange rate. Since both observed current and expected future policies are functions of these fundamentals, current policy signals future policy. Current policy may also provide information about the outcome of defense, since this may also depend on fundamentals.

To better understand these effects, consider the government's choice problem of whether to raise interest rates to defend the currency.[5] The key cost of raising interest rates to defend is the negative impact of high rates on the domestic economy – on economic activity, especially when the economy is seen as depressed; on raising 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 (as in the case of the United Kingdom in the early 1990s); on increasing the budget deficit; and, on possible destabilization of the banking system. (This last forms one of the bases of the Sachs-Stiglitz argument that high interest rates depreciate the currency.)

Given these costs, only that place a high value on maintaining a fixed rate and/or believe that the exchange rate is likely to collapse in the absence of a defense will incur the cost of raising interest rates to defend. It is in this sense that defense may simultaneously signal both strong commitment and weak economic fundamentals. As long as speculators do not fully observe these government characteristics, the policy of raising interest rates will signal these

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willingness to hold domestic currency will depend on the same factors as those that determine the behavior of speculators and in the same direction.

[5] In this discussion, we assume that the government's only defense option is raising interest rates. In Drazen (2000), the alternative of borrowing reserves to defend the exchange rate is considered. The key result in our analysis – that governments with low foreign exchange reserves are more likely to raise interest rates – emerges in both frameworks.

characteristics. Since these characteristics are associated with both policy choices and with the outcomes of policies, defense today (relative to no defense) may signal that if the currency is attacked tomorrow, both a defense and collapse is more likely.[6]

To make more precise the argument about the mixed signal inherent in defense, consider the following highly stylized two-period example. To capture the essential phenomenon, suppose that the level of reserves R_t is unobserved by speculators. To capture the effect of interest rate defense on speculators' behavior, suppose that the probability of collapse for type *R* is $1 > d(R) > 0$ if the government raises interest rates ("defends") and $1 > n(R) > d(R) > 0$ if it does not, where $n(R)$ and $d(R)$ are decreasing in *R*. Though increases in interest rates are not modeled explicitly, this formulation captures the basic effect of tight policy on the probability that the exchange rate regime collapses. Assume further that the difference $n(R) - d(R) = g(R)$ is decreasing in *R*. That is, the lower the level of reserves, the greater the relative benefit from defense in terms of lowering the probability of collapse, which seems reasonable. For simplicity, the functions $n(R)$ and $d(R)$ are assumed to be the same in both periods. Denote the value the government assigns to maintaining the fixed exchange rate by *x* and cost of raising interest rates in period *t* by ℓ_t.[7]

We solve the equilibrium backwards. In period two, a government defends via raising interest rates if the probability of collapse conditional on defense times the cost of collapse plus the cost of defending is less than the probability of collapse conditional on no defense times the cost of collapse. That is, a government with reserves R_2 defends if $d(R_2)x + \ell_2 \leq n(R_2)x$, or equivalently, if:

$$\ell_2 \leq g(R_2)x \qquad \textbf{(2)}$$

[6] Consider the analogy to sick patients. Since medicine cannot cure very sick patients with certainty, we are likely to observe that it is the patients who receive the most medicine, that is, those who are the sickest, are most likely not to recover.

[7] In Drazen (2003), the level of reserves, the government's commitment to defend *x*, and the cost of defense are all stochastic, with the first two variables not observed by speculators. In this more general model, we can then think of a "tough" and "weak" policymaker defined by preferences rather than level of reserves, and raising interest rates could signal "toughness." Another extension would be to allow higher interest rates to weaken fundamentals themselves, as in Drazen and Masson (1994) and Lahiri and Vegh (2001).

where $g(R) \equiv n(R) - d(R)$. Since $g(R) > 0$ and $g'(R) < 0$, (2) defines a critical value of R_2, call it $\tilde{R}_2(\ell_2)$ such that this type that is just indifferent between defending and not defending. Governments with $R_2 \leq \tilde{R}_2(\ell_2)$ defend, while those with $R_2 > \tilde{R}_2(\ell_2)$ do not.

In this two-period example, we assume that reserves do not change over time. This assumption is motivated primarily by simplicity of exposition, but can be justified by assuming that any reserve outflow flows back in at the end of the period as speculators close their positions. Assuming that the reserve position at *t*+1 depends on the government action at *t* and its outcome is more realistic (and would be crucial if the model is used to study phenomena like steady loss of reserves in an ultimately futile defense), but it would not affect the conceptual point about the signal content of defense in period 1 that we are making. Hence, we assume a full reserve reflow so that $R_2 = R_1$, which we denote simply by *R*.

The government's decision in period 1 depends on what it expects to do in period 2. It will choose the policy that gives it the minimum cost in period two, as given by (2).

The cost of defending in the first period is then:

$$\ell_1 + d(R)x + \beta\Big(d(R)x + (1 - d(R)\alpha^D \,\mathrm{E}(\min\{d(R)x + \ell_2, n(R)x\}\Big) \quad , \qquad \textbf{(3a)}$$

and the cost of not defending is:

$$n(R)x + \beta\Big(n(R)x + (1 - n(R)\alpha^N \,\mathrm{E}(\min\{d(R)x + \ell_2, n(R)x\}\Big), \qquad \textbf{(3b)}$$

where α^D is the probability of an attack in period two if there was a defense in period one and α^N is the analogous probability if there was no defense.[8]

The condition for defense to be optimal in the first period is thus:

$$\ell_1 \leq g(R)x + \beta O_2 \qquad \textbf{(4)}$$

where

$$O_2 \equiv g(R)x - \Big((1 - d(R))\alpha^D - (1 - n(R))\alpha^N\Big)\Big(\mathrm{E}(\min\{d(R)x + \ell_2, n(R)x\}\Big). \qquad \textbf{(5)}$$

O_2 is the "option value" for the second period associated with defending in the first

[8] The dependence of the attack probabilities α^D and α^N on the probability of collapse may be derived from optimal speculator behavior as outlined above, with the key result that a higher probability of collapse raises the probability of attack. See Drazen (2003).

period, since it gives the option of either defending or abandoning the exchange rate next period, depending on which has a lower cost.

One may easily show that the option value of defending is positive, that is, $O_2 > 0$ (note that this is the case even when $\alpha^D > \alpha^N$, that is, even when defense in period one raises the probability of attack in period two due to its "negative signal" content) and that $\partial O_2 / \partial R < 0$, that is, the option value of defending is higher the lower is *R*. Under this condition, the characterization of which types defend in period one is analogous to that for period two. There is a critical value $\tilde{R}_1$ such that governments with $R \le \tilde{R}_1$ defend, while those with $R > \tilde{R}_1$ do not. Note that since the option value is positive, $\tilde{R}_1 > \tilde{R}_2$, that is, any type that defends in period 2 also would defend in period one (though not vice versa)

We may now derive the probabilities of defense and of collapse in period two, conditional on first period policy. These may be derived as of the beginning of period two, which is when speculative decisions must be made two, conditional on no collapse in period one. Consider first the probability of a defense if attacked in period two. Using the definition of the cut-off value of R, the relative values of $\tilde{R}_1$ and $\tilde{R}_2$, the prior distribution of *R*, J(*R*), and the implied posterior, one may write

$$\Pr(\pi_2 = D \,|\, \pi_1 = D) = \Pr(R \le \tilde{R}_2 \,|\, R \le \tilde{R}_1) \equiv \frac{J(\tilde{R}_2)}{J(\tilde{R}_1)} \qquad \textbf{(6a)}$$

which is between 0 and 1, and

$$\Pr(\pi_2 = D \,|\, \pi_1 = N) = \Pr(R \le \tilde{R}_2 \,|\, R > \tilde{R}_1) = 0 \qquad \textbf{(6b)}$$

This is our first key result, namely that a defense in the first period raises the probability of a defense in the second period, which we summarize as:

Proposition 1: $\Pr(\pi_2 = D \,|\, \pi_1 = D) > \Pr(\pi_2 = D \,|\, \pi_1 = N)$

(If defense in the first period raises the probability of attack in second period, this inequality is even greater.) In a model with a richer uncertainty structure, the difference will not be as stark as in (6a) and (6b), but the same result will obtain. The observable implication is that an increase in the policy interest rate today will raise expected interest rates in the future.

The second key result concerns the probability of collapse in period two conditional on period one policy. For the two possible period one policies, we obtain:

$$\Pr(\textit{collapse at } t = 2 \,|\, \pi_1 = D) = \frac{\int_{R=0}^{R=\tilde{R}_2} d(R)\mathrm{d}J(R) \quad + \quad \int_{R=\tilde{R}_2}^{R=\tilde{R}_1} n(R)\mathrm{d}J(R)}{J(\tilde{R}_1)} \qquad \textbf{(7a)}$$

and

$$\Pr(\textit{collapse at } t = 2 \,|\, \pi_1 = N) = \frac{\int_{R=\tilde{R}_1}^{R=\infty} n(R)\mathrm{d}J(R)}{1 - J(\tilde{R}_1)} \qquad \textbf{(7b)}$$

Since the numerator in the second expression is taken over high values of R (and hence low values of $n(R)$), while the numerator in the first expression is taken over low values of R (and hence high values of $n(R)$ and $d(R)$)), the first expression may easily exceed the second. (For example suppose that $n(R) \to d(R)$). This is our second main result, namely that observing a defense in period one may lead speculators to increase the probability of a defense in period two, but at the same time to increase the probability of a collapse. We summarize this as:

Proposition 2: Though $\Pr(\pi_2 = D \,|\, \pi_1 = D) > \Pr(\pi_2 = D \,|\, \pi_1 = N)$ and $d(R) < n(R)$, Q_2^D may exceed Q_2^N.

The above argument suggests that raising interest rates may send an ambiguous signal, namely that a government is committed to defend but that it has weak fundamentals in some dimension. It thus may help understand why econometric estimation of the effect of interest rate policy on the survival of fixed rates may give ambiguous results. Moreover, effects working in opposite directions may appear at different horizons. High interest rates have the immediate effect of damping speculation but increase the perceived probability that the exchange rate will eventually be abandoned since it indicates the fundamentals are weaker and thus more susceptible to shocks.[9] This observation will be important in considering our term structure

[9] Since interest rates affect demand for reserves, economic activity, the fiscal balance, and financial sector balance sheets, there will be conflicting effects even in the absence of asymmetric information and signaling. Hence, the ambiguous and/or offsetting effects at different horizons can arise even under full information. For example, higher interest rates will reduce speculative demand but also worsen the fiscal position, which may induce expectations of a future inflation and a depreciation for the reasons discussed above. If the latter effect is one that depends on debt accumulating above a certain level, there may be an

results in the next section.

A further implication of the signaling approach is that there may be “disproportionalities” in the effect of interest rates on speculative activity. Raising interest rates may dampen speculation far more than an “arithmetic” argument may suggest or may have little effect. To the extent that it sends a negative signal, it may actually increase speculative pressures. If a “persistent” fundamental is signaled, then a short-lived increase in interest rates may have a much longer-term effect. Finally, the effects may be not only of different strengths at different horizons, but also of different signs, raising interest rates strengthening the exchange rate in the very short term, but weakening it at a longer horizon. We now turn to empirical assessment of interest rate defense on the basis of these insights.

4. 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. Therefore this section uses 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.

The analysis is geared specifically towards the ‘disproportionalities’ implied by a signaling model. First, the impact of interest rates on exchange rate expectations is allowed to be non-linear, thus accommodating the fact that the information content of the policy may not be proportional to the level of the interest rate. Second, signaling models also 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

immediate strengthening of the exchange rate, but a weakening at longer horizons, parallel to the effect discussed in this paragraph. This argument is made by Lahiri and Végh (2001).

something ‘fundamental’ is being signaled. In addition, the analysis enables us to distinguish between the effects of policy on interest rate expectations and those on risk- and term premia (with the effect on exchange rate expectations being the sum of both).

A. Empirical Framework

Recalling that $X_{t+j,t}$ refers to the expectation of the value of *X* at time *t+j* as formed at time *t* (the current value is denoted $X_t \equiv X_{t,t}$), we write the interest parity condition (1) as:

$$di_t^k = S_{t+k,t} - S_t + P_t^k \tag{8}$$

Here *k* denotes the maturity of the underlying asset (in other words, we are looking at, say, a *k*-month money market rate). di_t^k is the interest rate differential $i_t^k - i_t^{*k}$ and P_t^k is the risk premium (which may include a term premium, a currency risk premium, and a default risk premium) from *t* to *t+k*.

Using monthly data for exchange rate expectations and money market rates at the 1, 3, 6 and 12-month horizon, we can use (8) to decompose next month’s expected exchange rate $S_{t+1,t}$ into:

$$S_{t+1,t} = (S_{t+1,t} - S_{t+3,t}) + (S_{t+3,t} - S_{t+6,t}) + (S_{t+6,t} - S_{t+12,t}) + S_{t+12,t}\ , \tag{9}$$

where

$$S_{t+1,t} - S_{t+3,t} = (di_t^1 - di_t^3) + (P_t^3 - P_t^1) \tag{10a}$$

$$S_{t+3,t} - S_{t+6,t} = (di_t^3 - di_t^6) + (P_t^6 - P_t^3) \tag{10b}$$

$$S_{t+6,t} - S_{t+12,t} = (di_t^6 - di_t^{12}) + (P_t^{12} - P_t^6) \tag{10c}$$

In other words, the above allows us to decompose next month's expected exchange rate $S_{t+1,t}$ into the accumulated effects of interest rate expectations and risk over four different horizons. (Note that $di_t^{k+1} - di_t^k$ is the one-month interest rate at *t+k*.) As interest rates increase and risk decreases, the exchange rate components decrease (*i.e.*, the exchange rate appreciates). This represents the common intuition underlying the interest parity condition that higher interest rates will appreciate exchange rates, while increases in risk premia (if not matched by interest rates) will lead to a depreciation.

A key notion to take away from this decomposition is that $S_{t+1,t}$ is essentially a sum that we can break down into seven individual components along two dimensions – term and the components of interest rates versus risk premia. This is illustrated by the following matrix:

TABLE 1

Determinants of the Expected Exchange Rate $S_{t+1,t}$

Term / **Component**	2-3 mo.	4-6 mo.	7-12 mo.	12+ mo.	**Sum**
Interest Rates	$di_t^1 - di_t^3$	$di_t^3 - di_t^6$	$di_t^6 - di_t^{12}$		$di_t^1 - di_t^{12}$
'Risk'	$P_t^3 - P_t^1$	$P_t^6 - P_t^3$	$P_t^{12} - P_t^6$		$P_t^{12} - P_t^1$
Long-Term				$S_{t+12,t}$	$S_{t+12,t}$
Sum	$S_{t+1,t} - S_{t+3,t}$	$S_{t+3,t} - S_{t+6,t}$	$S_{t+6,t} - S_{t+12,t}$	$S_{t+12,t}$	$S_{t+1,t}$

By examining how each of the inner components reacts individually to interest rate policy (identified as changes in a very short-term money market rate), we hope to better understand the effects of raising interest rates and to be able to distinguish signaling effects from other, competing hypotheses. In general, we would expect that if interest rate policy bears an information content that outlasts the policy itself, then interest rate policy should have longer-term effects. These would show up in the above decomposition as decreases in the interest rate components (representing increases in interest rate expectations) that are spread out evenly across the different horizons.

For example, assume for a moment that term premia are zero, so that the *k*-month interest rate is simply the sum of expected one-month interest rates from *t* to *t*+*k*. In the absence of information effects, if the central bank raises the policy rate (say, an overnight money market rate) to extremely high levels in response to an attack, this will only lift interest rate expectations at the short (say, monthly) horizon. Longer-term interest rates, at horizons of 3 months or more, will be affected less, since the policy itself is unlikely to remain in place for long. Consequently, only the short-term components of $S_{t+1,t}$ in the above decomposition will improve. If one-month interest rate expectations increase for, say, 2 and 3 months out, then $di_t^1 - di_t^3$ will decrease, representing an increase in the interest rate at the 2-3 month horizon, so that the component $S_{t+1,t} - S_{t+3,t}$ will appreciate. If the policy is not expected to last beyond the 3-month horizon, however, then longer-term interest rate components will remain unchanged, so that $S_{t+1,t}$ is affected only by the short-term appreciation.

In contrast, assume that the temporary policy signals a permanent change in the policy stance in the sense of a commitment to supporting the exchange rate. This translates in permanently higher expectations of the one-month interest rate, so that the interest rate components at *all* horizons in (10a)-(10c) will decrease, thus appreciating exchange rate expectations across the board and resulting in a much stronger appreciation of their sum, $S_{t+1,t}$.

Finally, the decomposition of the exchange rate term component into an interest rate term and a risk term allows us to analyze separately the effect on the risk- and term premia. For example, if the Sachs-Stiglitz argument is correct (whereby higher interest rates may weaken the banking sector), we should detect an increase in the risk components in response to an interest rate policy hike, as risk premia increase[10].

B. Data and Regression Equations

To perform the decomposition implied by equations (9) and (10) as illustrated in the

[10] As data are available for exchange rate expectations and interest rates over different horizons, we are able to obtain data for P_t^k as the residual from interest rates and exchange rate expectations at the different horizons, essentially using (9). If interest rate forecasts and *k*-month forward rates were consistently available as well, we could also decompose P_t^k into its three components (compare (10)). Interest rates forecasts were indeed available for a small subset of the data, and were used for a cursory exploration of the role of term premia, available from the authors. Forward rate data were available throughout – we refrained, however, from using them to make a distinction between currency and default risk since this distinction is not the focus of our present work.

matrix, we gathered monthly data for nine European countries – Germany, Belgium, France, Italy, Denmark, Sweden, Norway, Ireland and Spain – for the time period around the 1992/3 ERM crisis to construct monthly time series for those seven components. During this period those countries essentially had their exchange rates fixed against the benchmark country Germany.[11] These data permit to construct the four exchange rate series on the right-hand side of (9), thus permitting us to look at the term structure of exchange rate expectations without being able to distinguish between interest rates and 'risk' as in (10a)-(10c).

Exchange rate forecasts are published monthly in the *Financial Times Currency Forecaster* (formerly *Currency Forecaster's Digest*). This is a 'combined consensus forecast', the geometric mean of a sample of professional currency forecasts, from institutions such as commercial banks and other multinational corporations. The reference currency for these forecasts is the US Dollar, so we used the US Dollar/DM forecast has been used to construct exchange rate forecasts relative to the DM. The forecasts come out monthly on the fourth Thursday of the month. *k*-month interest rate differentials (with respect to Germany) are represented through money market rates (from the day of the exchange rate forecast) that were obtained from Bloomberg or Datastream. The 'risk' data could then be backed out as the residual, according to (10a)-(10c). All these variables are expressed as logs and multiplied by 100, so changes are interpreted as percent changes (in the case of exchange rates) or percentage point changes (in the case of interest rates and risk).

All in all, the following seven equations were estimated for each country (one for each cell in the above matrix), where for convenience we define $X_t^{j,n} \equiv X_t^j - X_t^n$:

$$di_t^{1,3} = c_1 + a_1 dr_t + b_1 (dr_t)^2 + f_1 S_t + \varepsilon_{1t} \qquad \textbf{(11a)}$$

$$di_t^{3,6} = c_2 + a_2 dr_t + b_2 (dr_t)^2 + f_2 S_t + \varepsilon_{2t} \qquad \textbf{(11b)}$$

$$di_t^{6,12} = c_3 + a_3 dr_t + b_3 (dr_t)^2 + f_3 S_t + \varepsilon_{3t} \qquad \textbf{(11c)}$$

$$P_t^{3,1} = c_4 + a_4 dr_t + b_4 (dr_t)^2 + f_4 S_t + \varepsilon_{4t} \qquad \textbf{(11d)}$$

[11] Technically, with the exception of Norway and Sweden, these countries were part of the EMS system where each country agreed to fix its currency to within a band around a weighted basket of all other participating currencies. Treating Germany as the (sole) benchmark country simplifies the analysis, and is justified in light of the fact that the DM had the biggest weight in that basket.

$$P_t^{6,3} = c_5 + a_5 dr_t + b_5 (dr_t)^2 + f_5 S_t + \varepsilon_{5t} \qquad \textbf{(11e)}$$

$$P_t^{12,6} = c_6 + a_6 dr_t + b_6 (dr_t)^2 + f_6 S_t + \varepsilon_{6t} \qquad \textbf{(11f)}$$

$$S_{t+12,t} = c_7 + a_7 dr_t + b_7 (dr_t)^2 + f_7 S_t + \varepsilon_{7t} \qquad \textbf{(11g)}$$

The main regressor is an overnight or one-day money market rate differential $dr_t \equiv r_t - r_t^*$, which presumably reflects the degree to which the government chooses to engage in an interest rate defense. Some of the governments in the sample actually increased official discount rates to engage in interest rate defense, which should be picked up well by these very short-term rates. Other governments merely engaged in interest rate defense to the extent that they chose not to intervene, and “let” money market rates be driven up by devaluation expectations. In a portfolio balance context, this is an interest rate defense in the sense that the government could have kept a lower interest rates by intervening in support of the domestic currency (see Hubrich (2001b)). This variable is obtained as the average (from daily observations) between two exchange rate forecasts, expressed in percentage points[12]. It is allowed to enter squared as well, in order to assess non-linearities related to signaling.

The only other regressor (aside from a constant) is S_t, the actual observed exchange rate at the time of the forecast. This regressor was included to control, at least partially, for potential biases stemming from the endogeneity of the policy measure $dr_t \equiv r_t - r_t^*$. It is likely that the same factors that affect policy (the onset of a crisis, speculative pressure etc.) also have a direct effect on the dependent variable through the error term *e*, which leads to an endogeneity bias in the coefficients *a* and *b*. To the extent that these factors also lead to movements of the actual exchange rate (within its band [13]), including the exchange rate can control for this effect. We have made no attempt has been made to treat endogeneity more formally (using, e.g., instrumental variables), so that we cannot be entirely certain that the estimation is free of biases

[12] At an earlier stage of this work we also used the maximum observation between two forecasts. This did not make a qualitative difference.

[13] During the crisis of 1992/3, there was substantial fluctuation, and periods of strong speculative attacks were often characterized by the fact that the exchange rate under attack hit the boundary of the band. In addition, there were realignments and widening of bands during the estimation period. Including the actual

stemming from endogeneity

In order to be able to focus on the term structure (without distinguishing between interest rate and ‘risk’ components), the following three equations were also estimated (the implied equation for $S_{t+12,t}$ is identical to (11g)):

$$S_{t+1,t} - S_{t+3,t} = c_8 + a_8 dr_t + b_8 (dr_t)^2 + f_8 S_t + \varepsilon_{8t} \qquad \textbf{(12a)}$$

$$S_{t+3,t} - S_{t+6,t} = c_9 + a_9 dr_t + b_9 (dr_t)^2 + f_9 S_t + \varepsilon_{9t} \qquad \textbf{(12b)}$$

$$S_{t+6,t} - S_{t+12,t} = c_{10} + a_{10} dr_t + b_{10} (dr_t)^2 + f_{10} S_t + \varepsilon_{10t} \qquad \textbf{(12c)}$$

Before running the actual regressions, we explored the time-series properties of the data with a battery of unit-root tests. We found that for the majority of the series we could reject the unit root hypothesis at the 10% level, using augmented Dickey-Fuller tests that included a constant term but no trend. Most failures to reject the unit-root hypothesis occurred for interest rate series, where we could reject the unit-root only for about 50% of the series. Since non-stationary interest rates are difficult to conceptualize economically, we attribute these failures to the weakness of the tests due to the generally small sample size for the regressions. Therefore, being aware of the problems involved with over-differencing the data, we decided to run the regressions in levels as laid out above.

C. The Basic Results

Since the policy variable of interest, $dr_t \equiv r_t - r_t^*$, enters the regression quadratically, the point estimates of the coefficients are difficult to interpret. Therefore in tables 2-9 we report, for each country, two blocks of results. The top block shows the estimated coefficients *a* and *b* for the various regressions in (11a)-(11g) and (12a)-(12c), which reflect the (possibly non-linear) impact of the policy variable on the corresponding component. The bottom block then focuses on the economic meaning of the point estimates, as we discuss below.

Since either equations (11a)-(11g) or equations (12a)-(12c) were estimated simultaneously (using Seemingly Unrelated Regression, or SUR), the top block also reports

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exchange rate as a regressor is a natural way of controlling for such events.

about some Wald tests of certain cross-equation restrictions. In the last column of the table we shows tests against the null hypothesis that all the coefficients *b* in the regression are equal to zero, in effect testing for the overall non-linearity present in the regression. It turns out that linearity is rejected throughout, with the exception being regressions (12a)-(12c) (looking only at the term structure) for Italy and Ireland. For these two countries, linearity was rejected when looking at the interest rate and ‘risk’ components separately. At the bottom of the top block, we show tests of the importance of splitting up a given term component into an interest rate and a ‘risk’ component. For that split, it tests whether the coefficients *a* and *b* are identical across interest rate and 'risk' equations. While equality sometimes cannot be rejected for individual coefficients, especially for the early 2-3 month term, it is generally rejected for both coefficients combined, especially when all terms are considered simultaneously. To summarize, the Wald tests reject both the linearity of the impact of the policy rate, and the equality of that impact across interest rate versus ‘risk’ components. This points towards the non-linearities to be expected from a signaling environment, and it suggests that the distinction between interest rate and ‘risk’ components will yield additional insight.

In the bottom block of each table, we use the point estimates to calculate the impact of an increase in the policy rate at different horizons. A negative value implies that increasing the interest rate reduces the term component, and therefore appreciates $S_{t+1,t}$. In particular, positive signaling (for example, with high interest rates signaling strong commitment to defend) would imply a negative entry in the case of *S* or *di*.

We show, for each estimated equation, the impact of three different size interest rates increases in the policy interest rate on the dependent variable, taking into account the non-linearity inherent in the point estimates of *a* and *b* – an increase in the policy rate by one percentage point over the sample mean; an increase by half the difference between the sample mean and the sample maximum; and, finally, an increase all the way to the sample maximum. In the latter two cases the change in the dependent variable was divided by the size of the increase in order to get the effect per percentage point increase, which in turn allows us to compare the three numbers. The dependent variable is measured as 100 x ln(.), while the policy measure is expressed in percentage points. Therefore the table entries can be interpreted as elasticities, giving the percentage change in a $S_{t+1,t}$ component per percentage point increase in the overnight interest rate differential.

For any size interest rate increase, the overall effect on exchange rate expectations across the term (*S* in the bottom rows) can be decomposed into an interest rate effect *di* and a 'risk' effect *P*, the first and second rows, as in Table 1 above. By construction, the entry in the *S* rows is the sum of the corresponding *di* and *P* entries. Corresponding to the sum row in Table 1, the effect of raising the overnight interest rate on the one-month-ahead expected exchange rate $S_{t+1,t}$ is the arithmetic sum of three components – the effect on the interest rate over the twelve-month horizon, the effect on risk premia over the twelve-month horizon, and the effect of the expected exchange rate at a horizon of greater than twelve months. We use this below in interpreting the results.

Looking down the rows for one component in a block, one can identify (and quantify) non-linearities in the interest rate effect. A perfectly linear relationship ($b = 0$) would yield identical entries in each row. By contrast, a concave relationship (where small interest rate increases already have large effects, but additional increases have little additional effects) would have the entries decreasing in absolute value as we are going down.

Looking across the columns for one component in a block, we can examine the term structure of interest rate effects. The leftmost column represents the nearest term (the next two months), and the term increases as we move to the right. The far right column (labeled "1 month") reports the cumulative effect across all terms (these correspond to the far-right cells in Figure 1).

D. Interpretation of Results

In interpreting our results, we focus primarily on the common traits across countries, where there are some clear patterns in the sample.

First, and especially striking, for every country in the sample, at every horizon and for every size change in the interest rate, the interest rate effects are always significant with an increase in the overnight interest rate leads to an increase in the interest rate at all horizons, which in turn strengthens the exchange rate. (Note that this is *not* an arithmetic shifting of the whole term structure, since the columns represent the j-month interest rate from at $t+k$ to $t+k+j$.) This is the prediction in Proposition 1 in section 3 – defending the currency via raising interest rates at a point in time leads to the expectation that the currency will be similarly defended in the future, so that future interest rates will be higher.

Second, this strengthening of the currency via the interest rate component generally does *not* however correspond to a higher one-month-ahead exchange rate forecast $S_{t+1,t}$, as seen in the southeast corner of the lower block in each table (the entries under "1 month" for expected exchange rates). The effect of raising the overnight interest rate on $S_{t+1,t}$ is usually insignificantly different from zero (Denmark, France, Italy, Norway, and Sweden). In two cases raising overnight rates actually leads to an expected depreciation one month out (Belgium and Ireland). In only one of the eight countries, Spain, does raising the overnight rate lead to an expected strengthening one month out. Even in this case, the expected appreciation is far less than what the interest rate effect alone would predict.

The reason that high interest rates do not lead to an expected appreciation in our sample countries is that the interest rate effect is generally offset by a risk effect (at horizons greater than one month) of the opposite sign. This phenomenon is observed in six of the eight countries – Denmark, Ireland, Italy, Norway, Spain, and Sweden. (In the first three cases, an expected depreciation at horizons of twelve months or greater contributes to the offsetting effect.) It is striking that the interest rate components *di* and the 'risk' components *P* almost always have significant movements of the same size, but in opposite directions. That is, the interest rate components typically decrease by about 0.5% (looking at the total across all horizons), while the risk premia increase by about the same amount. Interest rate defense therefore does increase interest rate expectations and *ceteris paribus* appreciates $S_{t+1,t}$, but this is offset by an adverse increase in risk premia in most countries.

The two exceptions to this pattern are Belgium and France, where increases in the overnight interest rate do *not* lead to a significant increase in the 'risk' term. One possible explanation is that these countries were argued to be "core" countries in the ERM, and therefore may have been believed to have had a greater ability to borrow reserves.[14] This would be consistent with the model in the sense that increases in the policy interest would be less likely to be taken as a sign of low reserves. In both cases, the positive interest rate effect was offset by a higher expected depreciation at horizons of twelve months or greater as a result of the increases in the overnight rate, as was also found in Denmark, Ireland, and Italy.

Both the interest rate and the risk terms are usually stronger in the longer term, thus revealing important long-term effects for the usually short-term interest rate policy. The joint occurrence of these two effect leads to a much smaller, more ambiguous effect on the exchange rate expectations (the *S* rows) across the horizon. The “average” effect on exchange rate expectations seems to be a small appreciation (a decrease) in the short term, coupled with a deterioration in the long-term components, yielding a slightly positive and often insignificant overall effect, usually on the order of less than 0.05%. In other words, it appears that interest rate expectations dominate in the short run, while ‘risk’ dominates the long run, and the two cancel out much of each other along the way.

Finally, regarding non-linearities, it is often the case that – for any of the components *S*, *di* or *P*, the larger interest rate increases have different effects than the smaller ones. The direction of that non-linearity, however, varies considerably across countries in the sample.

Taken as a whole, this pattern suggests that certainly more is going on than the mere “arithmetic”, opportunity cost-based effects of interest rate defense. We argue that these results are consistent with a signaling argument. Short-term interest rate policy has strong effects on the interest rate expectations embedded in long-term interest rates, with the sign of these effects suggesting that an increase in overnight interest rates is taken as a signal to defend the exchange rate over a longer horizon. Moreover, these effects are often non-linear in nature. These findings point towards information effects triggered by interest rate policy. Note here that the signaling hypothesis would support both concavities (larger increases have smaller relative effects) and convexities. Concavities could arise when the mere “activation” of interest rate policy, even only a mild increase, signals the general preparedness of the government to use monetary policy in defense of the exchange rate. Convex relationships, by contrast, could arise when only unusually

[14] We are indebted to Richard Portes for pointing this out.

or unexpectedly high, “extreme” interest rates signal news about the policy. The evidence gives more support to the former, whereby the (informational) effect of interest rate increases is largely captured by small changes.

An alternative argument for non-linear effects is that suggested by Lahiri and Végh (2001). They stress the interaction between the direct effect of higher interest rates on demand for domestic currency – higher interest rates worsen the fiscal position and induce the expectation of greater future monetization. The first effect strengthens the domestic currency, while the second weakens it. In their set-up, they find that the first effect will dominate for small increases in the interest rate, while the second dominates for large increases. Moreover, the effects differ over the horizon, with the first effect being stronger in the short-term, the second in the long-term.

It is also interesting to note that risk premia react as well, and almost as strongly, to interest rate policy. This could be associated with the Sachs-Stiglitz argument, grounded in the adverse effects of high interest rates on the domestic banking sector, and increasing default risk premia accordingly. However, it might also be associated with a “negative” signaling story along the lines of high policy interest rates signaling low reserves (or the lack of alternatives to an interest rate defense). In that case, the peg may appear weaker than previously thought, which would increase currency risk premia.

5. Conclusions

In this paper we have considered both why high interest may be effective in deterring speculation against a currency and how one may empirically test the effectiveness of the interest rate defense. We have summarized one explanation for the effectiveness of high interest rates in deterring speculation, namely that high interest rates serve as a signal of the government’s willingness or ability to defend the exchange rate. We also presented several types of econometric evidence consistent with the signaling approach.

We begin with a summary of our key empirical findings. First, the effects of changes in overnight interest rates are clearly non-linear, 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 consistent with the signaling explanation (as well as some other explanations). Second, there is little or no clear statistically significant effect of raising interest rates on next month's expected exchange rate $S_{t+1,t}$. (Belgium and Ireland show some evidence of an adverse effect.) However, this masks significant effects on different components of $S_{t+1,t}$ and at different horizons. Certain regularities are observed across countries. There are effects at longer horizons, in contrast to what the simple arithmetic argument would imply. More specifically, there is some evidence of a positive (*i.e.*, appreciating the exchange rate) short-term effect, coupled with a negative longer-term effect, at horizons of 12 months or longer. In terms of the three determinants of next month's expected exchange rate $S_{t+1,t}$ listed in table 1 (interest rates and risk premia at horizons up to twelve months, and the twelve-month-ahead exchange rate forecast), 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 $S_{t+1,t}$, but also an increase in risk premia and $S_{t+12,t}$, the twelve-month-ahead exchange rate forecast, implying a depreciation.

We argued that these results are consistent with the signaling hypothesis. First, the existence of longer term, non-linear effects in themselves suggest that something more than the arithmetic effect is at work. The sign of short-term interest rate policy on interest rate expectations suggests that interest rate increases are taken as a sign of commitment to defend. The deterioration over longer horizons may indicate that weak fundamental are being signaled. As indicated, some of the results are also supportive of other models. Perhaps the most important conclusion that tests looking at the effect of high interest rates on "summary measures" like the outcome of an attack are inconclusive due to offsetting effects, which become clear when one disaggregates the effects of raising interest rates across different time horizons and across different determinants of short-term expected exchange rates.

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TABLE 2

Term Structure Regressions BELGIUM

Estimated Coefficients

Dependent Variable	Horizon: 2-3 months a	2-3 months b	4-5 months a	4-5 months b	6-11 months a	6-11 months b	12+ months a	12+ months b	Nonlinearity Null: all b=0
$S^{j,k}$	-0.086	0.073	-0.779 ***	0.2339 ***	-0.3184 **	0.0401	1.266 ***	-0.2664 ***	S: ***
$di^{j,k}$	-0.1478 ***	0.0196 ***	-0.2165 ***	0.0476 ***	-0.2817 ***	0.0555 ***			di: *** all: ***
$P^{k,j}$	0.0618	0.0534	-0.5626 ***	0.1863 ***	-0.0367	-0.0155			P: **
Equality across di, P	a: - a, b: *	b: -	a: - a, b: *	b: **	a: - a, b: -	b: -			Overall di, P Equality: *

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	**Mean Interest Rate**	**Changed Interest Rate**	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	**1 month**
$di^{j,k}$	0.752	0.852	-0.987 ***	-0.0973 ***	-0.1426 ***		-0.3386 ***
		2.500	-0.0841 ***	-0.0616 **	-0.1011 ***		-0.2468 ***
		4.429	-0.0499 ***	0.0216	-0.0040		-0.0322
$P^{k,j}$	0.752	0.852	0.1955	-0.0961	-0.0754		0.0240
		2.500	0.2355	0.0433	-0.0870		0.1918
		4.429	0.3289	0.3690	-0.1141		0.5838
$S^{j,k}$	0.752	0.852	0.0968	-0.1934	-0.2181 *	0.5991 ***	0.2844 **
		2.500	0.1514	-0.0183	-0.1881	0.3998 **	0.3447 *
		4.429	0.2790	0.3906	-0.1181	-0.0660	0.4856

> Monthly data, sample period: 89:1-94:12

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 3

Term Structure Regressions DENMARK

Estimated Coefficients

Dependent Variable	Horizon: 2-3 months a		2-3 months b		4-5 months a		4-5 months b		6-11 months a		6-11 months b		12+ months a		12+ months b			Nonlinearity Null: all b=0
$S^{j,k}$	-0.1625	***	0.0125	***	-0.2531	***	0.0204	***	-0.1311	**	0.0118	***	0.5854	***	-0.0474	***		***
$di^{j,k}$	-0.1212	***	0.0037	*	-0.1535	***	0.0087	***	-0.2308	***	0.0116	**					di:	***
																	all:	***
$P^{k,j}$	-0.0413		0.0088	*	-0.0996	**	0.0116	***	0.0996		0.0003						P:	***
Equality across di, P	a: -		b: -		a: -		b: -		a: ***		b: -						Overall di, P Equality:	***
	a, b: ***				a, b: ***				a, b: ***									

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	Mean Interest Rate	Changed Interest Rate	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	1 month
$di^{j,k}$	2.209	3.209	-0.1011 ***	-0.1061 ***	-0.1681 ***		-0.3754 ***
		7.833	-0.0840 ***	-0.0657 ***	-0.1146 ***		-0.2644 ***
		13.457	-0.0632 ***	-0.0166	-0.0496		-0.1293 *
$P^{k,j}$	2.209	3.209	0.0064	-0.0366	0.1012 **		0.0709
		7.833	0.0470 ***	0.0171	0.1025 ***		0.1666 ***
		13.457	0.0965 ***	0.0824 ***	0.1041 ***		0.2829 ***
$S^{j,k}$	2.209	3.209	-0.0948 ***	-0.1428 ***	-0.0669 *	0.3283 ***	0.0239
		7.833	-0.0370 **	-0.0487 ***	-0.0121	0.1090 ***	0.0112
		13.457	0.0333 *	0.0658 ***	0.0545 **	-0.1578 ***	-0.0042

> Monthly data, sample period: 89:1-94:12

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 4

Term Structure Regressions FRANCE

Estimated Coefficients

Dependent Variable	Horizon: 2-3 months a		2-3 months b		4-5 months a		4-5 months b		6-11 months a		6-11 months b		12+ months a		12+ months b			Nonlinearity Null: all b=0
$S^{j,k}$	-0.5980	**	0.1137		-0.9830	***	0.2075	***	-0.4411	**	0.0407		2.048	***	-0.3581	**		**
$di^{j,k}$	-0.1917	***	0.0191		-0.2446	***	0.0275	*	-0.5421	***	0.0833	***					di: all:	*** ***
$P^{k,j}$	-0.4063	*	0.0946		-0.7384	***	0.1799	***	0.1010		-0.0427						P:	***
Equality across di, P	a: - a, b: -		b: -		a: ** a, b: ***		b: ***		a: *** a, b: ***		b: *						Overall di, P Equality:	***

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	Mean Interest Rate	Changed Interest Rate	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	1 month
$di^{j,k}$	1.211	2.211	-0.1262 ***	-0.1504 ***	-0.2569 ***		-0.5335 ***
		2.411	-0.1224 ***	-0.1448 ***	-0.2403 ***		-0.5075 ***
		3.611	-0.0995 ***	-0.1118 ***	-0.1403 ***		-0.3516 ***
$P^{k,j}$	1.211	2.211	-0.0826	-0.1227 **	-0.0451		-0.2503 *
		2.411	-0.0637	-0.0867	-0.0536		-0.2040
		3.611	0.0498	0.1292	-0.1048		0.0742
$S^{j,k}$	1.211	2.211	-0.2088 ***	-0.2730 ***	-0.3020 ***	0.8225 ***	0.0386
		2.411	-0.1861 **	-0.2316 ***	-0.2939 ***	0.7509 ***	0.0394
		3.611	-0.0496	0.0174	-0.2451 *	0.3213	0.0439

> Monthly data, sample period: 89:1-94:12

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 5

Term Structure Regressions IRELAND

Estimated Coefficients

Dependent Variable	2-3 months a		2-3 months b		4-5 months a		4-5 months b		6-11 months a		6-11 months b		12+ months a	12+ months b		Nonlinearity Null: all b=0
$S^{j,k}$	-0.0902		-0.0054		0.0230		-0.0029		-0.0727		0.0055		0.3346	0.0029		-
$di^{j,k}$	-0.1897	***	0.0113	***	-0.1450	***	0.0042	***	-0.5150	***	0.0226	***			di: all:	*** ***
$P^{k,j}$	0.0994		-0.0166		0.1680	**	-0.0071	**	0.4423	**	-0.0171	-			P:	**
Equality across di, P	a: ** a, b: -		b: *		a: *** a, b: ***		b: ***		a: *** a, b: ***		b: **				Overall di, P Equality:	***

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	Mean Interest Rate	Changed Interest Rate	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	1 month
$di^{j,k}$	1.741	2.741	-0.1391 ***	-0.1263 ***	-0.4135 ***		-0.6790 ***
		10.111	-0.0560 ***	-0.0956 ***	-0.2466 ***		-0.3982 ***
		18.481	0.0384	-0.0607 ***	-0.0571 ***		-0.0794
$P^{k,j}$	1.741	2.741	0.0249	0.1364 ***	0.3656 **		0.5269 ***
		10.111	-0.0978	0.0844 ***	0.2395 ***		0.2261 **
		18.481	-0.2371	0.0254 ***	0.0962 ***		-0.1154
$S^{j,k}$	1.741	2.741	-0.1143 *	0.0101	-0.0479	0.3478 **	0.1957
		10.111	-0.1538 ***	-0.0112	-0.0072	0.3695 ***	0.1974 **
		18.481	-0.1986 *	-0.0353 **	0.0391 **	0.3942 ***	0.1994 **

> Monthly data, sample period: 91:6-94:12

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 6

Term Structure Regressions ITALY

Estimated Coefficients

Dependent Variable	Horizon: 2-3 months a	2-3 months b	4-5 months a	4-5 months b	6-11 months a	6-11 months b	12+ months a	12+ months b	Nonlinearity Null: all b=0
$S^{j,k}$	0.1669	-0.0407	-0.3037	0.0318	-1.523 **	0.1639 **	1.921 *	-0.1853	-
$di^{j,k}$	0.0040	-0.0151 ***	0.2190 *	-0.0462 ***	0.5436 **	-0.0954 ***			di: ***
									all: ***
$P^{k,j}$	0.1629	-0.0256	-0.5227 ***	0.0779 ***	-2.066 ***	0.2593 ***			P: ***
Equality across di, P	a: -	b: -	a: ***	b: ***	a: ***	b: ***			Overall di, P Equality: ***
	a, b: -		a, b: ***		a, b: ***				

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	Mean Interest Rate	Changed Interest Rate	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	1 month
$di^{j,k}$	3.365	4.365	-0.1126 ***	-0.1380 ***	-0.1942 ***		-0.4448 ***
		4.973	-0.1218 ***	-0.1661 ***	-0.2522 ***		-0.5401 ***
		6.581	-0.1461 ***	-0.2404 ***	-0.4057 ***		-0.7921 ***
$P^{k,j}$	3.365	4.365	-0.0347	0.0798 *	-0.0616		-0.0165
		4.973	-0.0502	0.1272 ***	0.0961		0.1730
		6.581	-0.0913	0.2525 ***	0.5131 ***		0.6741 ***
$S^{j,k}$	3.365	4.365	-0.1473 **	-0.0582	-0.2558	0.4880 **	0.0267
		4.973	-0.1720 **	-0.0389	-0.1562	0.3754 *	0.0083
		6.581	-0.2374 **	0.0122	0.1074	0.0773	-0.0405

> Monthly data, sample period: 90:5-92:8

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 7
Term Structure Regressions NORWAY

Estimated Coefficients

Dependent Variable	**Horizon** 2-3 months a	2-3 months b	4-5 months a	4-5 months b	6-11 months a	6-11 months b	12+ months a	12+ months b		Nonlinearity Null: all b=0
$\mathbf{S^{j,k}}$	-0.0786	0.0388	0.2742	0.0692	0.5372 **	0.1382 ***	-1.230 ***	-0.3366 ***		***
$\mathbf{di^{j,k}}$	-0.1927 ***	-0.0120 **	-0.3143 ***	-0.0295 **	-0.7314 ***	-0.0910 **			di:	***
									all:	***
$\mathbf{P^{k,j}}$	0.1141	0.0509	0.5885	0.0987	1.269 ***	0.2291 ***			P:	***
Equality across di, P	a: -	b: -	a: **	b: *	a: ***	b: ***			Overall di, P Equality:	***
	a, b: -		a, b: -		a, b: **					

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	**Mean Interest Rate**	**Changed Interest Rate**	**Horizon** 2-3 months	4-5 months	6-11 months	12+ months	**1 month**
$\mathbf{di^{j,k}}$	-1.934	-0.934	-0.1582 ***	-0.2298 ***	-0.4706 ***		-0.8585 ***
		-0.370	-0.1650 ***	-0.2464 ***	-0.5218 ***		-0.9332 ***
		-1.193	-0.1838 ***	-0.2925 ***	-0.6641 ***		-1.140 ***
$\mathbf{P^{k,j}}$	-1.934	-0.934	-0.0319	0.3055	0.6114 ***		0.8851 **
		-0.370	-0.0032	0.3612	0.7406 ***		1.099 **
		-1.193	0.0764	0.5154	1.099 ***		1.691 ***
$\mathbf{S^{j,k}}$	-1.934	-0.934	-0.1900	0.0758	0.1409	-0.2643	-0.2377
		-0.370	-0.1681	0.1148	0.2188	-0.4541	-0.2886
		-1.193	-0.1074	0.2230	0.4349 **	-0.9805 **	-0.4300 *

> Monthly data, sample period: 89:1-92:10

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 8

Term Structure Regressions SPAIN

Estimated Coefficients

Dependent Variable	Horizon: 2-3 months a	2-3 months b	4-5 months a	4-5 months b	6-11 months a	6-11 months b	12+ months a	12+ months b		Nonlinearity Null: all b=0
$S^{j,k}$	-0.4656	0.0375	-1.111 ***	0.1108 ***	-0.0971	0.0082	1.960 ***	-0.1873 ***		***
$di^{j,k}$	-0.0542	-0.0081	0.0134	-0.0204 ***	-0.1940	-0.0185			di: all:	*** ***
$P^{k,j}$	-0.4114	0.0456	-1.125 ***	0.1312 ***	0.0969	0.0266			P:	***
Equality across di, P	a: - a, b: ***	b: -	a: *** a, b: ***	b: ***	a: - a, b: ***	b: -	Overall di, P Equality:			***

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	Mean Interest Rate	Changed Interest Rate	Horizon: 2-3 months	4-5 months	6-11 months	12+ months	1 month
$di^{j,k}$	4.954	5.954	-0.1422 ***	-0.2088 ***	-0.3957 ***		-0.7467 ***
		6.781	-0.1489 ***	-0.2256 ***	-0.4110 ***		-0.7855 ***
		8.608	-0.1636 ***	-0.2628 ***	-0.4447 ***		-0.8712 ***
$P^{k,j}$	4.954	5.954	0.0860	0.3061 ***	0.3875 ***		0.7797 ***
		6.781	0.1237 **	0.4145 ***	0.4096 ***		0.9478 ***
		8.608	0.2070 *	0.6541 ***	0.4582 ***		1.319 ***
$S^{j,k}$	4.954	5.954	-0.0562	0.0973	-0.0082	-0.0831	-0.0501
		6.781	-0.0252	0.1889 **	-0.0014	-0.2379 *	-0.0756 *
		8.608	0.0434	0.3913 ***	0.0135	-0.5800 **	-0.1319 **

> Monthly data, sample period: 89:1-94:12

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).

TABLE 9

Term Structure Regressions SWEDEN

Estimated Coefficients

Dependent Variable	Horizon 2-3 months a		2-3 months b		4-5 months a		4-5 months b		6-11 months a		6-11 months b		12+ months a		12+ months b		Nonlinearity Null: all b=0	
$S^{j,k}$	-0.1247	*	0.0050	**	-0.0438		0.0011		-0.1276		0.0054	*	0.2699	*	-0.0095	**		*
$di^{j,k}$	-0.1421	***	0.0046	***	-0.1843	***	0.0048	***	-0.4119	***	0.0120	***					di: all:	*** ***
$P^{k,j}$	0.0174		0.0004		0.1405	***	-0.0037	***	0.2843	***	-0.0066	***					P:	***
Equality across di, P	a: a, b:	** ***	b:	**	a: a, b:	*** ***	b:	***	a: a, b:	*** ***	b:	***					Overall di, P Equality:	***

Economic Impact on Exchange Rate Expectations

(increase in dependent variable implied by increase in policy interest rate, divided by size of increase)

Dependent Variable	**Mean Interest Rate**	**Changed Interest Rate**	Horizon 2-3 months	4-5 months	6-11 months	12+ months	**1 month**
$di^{j,k}$	4.600	5.600	-0.0952 ***	-0.1358 ***	-0.2898 ***		-0.5208 ***
		17.207	-0.0419 ***	-0.0806 ***	-0.1509 ***		-0.2734 ***
		29.813	0.0161 ***	-0.0207 ***	0.0002		-0.0046
$P^{k,j}$	4.600	5.600	0.0219	0.1027 ***	0.2171 ***		0.3417 ***
		17.207	0.0270	0.0598 ***	0.1406 ***		0.2273 ***
		29.813	0.0326 ***	0.0131 ***	0.0575 ***		0.1031 ***
$S^{j,k}$	4.600	5.600	-0.0733	-0.0331	-0.0727	0.1728	-0.0064
		17.207	-0.0148	-0.0209 *	-0.0103	0.0622	0.0162
		29.813	0.0487 ***	-0.0076 *	0.0575 ***	-0.0579 ***	0.0406 ***

> Monthly data, sample period: 89:4-92:10

> Dependent variables are expressed as 100xln(.) and main regressor (overnight money market rate differential) is expressed in percentage points, so results can be interpreted in terms of percentage devaluations in response to percentage point changes in policy variable.

> Regressions also include current exchange rate as well as a constant term (not reported; see equations (7a)-(7g) and (8a)-(8d) in text).

> *, ** and *** stand for significance at the 10%, 5% and 1% level, respectively (based on heteroskedasticity-consistent standard errors).