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TARGETING THE EXCHANGE RATE: AN EMPIRICAL INVESTIGATION

Shula Pessach

Assaf Razin

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ABSTRACT

The purpose of this paper is to implement empirically a variant of the new theory of exchange rate targeting, suitable for high inflation small open economies. The theory formulates an expectations induced relationship between the exchange rate and the fundamental subject to random shocks and target zone constraints on rates of depreciation. The empirical analysis identifies the roles played by policy and market fundamentals in foreign exchange markets, and estimate the key parameters of the exchange rate dynamic equation.

Shula Pessach
Research Department
Bank of Israel
Jerusalem, Israel 91007
and
Stern School of Business
New York University
Economics Department
New York, NY 10006-1594

Assaf Razin
Department of Economics
University of Chicago
Chicago, IL 60637

I. Introduction

It is common place in many inflationary episodes that monetary authorities set upper limits on the exchange rate movements to slow inflation. By affecting expectations the management of the exchange rate changes systematically the equilibrium relationship between the exchange rate and market fundamental factors (such as the money supply). A challenge to the empirical research is to separate out the effects on the exchange rate, which arise from market fundamentals, from policy interventions.

The new exchange rate target zone literature has been able to formulate in a simple way the expectations-induced relationship between the exchange rate and the fundamentals, subject to random shocks[1]. The theory's key prediction is that the existence of an upper barrier to

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[1]See Bertola and svensson (1990), Krugman (1987, 1988, 1989), Flood and Garber (1989), Froot and Obstfeld (1989), Miller and Weller (1988) and Svensson (1989). A recent paper by Flood, Mathieson and Rose (1990) (adopting an approach similar to the present paper) implements the target zone exchange rate theory on EMS exchange rate data.

exchange rate fluctuations shifts down the entire schedule representing the relationship between the exchange rate and the fundamental.

The purpose of this paper is to implement empirically the exchange rate target zone theory, for inflation-prone economies. In this context the paper provides an empirical analysis of exchange rate policies for a representative small-open economy, under inflation (Israel: 1978-90). This period, which is characterized by high and variable inflation rates, intensive exchange rate targeting and fluctuating interest differentials (reflecting varying expectations), seems especially suitable for testing the target zone theory.

The empirical results of the paper conform to the model's predictions and are statistically significant. We further consider, both theoretically and empirically, the implications of the exchange rate regime for rates of return to different currency denominated bonds and derive an estimate for the probability of a discrete devaluation. The estimated probability is found to be highly correlated with contemporaneous capital flows.

The paper is organized as follows. In Section II we outline the key features of the target-zone exchange-rate theory and present the variant of the theory which is suitable to the study of inflationary environments. Section III provides an overview of the foreign exchange market in Israel. In section IV we implement the model to the data, whereas in section V we outline the theoretical applications of the target zone exchange rate for rates of return to assets of different currency denominations and the derived probability of a discrete devaluation. This enable us to test the credibility of the exchange rate regime and the role of the probability of a discrete devaluations in explaining capital flows. Section VI concludes the paper with a summary and suggested extensions.

II. The Analytical Framework

Consider the standard log-linear model of exchange-rate behavior.[2] The exchange rate is determined by:

$$(1) \quad s_t = v_t + \delta\{E_t[ds_t]\}/dt \qquad , \delta > 0,$$

where

s_t = exchange rate,

v_t = fundamental,

δ = interest-rate (semi) elasticity of money demand, and

E_t = expectations operator (conditioned on information in period t).

This specification of exchange-rate behavior could be derived from a standard demand for money function $m - p = c + \alpha y - \delta i + \epsilon$ and the interest parity condition $i = i^* + \{E_t[ds_t]\}/dt$; under this specification the fundamental is given by:

[2]See Krugman (1989), and Svensson (1989).

(2) $v_t = m_t + q_t - c - \alpha y_t + \delta i^*_t - \epsilon_t \qquad , \alpha > 0,$

where

m = money supply,

q = $s + p^* - p$, real exchange rate,

p = domestic price level,

p^* = world price level,

c = a constant of the money demand equation,

α = output elasticity of money demand,

y = domestic output,

i = domestic rate of interest,

i^* = world rate of interest, and

ϵ = money demand disturbance.

As usual, equations (1)-(2) imply that the exchange rate (the price of foreign currency in terms of domestic currency) depends positively on the money supply, the world rate of interest and the real exchange rate and negatively on domestic output and money demand shocks. Crucially, the exchange rate depends also positively on the expected rate of depreciation, $(E_t[ds_t])/dt$.

A forward solution to equation (1) (assuming that there are no bubbles) implies that:

$$(3) \quad s_t = \left(\frac{1}{\delta}\right)\int_t^\infty E_t\, v_\varphi\, e^{-\frac{\varphi - t}{\delta}}\, d\varphi$$

Equation (3) implies that the exchange rate can be viewed as the discounted sum of present and the expected future values of the fundamentals. We assume that the rate of change of the fundamental, f, follows a Brownian motion. The assumption implies that:

(4) $f_t = dv_t/dt,$

and

(5) $df_t = \mu dt + \sigma dz$

where z is a Weiner process with $E[dz] = 0$ and $E[(dz)^2] = dt$. The term μ is the drift and σ is the instantaneous standard deviation of the rate of change of the fundamental.

Integrating (4) and taking expectations yields:

$$(6) \quad E_t v_\varphi = v_t + \int_t^\varphi E_t f_\theta d\theta$$

Upon substituting (6) into (3) we get:

$$(7) \quad s_t = \frac{1}{\delta}\int_t^\infty \{ v_t + \int_t^\varphi E_t f_\theta d\theta \} e^{-\frac{\varphi - t}{\delta}} d\varphi$$

Because the rate of change of the fundamental, f, follows a Brownian motion we can write the second term on the right hand side of (7) (which consists of future values of f) as a function, h(f), of the current value of f. That is:

$$(8)\quad h(f_t) = \frac{1}{\delta}\int_t^{\infty} \left(\int_t^{\varphi} E_t\, f_\theta\, d\theta \right) e^{-\frac{\varphi - t}{\delta}}\, d\varphi$$

Observe that the first term on the right hand side of (7) is equal to v_t. We thus have:

$$(9)\quad s_t = v_t + h(f_t)$$

Differentiating (9), while applying Ito's Lemma and taking expectations yields:

$$(10)\quad E_t ds_t = dv_t + h'(f_t)\mu dt + \frac{1}{2}h''(f_t)\sigma^2 dt$$

Substituting (10) into (1), using $dv_t = f_t dt$, yields:

$$(11)\quad s_t = v_t + \frac{\delta}{dt}\left[f_t dt + h'(f_t)\mu dt + \frac{1}{2}h''(f_t)\sigma^2 dt \right]$$

Equations (11) and (9) yield the fundamental differential equation for $h(f_t)$, namely:

$$(12)\quad h(f) = f\delta + h'(f)\mu\delta + h''(f)\frac{\delta}{2}\sigma^2$$

The solution to (12) is given by:

(13) $h(f) = f\delta + \delta^2\mu + Ae^{\tau f} + Be^{\beta f}$

where A and B are the solution parameters and $\tau > 0$, $\beta < 0$ are the roots of the characteristic equation associated with (12). The characteristic equation is given by:

(14) $(\delta/2)\sigma^2\tau^2 + \delta\mu\tau - 1 = 0.$

The term $\delta f + \delta^2\mu$ in (13) represents the specific solution of the differential equation, while the second term, $Ae^{\tau f} + Be^{\beta f}$, represents the homogeneous solution. The coefficients A and B are the constants of integration. Substituting equation (13) into (9) the solution for the exchange rate is given by:

(15) $s_t = v_t + \delta f_t + \delta^2\mu + Ae^{\tau f_t} + Be^{\beta f_t}$

The economic interpretation of equation (15) is that the first term, $v + \delta f + \delta^2\mu$, represents the effect of the rate of change of the fundamental on the exchange rate, while the second term, $Ae^{\tau f} + Be^{\beta f}$, represents the deviation of the exchange rate from this path due to the intervention by the central bank

The hall mark of the exchange rate target zone model is the regulation of the stochastic process of the exchange rate (or the fundamental). The view underlying the model is that under high inflation the monetary policy could be described as management of the rate of depreciation rather than the exchange rate level. Accordingly, we impose an upper limit to the rate of change of the fundamental.

Denoting by x the expected rate of depreciation of the exchange rate, equations (1) and (15) imply that:

$$(16)\quad x_t = \frac{1}{dt}E_t ds_t = f_t + \delta\mu + \frac{1}{\delta}[\, Ae^{\tau f_t} + Be^{\beta f_t} \,]$$

The upper limit on the rate of change of the fundamental implies, in turn, an upper limit on x_t, which is denoted by $\bar{x}$, namely:

$$(17)\quad x_t \leq \bar{x}$$

Excluding bubbles, the expected rate of depreciation under the free float exchange-rate regime, x_F, is determined by:

$$(18)\quad x_{Ft} = \delta\mu + f_t.$$

Namely, the expected rate of depreciation depends positively on the drift of the rate of change of the fundamental (multiplied by the interest rate semi-elasticity of the demand for money) and the realization of the rate of change of the fundamental.

As indicated above we assume that the monetary authority places an upper barrier to the rate of change of the fundamental, thus, the expected rate of depreciation is also regulated. Assuming that no lower limit is placed, the no-bubble condition must imply that $B = 0$. Hence the expected rate of depreciation under the managed exchange-rate regime, x_M, is given by:

$$(19) \quad x_{Mt} = \delta\mu + f_t + (1/\delta)Ae^{\tau f t}$$

The integration constant, A, is determined from the smooth pasting condition . Since the authorities impose the upper bound on f the smooth pasting condition is $h'(\bar{f}) = 0$, which is the same as $x_M'(\bar{f}) = 0$. The last condition simply reflects the fact that near the upper limit there exists only one-sided risk in exchange rate fluctuations.[3]

Differentiating equation (19) and evaluating the derivatives around $f = \bar{f}$ yields:

$$(20) \quad A = -(1/\tau)e^{-\tau\bar{f}} < 0.$$

Since A is negative, equations (18) and (19) imply that the expected rate of depreciation under the managed exchange-rate regime never exceeds the free-float depreciation rate.

[3] In our model the upper barrier is imposed on the rate of change of the fundamentals and, thereby, on the rate of expected depreciation. See Bertola and Caballero (1989) for a model with bounds on the level of the exchange rate with an extension which allows for realignments; in which case the smooth pasting condition is modified.

Finally, the substitution of equation (20) into equation (19) yields a relationship between the upper barrier depreciation rate $\bar{x}$ and the upper bound on the rate of change of the fundamental f which is given by:

(21) $\bar{x} = \delta\mu - (1/\tau) + \bar{f}$

To summarize, we specify an equilibrium expected rate of depreciation which can be decomposed into a term governed by the behavior of the random fundamental factors and a term which captures the effect of the ceiling of depreciation. This allows us to evaluate the deviations of the depreciations under a managed exchange-rate regime from the corresponding rates of change under the free float exchange-rate regime. The model is implemented empirically in the subsequent sections.

III. Exchange Rates in Israel: An Overview

In this section we survey the exchange rate policies in Israel. Israel, can be thought of as a representative economy for empirical assessments of the effects of foreign exchange interventions, under inflationary conditions. Table 1 presents indicators of the balance of payments and the foreign exchange market in Israel throughout the years 1979-89.

Since its early days Israel used a fixed exchange rate system in which the exchange rates had been periodically adjusted through discrete realignments. With the increase in inflation in 1975 the regime changed to a crawling peg (with a 2 percent devaluation per month on average). The liberalization of capital transactions in 1977 changed the system to managed float. The central bank opened a "trading room" where the banks (the official foreign exchange traders) posted purchase or sale requests. Effectively, the price of foreign exchange was predetermined by the central bank, which cleared the market by supplying the excess demand from its official reserves.

The escalation of inflation in 1978 and the increase in domestic interest rates sparked significant portfolio adjustments and large private sector capital inflows, resulting in a significant accumulation of foreign currency reserves. Nominal devaluations had been lagging significantly after inflation (See Table 1).

In 1979 inflation increased further to the 3-digit range. Imported fuel prices rose sharply during this year, thereby impairing the balance of payments. Long and medium-term capital imports of both the private and the public sectors were insufficient to finance the current account deficit, necessitating short-term capital inflows. A PPP exchange-rate policy was adopted to prevent continuing deterioration in competitiveness. The exchange rate had been adjusted according to expected inflation with a partial reaction by the monetary authorities to day to day changes in supply and demand.

The sharp deterioration in the balance of payments in 1979 was arrested in 1980, by severe contractionary measures. Economic activity picked up later in 1981 and the escalation of inflation stopped (the inflation slowed down to 101 percent during the year from 132 percent in the previous year). The government launched a synchronization program (which included the exchange rate and the controlled prices but not wages) whose purpose was to further stabilize inflation. The program consisted of a rigid rule of a 5 percent monthly devaluation while the core inflation had been 7 percent per month. The balance of payments deteriorated sharply and a widespread perception was that a corrective discrete devaluation is unavoidable. In October 1983 the synchronization policy was abandoned with a 23 percent devaluation and some tighter fiscal measures were taken. The policy produced mixed results: an improvement in the balance of payments on the one hand, and escalation of inflation on the other hand.

In 1984, the national unity government implemented a sequence of "package deals" with caps on growth rates of the exchange rate, controlled prices and wages. Anticipations of more fundamental policy measures including a discrete devaluation and possible taxation of income from financial assets, spurred sizeable capital outflows. These expectations were reflected in the high exchange rate premium in the black market dollar (see Table 1).

In mid-1985 the government introduced a comprehensive economic stabilization program, including a 13 percentage GDP points cut in the budget deficit. The program successfully lowered the inflation from a level of 400 percent to the level of about 20 percent per year. One of the main features was the pegging of the exchange rate, initially to the dollar and later to a basket of currencies. Due to remaining inflation differentials between Israel and its main trading partners several realignments over the 1986-88 period took place.

In 1989 the exchange rate was officially allowed to fluctuate within a target zone. In effect, however, the central bank continued to set the daily price of foreign exchange and clear the market through sells or purchases of foreign exchange from the stock of its reserves. Figure 1 describes the percentage deviations of the actual rate from the post devaluation rate during the so called exchange-rate freeze (1985-1990).

The overall conclusion which emerges is that throughout the period the central bank placed <u>upper barriers</u> on exchange rate fluctuations, possibly because of concern about inflationary consequences of depreciations. It is reasonable to assume that the private sector has been aware of such exchange rate targeting, and that these public perceptions have been reflected in continuous adjustments in asset portfolios and trade transactions. These features, captured by the analytical model (described in Section II) make the foreign exchange market in Israel suitable to serve as a testing ground of the new target zone theory. The theory assumes free capital mobility since it relies on uncovered interest rate parity. Officially, there are numerous controls on capital flows. Based on the above mentioned description of events we argue, however, that there have been enough possibilities to circumvent the controls so that there still have been sufficient capital mobility.

IV. A Target Zone Model: Empirical Application

In this section we implement a variant of the exchange rate target zone theory on the monthly data from Israel: 1978:08 – 1990:06. The estimation of the model is carried out in three stages.[4]

First, we estimate a standard demand for money equation. World price fluctuations and nonsystematic deviations from PPP are subsumed into the residual of the equation and expectations are assumed to be unbiased. Accordingly, the demand for money is given by:

(22) $m_t - s_t = c + \alpha y_t - \delta E(s_{t+1} - s_t) + w_t$

where w is a stochastic residual (which is equal to $\epsilon - q$ in equation (2)).

Second, using the estimates of c, α, and w, we estimate the drift (μ) and variability (σ) parameters of the rate of change of the fundamental ($v = m - c - \alpha y - w$) from first differences of f. The variability measure, σ, is the standard error of the drift-adjusted periodic changes

[4]The application is based on the to discrete time approximation of the model.

in f. At this stage we calculate the root of the characteristic equation, τ, from equation (10).[5] The estimated root is:

$$(23)\quad \hat{\tau} = [-\hat{\delta}\hat{\mu} + (\hat{\delta}^2\hat{\mu}^2 + 2\hat{\delta}\hat{\sigma}^2)^{1/2}]/\hat{\delta}\hat{\sigma}^2$$

where a "hat" indicates an estimate.

<u>Third</u>, using $\hat{\tau}$ and $\hat{f}$ we estimate the interventions' parameter, A, in equation (15) from the following equation:

$$(24)\quad s_t = v_t - \delta \hat{f}_t - \delta^2\mu + Ae^{\hat{\tau}\hat{f}} + u_t$$

where u_t is a stochastic residual. Note that although equation (15) is deterministic (with the value of B set equal to zero by the no-bubble condition) we allow in equation (24) a stochastic deviation from trend, to capture errors in measurements which are likely to result from deviations from PPP, and other missing variables.

The variables used in the empirical application are:

m = the monetary aggregate M_2,

s = the shekel-dollar exchange rate,

y = the index of industrial production

Assuming rational expectations, the expected future exchange rate depreciation (see the right hand side of equation (9)) is constructed from the actual depreciation rate, one month ahead, until June 1985. For

[5]See equation (14).

subsequent period we use a measure which is derived from the interest rate differential[6]. The demand for money is estimated by using instrumental variables for y_t and $E(s_{t+1}-s_t)$.

Tables 2a and 2b report the empirical findings. The first equation in Table 2a describes the demand for money. The estimates for the long run output elasticity, is $\alpha = 5.73$, and the long run interest rate semi-elasticity, $\delta = -10.7$, is in the confidence intervals of previous estimations of the demand for money in Israel.[7] The behavior of the growth rate of the fundamental (capturing changes in both money supply and money demand) is estimated for six sub-periods, corresponding to the changes in the economic environment described in section III. The drift measure, which reflects the average growth rate of the excess supply of money, ranges from -5 percent per month to 5.5 percent per month. The variability measure exhibits significant variations across periods.

Table 2b reports the estimated interventions' coefficient, A, for each period (see equation (24)). As the theory predicts, the interventions' coefficient (which is determined by the upper bound set by the authorities on exchange-rate depreciations) is negative, and statistically significant.

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[6]This measure is only available from 1985. From July 1985 we could not used actual depreciation rates due to the nature of the exchange rate regime, which amounts to a relatively fixed exchange rate with discrete devaluations.

[7]See, for example, Leiderman and Marom (1985).

Table 2a: Estimation[1]

Demand for Money:[2]

$$m_t - s_t = -2.677 + 0.852(m_{t-1} - s_{t-1}) + 0.845y_t - 1.580E(s_{t+1} - s_t) + 0.234D_1 - 0.123D_2,$$
$$\quad (4.49) \quad (30.40) \qquad\qquad (4.98) \qquad (5.42) \qquad\qquad (3.74) \quad (2.47)$$

$$R^2 = 0.995, \quad AR(1) = 0.34, \quad D.W. = 1.96$$
$$\qquad\qquad (3.91)$$

Rates of Change of the Fundamental:

Period i	Drift (μ_i)	Variability (σ_i)	Root (τ_i)
1978:08–1981:03	−0.00035	0.25673	1.689
1981:04–1983:07	−0.02262	0.31719	1.606
1983:08–1985:06	0.05570	0.88714	0.422
1985:07–1986:07	−0.05163	0.17352	4.739
1986:08–1988:12	0.00074	0.03232	12.685
1989:01–1990:06	−0.00279	0.03855	13.254

[1] t–ratios are reported in parentheses.

[2] To correct for simultaneous equation bias we use the following instruments: y_{t-1}, y_{t-2}, $(s_t - s_{t-1})$, $(s_{t-1} - s_{t-2})$, $(s_{t-2} - s_{t-3})$, $(m_{t-1} - s_{t-1})$ and dummy variables which capture discrete changes of the regime, D_1 for September 1983 and D_2 for June 1985.

Table 2b: Estimation[1]

Depreciations under the Managed Exchange-Rate Regime:

$$s_t - v_t - \delta f_t - \delta^2 \mu_i = \text{Constant}_i - A_i e^{\tau_i f} t$$

Period i	A_i	Constant_i
1978:08–1981:03	-5.537	6.333
	(14.45)	(13.77)
1981:04–1983:07	-5.038	8.736
	(17.474)	(23.509)
1983:08–1985:06	-25.656	21.365
	(36.375)	(27.028)
1985:07–1986:07	-0.425	6.1556
	(7.117)	(20.597)
1986:08–1988:12	-0.6698	0.679
	(1.811)	(1.571)
1989.01–1990:06	-0.3174	0.698
	(2.029)	(2.205)

$R^2 = 0.97$, AR(1) = 0.204, D.W. = 2.08
(2.14)

[1] t-ratios are reported in parentheses.

The estimates in Tables 2a and 2b can be used to calculate the free float expected rates of depreciation, x_F, the corresponding rates of the managed exchange, x_M, and the upper-bound depreciation rate, $\bar{x}$. The free-float rate is calculated from equation (18) using the estimates of δ, μ, and f. The managed rate is obtained from equation (19), while the upper-bound rate is calculated from equations (20) and (21).

Figure 2 describes the sample paths of the (derived) upper-bound and managed depreciation rates, over the period 78:08 - 90:06. As suggested by the theory, the managed rate is always below the upper bound, set by the monetary authorities to limit exchange rate fluctuations. Interestingly, figure 2 shows that in the period 1978-83, and in particular between 1981 and 1983, the upper limits are binding. Thus, even though the exchange rate is officially declared as being determined to a large extent by market forces, the fluctuations of the exchange rate are in fact influenced by the intervention. The figure indicates relatively weak constraints on the rates of depreciation in the high (and accelerating) inflation period of 1983 to mid-1985. The post 1985 stabilization period, that started with a large discrete devaluation and followed by an exchange rate freeze, is divided into three sub-periods: mid 1985 to mid 1986, mid 1986 to the end of 1988 and 1989 to 1990. The figure shows that in the first sub period the depreciation ceilings are not binding, possibly reflecting the effect of the excessive devaluation that took place at the initial stage of the stabilization program. This finding could suggest that the period should be viewed as an adjustment period. The figure also demonstrates that during the second sub period the freeze is almost fully binding. This may indicate a possibility that the exchange rate policy has become less credible. In the third sub period, however, the limits on the fluctuations of the expected exchange rate depreciation seem to be somewhat less binding, which may imply that the exchange rate policy has become more credible during that period.

The M curve in Figures 3a–3f portrays the relationship between the expected managed depreciations and the growth rate of the fundamentals (see equation (19)). The F curve describes the corresponding relationship for the free float expected depreciation (see equation (18)). These figures are an empirical counterpart of the main analytical geometrical device, used in the target zone literature (see Krugman (1988, 1989), Flood and Garber (1989), Froot and Obstfeld (1989) and Svensson (1989)). As the theory suggests, the relationships between the M and the F curves must satisfy the following properties:

a) Since the intervention coefficient, A, is negative, the M curve must lie below the F curve. This implies that expectations that the monetary authority will not let the rate of depreciation go above the upper-barrier $\bar{x}$, hold down the expected depreciation rate, compared to what it would have been otherwise. In other words, the upper barrier <u>stabilizes</u> the exchange rate within the target zone.

b) The M curve is tangent to the upper bound at the point in which the managed rate of depreciation reaches the bound and the curve bends downward for larger rates of change of the fundamental. This implies that the underlying intervention policy has been characterized by discrete changes in the fundamentals. The points on the bending downward segment of the M curve corresponds to such discrete interventions in the fundamental (see Appendix I). Indeed, the existence of a downward bending segment in the M curves is especially notable in the first three periods, where the exchange rate policy was not explicit, as is the case in the last three sub periods, after the stabilization program was launched.

c) Managed depreciations approach the free float asymptotically as the rate of increase of the fundamental falls. That is, the effects of the target zone on the managed float weaken as the demand for money increases.

V. Upper Bounds on Rates of Return

An exchange rate target zone with explicit restrictions on expected depreciations implies also a bound on the rates of return to foreign currency denominated investment, in terms of domestic currency. With an efficient domestic bond market, this implies specific restrictions on the rates of return to domestic currency denominated investment as well.

V.1. Theory

Denote the spot exchange rate in period t, the annualized domestic interest rate in period t and the annualized interest rate on foreign-currency denominated bonds in period t, by S_t, i_t and i^*_t, respectively. The effective annualized domestic-currency ex-post rate of return on a foreign currency investment in period t, R_t, is given by:

$$(25) \quad R_t = (1+i^*_t)(S_{t+j}/S_t) - 1$$

where S_{t+j} is the spot exchange rate at t+j. The expected rate of return on this investment depends, therefore, on the expected exchange rate S^e_{t+j}, and thereby on the expected rate of depreciation. If an upper bound is placed on the expected rate of depreciation $\bar{x}$, the rate of return R_t is also restricted. The corresponding upper bound on the expected rate of return $\bar{R}^e_t$ is:

$$(26) \quad \bar{R}^e_t = (1+i^*_t)(1+\bar{x}_t) - 1$$

With efficient domestic bond markets the domestic interest rate, i_t, must always lie below the upper bound $\bar{R}_t$. If the domestic interest rate exceeds the bound, there is completely safe arbitrage that allows for unlimited profits. Such arbitrage possibilities are not compatible with an efficient domestic financial market. Thus, if, indeed, the domestic interest rate in any period is above the upper bound (26), and if there exist domestic and foreign assets with equal maturity and risks of default, the commitment of the foreign exchange authorities to set an upper bound cannot be completely credible. That is, investors perceive a risk of a realignment. Therefore, as shown in Svensson (1990), the simplest test of whether the upper bound is completely credible is to check whether domestic interest rate is always below the upper bound rate of return.

Consider now the implications of the assumption of uncovered interest rate parity, so that, the expected rate of depreciation compensates fully for the interest rate differential between domestic-currency and foreign-currency investments. That is:

$$(27) \quad \frac{S_{t+j}}{S_t} = \frac{(1+i_t)}{(1+i^*_t)}$$

The interest rate differential is defined by:

$$(28) \quad d_t = \frac{(1+i_t)}{(1+i^*_t)} - 1$$

Clearly, an upper bound on the expected rate of depreciation places also a bound on d_t that is, $d_t \leq \bar{x}_t$.

Since the introduction of the economic stabilization policy in mid 1985 the exchange rate has been fixed with periodic discrete realignments. This feature of the exchange rate regime can be seen from the upper bound depreciation rate where since 1985 the upper bound has not been zero (see figure 2). Such realignments imply that the devaluation process can be formulated as a Poisson stochastic process. This means that devaluations are expected to occur regularly over time and if and when they occur, they are expected to be of a given size v (measured in percents). If the probability per unit of time of such a devaluation is Γ_t, then the expected rate of devaluation per unit time d_t, is simply the product of the probability per unit of time of a devaluation and the magnitude of the devaluation: $d = \Gamma v$.

The measured expected rate of devaluation per unit time d_t can be used also to test the credibility of the exchange rate regime. If the upper bound depreciation rate is credible the expected rate of depreciation d_t should always lie below it.

Indexed bonds play a significant role in the Israeli financial market. Rates of return on such bonds depend on the expected future path of the relevant price index. The expected rate of return on a CPI indexed bond with interest rate r_t, Z^e_t is:

$$(29) \quad Z^e_t = (1 + r_t)(1 + \pi^e_{t,j+t}) - 1$$

where $\pi^e_{t,j+t}$ is the annualized expected inflation rate from time t to time t+j. This rate of return is comparable to the expected rate of return on a dollar indexed bond, R^e_t, as defined in (25).

With efficient domestic bond markets the expected rate of return on the same maturity bonds should be the same. This implies that the expected rate of return on CPI indexed bonds should be bound by the upper bound rate of return on dollar indexed bonds $\bar{R}_t$:

$$(30) \quad Z^e_t \leq R_t$$

This, in turn, implies an upper bound on the expected inflation rate. That is:

$$(31) \quad \bar{\pi}^e_{t,J+t} = \frac{(1 + R_t)}{(1 + r_t)} - 1$$

V.2. Empirical Applications

The preceding tests and estimates require data on domestic-currency denominated and foreign-currency denominated interest rates. In Israel there is a variety of instruments, consisting of both Shekel denominated interest rates and Dollar denominated interest rates. However, most of the financial instruments are not compatible one with the other, due to the differences in liquidity, maturity and risk of default. As a result the, credibility test may reflect not only the credibility of the target zone, but also other aspects in the domestic financial market, such as the effect of credit restrictions, and imperfect competition among financial institutions, (resulting in a debit-credit spreads).

Keeping in mind such differences, in the subsequent tests we use three different domestic interest rates: The interest rate on overdraft credit (Chachad), interest rate on one month unindexed treasury bill (Makam) and the interest rate on a 10 years CPI indexed bond (Galil). The last two instruments are traded in the Israeli bond market, while the first interest rate is set by the banking system. For the foreign-currency denominated rate of return, we use the interest rate on foreign currency deposit for 12 months (Patam), which is set by the banking system. Alternatively from the bond market we employ also two interest rates. The first is the interest rate on dollar indexed government bonds, initially issued as banking stocks[7]; the second is the rate on a 10 years dollar indexed bond (Gilboa).

All the subsequent tests are carried out with the following pairs of interest rates: the interest rates on Chachad and Patam accounts, the interest rate on Makam and the rate on the bond equivalent of banking stocks, and the rate of returns on the two indexed bonds, Galil and Gilboa.

Credibility: Figures 4 and 5 portray the monthly domestic interest rate i_t versus the upper bound rate of return on foreign denominated assets, $\bar{R}_t$. Figures 4 and 4a include the Chachad versus the Patam interest rates. For most of the period the domestic interest rate is shown to be

[7] During the October 1983 financial crash the government, with its afford to prevent the collapse of the banking system, have agreed to turn the banking stocks to government liability and consequently they have became dollar indexed bonds.

below the upper bound. Only during 1987 and 1988 the domestic interest rate is above the upper bound. This result indicates credibility problems for the target zone during 1987-1988. The result, however, may also reflects the different features of the two instruments involved. The Chachad, as explained previously, is a highly liquid credit account, while the Patam is a less liquid deposit account. Hence, the results in these figures may reflect the effects of the liquidity constraints, as well as the effects of credit restrictions and the debit-credit spreads due to lack of competition within the banking system.

Figures 5 and 5a, portraying i_t and $\bar{R}_t$ derived from the second pair of assets (the one month unindexed bond - makam, and the dollar indexed banks' stocks), show that for almost the entire period the domestic interest rate is below the upper bound rate. This indicates that the upper bound is credible. In view of this, it seems that the higher domestic interest in overdraft credit is indeed accounted for by factors other than target zone credibility. Only during the last two months of 1988 the domestic interest rate exceeds the upper bound, reflecting only a short episode of lack of credibility. In fact, at the end of 1988, after two years (1987 and 1988) with no realignment, expectations of a discrete depreciation seem to have emerged. The expectations were expressed by a sharp rise of the dollar-premium in the black market and the eminent capital outflows (see table 1). More over the above result indicates that the devaluation expectation exceeded the upper bound, (which were at the time around 13 percents per year). Subsequent tests support this conclusion with respect to the credibility of the target zone during the last months of 1988. It is worth noting that indeed in January 1989 a devaluation of about 13 percent was carried out, along side an official permission for an exchange rate fluctuation within a target zone[8]. Moreover, since then during 1989 several additional exchange rate adjustments were carried out, accumulated to additional 7 percents.

In the beginning of 1987 for a short period the domestic interest rate approached the upper bound foreign rate of return, reflecting expectations for imminent exchange rate realignment (see figure 5a). However, in this episode the devaluation had been expected to be <u>within</u> the target zone.

Probability of Discrete Devaluation: In the last few years Israel have experienced considerable speculative capital flows, which were associated with the discrete devaluations. Evidently the size of the capital flows depends crucially on the probability of such devaluations. Using the second pair of interest rates (the Makam and the dollar indexed banking stocks) we can derive from the observed nominal interest rates the expected rate of devaluation per unit of time, d_t, as defined in equation (28). The timing and the expected magnitude of a once and for all depreciation rate, v, are not observable, thus the choice of v is somewhat arbitrary. However, as long as v is assumed to be constant it can only effect the scale, but not the evolution of the probability measure. A plausible assumption is that the expected annual devaluation is equal to the average annual inflation rate, which had been around 17%.

[8] There were also some adjustments of controlled price goods.

Figure 6 describes the measured probability of discrete devaluation between 1987 and 1990. Interestingly, during the first quarter of 1987 ,following the devaluation in the beginning of the year, the probability of yet another discrete devaluation increased, and then dropped sharply. Only toward the end of the year it rose again. There had not been any discrete devaluation in 1988, while inflation was on average 1.3 percent per month, consequently the probability steadily increased, until the end of the year. In December 1988 it approached 1. This is consistent with the result shown in figure 5a. Following the discrete devaluation that in effect took place at the beginning of 1989, the probability dropped,but picked up again in the middle of 1989. Overall, this pattern conforms with the corresponding pattern of the relation between the domestic interest rate in comparison to the upper bound rate of return, as seen in figure 5a. Moreover, the probability of a discrete devaluation is negatively related to the actual change in the exchange rate, due to the mean reverting nature of the exchange rate regime. This relationship can be seen in figure 6a, which depicts both the probability and the actual devaluation.

The measured probability can be used also to address the credibility question. If the upper bound depreciation rate is fully credible then the expected rate of depreciation v cannot exceed this bound. Thus we also measure the probability of a discrete devaluation per unit of time assuming the public anticipates that the magnitude of the devaluation, in the next realignment episode, will be equal to the upper bound depreciation rate. If the derived probability exceeds 1, then it is evident that the upper bound is not credible[9]. Figure 6b depicts the probability measure $\bar{\Gamma} = d/\bar{x}$. The figure shows that in December 1988 the measure exceeds 1. This finding reinforces our previous inference, that the upper bound depreciation rate had not been credible.

As usual expectations for exchange rate realignment induce capital flows. The magnitude of these flows depends, among other things, on the probability of devaluation. To explore the link between the devaluation probability and capital flows we examine the size of foreign exchange interventions by The Bank of Israel. Figure 7 describes the probability measure along side the monthly foreign exchange interventions. Positive values denote foreign exchange inflows (Private sector sales of foreign currency to the central bank). Evidently, there is a strong negative correlation between them. The regression in table 3 confirms that indeed the two variables are negatively correlated.

Inflationary expectations: Using the two indexed bonds, figure 8 portrays the maximum annualized level of expected inflation as derived in equation (31), along with the annualized three-month-ahead (actual) inflation rate. In several episodes the actual inflation rate exceeds the upper bound inflation rate. The most striking episode is toward the end of 1988. This again reinforces the previous observation that the upper bound

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[9]Obviously, if the probability fall short of 1 it does <u>not</u> imply that the bound is credible.

exchange rate depreciation during that period was not credible. Thus, the expected inflation, derived from the upper bound, was not credible as well.

Table 3:[1]

K = Foreign Currency Purchases by the Central Bank[2].

$$K_t = 0.358K_{t-1} - 175.422\Gamma_t + 110.947(s_t - s_{t-1})$$
$$\quad (2.83) \qquad (2.311) \qquad (3.777)$$

$R^2 = 0.60$, MA = 0.378, D.W.= 1.879
(1.82)

[1] t-ratios are reported in parentheses.

[2] To correct for a simultaneous equation bias we estimate the equation using instrumental variables for Γ_t and $(s_t - s_{t-1})$. The instrumental variables are: Γ_{t-1}, Γ_{t-2}. $(s_{t-1} - s_{t-2})$, K_{t-1}, K_{t-2}, π_{t-1} and π_{t-2}.

VII. Conclusion

Target zone exchange rate theory is shown to be useful for an empirical analysis which separates the effects on exchange rate behavior of market fundamentals from policy actions. The implementation of the theory to the out data set generates plausible estimates of the parameters of the exchange rate targeting rule.

The theory, however, provides no normative guide for the design of exchange rate policy. Should policy makers attempt to stabilize the exchange rate at the expense of increasing interest rate variability? Should they stabilize exchange rate fluctuations by employing sterilize interventions or should they act directly on the fundamentals? These questions must await further advances in theory.

Appendix I

Discrete Interventions and Exchange Rate Behavior

In this appendix we show how discrete-intervention rules are used in order to limit the movements of the exchange rate so that the expected depreciations will never exceed a specified upper limit $\bar{x}$. The monetary authority chooses the pair $(\underline{f}, \bar{f})$ so that whenever the rate of change of the fundamental reaches $\underline{f}$ or $\bar{f}$ there is a discrete intervention, that shifts f from point A to point B (see Figure 9) so as to satisfy the value-matching condition. The intervention rule "positions" the exchange rate depreciation curve so as to be tangent to the $\bar{x}$ line at point C.

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Table 1. Foreign Exchange Market Indicators in Israel, 1978-89 1/

Quarter	Current Account Surplus	Private Sector Foreign Exchange Purchases from Central Bank	Capital Flight (1)	Reserves Movements	Depreciation Rate	Inflation Rate	Dollar Premium (percents)	Interest Rate Differential
	Balance of Payments Indicators (In millions of U.S. dollars)				Price Indicators (Quarterly % Change)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1978:1	-132	...	...	-99.2	2.52	--	...	0.39
1978:2	-178	...	...	17.8	3.11	10.71	...	0.52
1978:3	-416	...	...	6.4	2.59	7.08	...	1.06
1978:4	48	...	...	-847.2	5.14	14.52	...	1.91
1979:1	-155	...	...	-734.1	4.33	13.31	...	0.56
1979:2	-228	...	...	234.8	5.66	18.56	...	-3.27
1979:3	-697	...	...	160.1	7.29	18.90	...	0.04
1979:4	362	...	...	105.4	8.55	27.33	...	-0.51
1980:1	-27	...	...	-349.6	5.79	22.21	...	1.27
1980:2	-296	...	...	77.4	8.09	24.92	...	1.53
1980:3	-597	...	...	-69.6	6.63	19.67	...	1.61
1980:4	297	...	...	-226.0	8.79	29.26	...	-0.91
1981:1	-5	-239.00	...	-563.8	5.87	20.86	...	1.29
1981:2	-546	155.00	...	115.2	5.58	19.81	...	-1.90
1981:3	-638	211.00	...	101.9	6.03	15.06	...	2.33
1981:4	141	253.00	...	-229.9	6.66	22.80	...	1.98
1982:1	-222	184.00	...	-237.1	6.36	20.40	...	-0.50
1982:2	-591	545.00	...	157.2	7.64	23.70	...	-0.96
1982:3	-1,227	36.00	...	-97.9	8.22	24.96	...	-1.25
1982:4	58	-252.67	...	-740.4	6.81	23.84	...	2.08
1983:1	-602	-302.18	...	-316.3	6.73	21.64	...	1.15
1983:2	-645	182.29	...	511.0	7.46	25.61	...	1.13
1983:3	-1,149	390.90	...	356.3	7.47	19.52	...	-2.06
1983:4	363	711.30	...	14.3	15.95	50.03	13.55	-7.58
1984:1	-573	387.01	-177.01	45.8	12.52	44.36	12.23	1.37
1984:2	-656	503.81	-101.81	-215.0	16.08	52.99	30.52	3.81
1984:3	-1,058	686.70	103.10	1,299.2	16.73	51.48	21.68	2.03
1984:4	914	216.64	-156.14	-621.2	15.07	68.75	18.24	3.24
1985:1	-392	356.08	-253.38	570.0	10.28	29.45	25.65	4.99
1985:2	-309	457.95	-310.65	28.9	13.70	46.88	34.34	6.54
1985:3	572	- 22.63	56.73	-285.7	11.48	47.66	9.43	6.36
1985:4	1,279	279.46	-425.16	-713.0	2.14	8.89	7.68	8.45
1986:1	30	170.82	-64.22	288.1	0.61	1.26	7.65	4.29
1986:2	225	122.17	35.73	-140.9	2.19	6.63	7.84	2.75
1986:3	66	264.03	-7.33	-371.1	1.01	3.02	3.54	3.29
1986:4	1,234	102.40	29.70	-768.1	2.24	6.57	1.17	3.31
1987:1	-285	-461.99	593.89	-403.9	1.47	5.25	-0.48	1.03
1987:2	-487	-376.12	488.02	-113.9	1.28	4.22	0.42	3.99
1987:3	-892	261.72	42.78	430.4	0.80	2.24	4.70	3.26
1987:4	696	675.79	-339.39	-665.1	1.47	4.12	8.95	3.99
1988:1	-2	-22.32	-63.48	-34.9	1.36	4.15	5.80	2.58
1988:2	-604	-177.00	502.00	-16.9	1.40	5.05	6.26	2.10
1988:3	-795	630.30	-226.30	726.3	0.86	1.77	9.31	1.44
1988:4	725	--	-1,789.90	496.0	1.50	5.09	16.11	2.95
1989:1	375	--	1,541.40	-1,897.5	2.27	6.93	-0.13	-2.19
1989:2	-361	--	-179.00	494.0	1.56	4.48	4.35	-0.87
1989:3	95	--	--	181.1	1.11	3.05	5.44	0.44
1989:4	--	--	--	--	1.39	3.95	--	--

1/ Capital flight is defined as the difference between private sector purchases of foreign exchange from the central bank and the private sector deficit on current account.

Figure 1
Percentage Deviations from the Official Exchange Rate, 1985-89

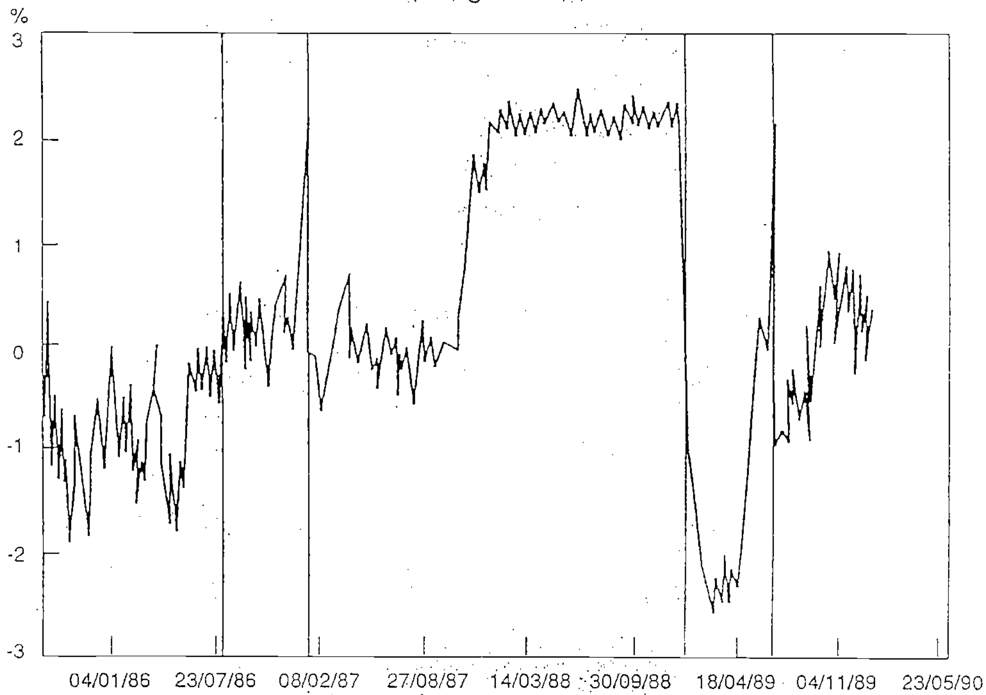

Figure 2:
Upper Bound and Managed Rates of Depreciation

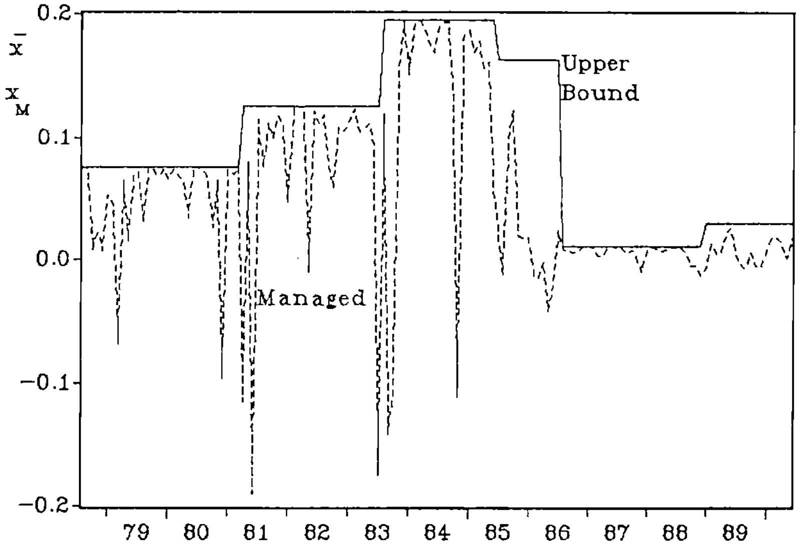

Figure 3a:
Free and Managed Depreciation Rates

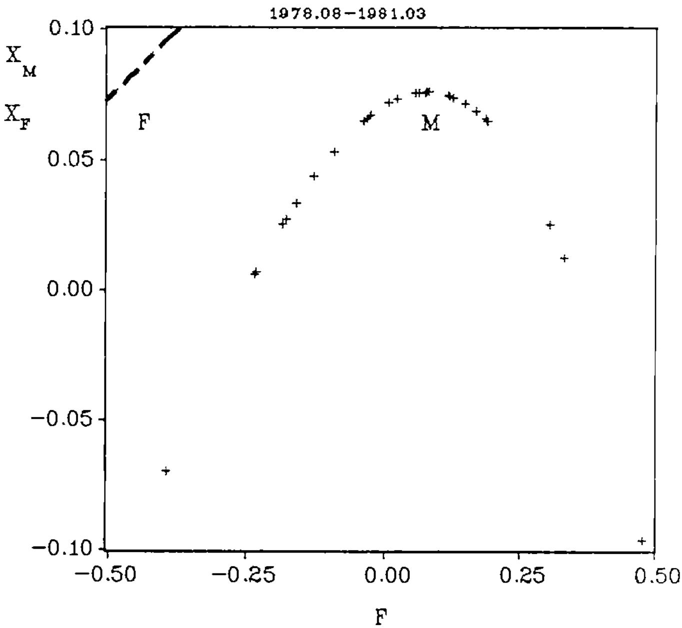

Figure 3b:
Free and Managed Depreciation Rates:

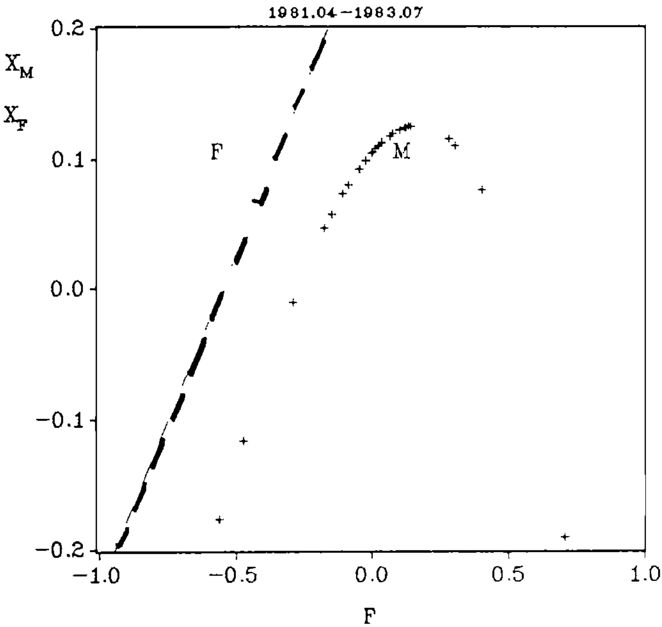

Figure 3c:
Free and Managed Depreciation Rates:

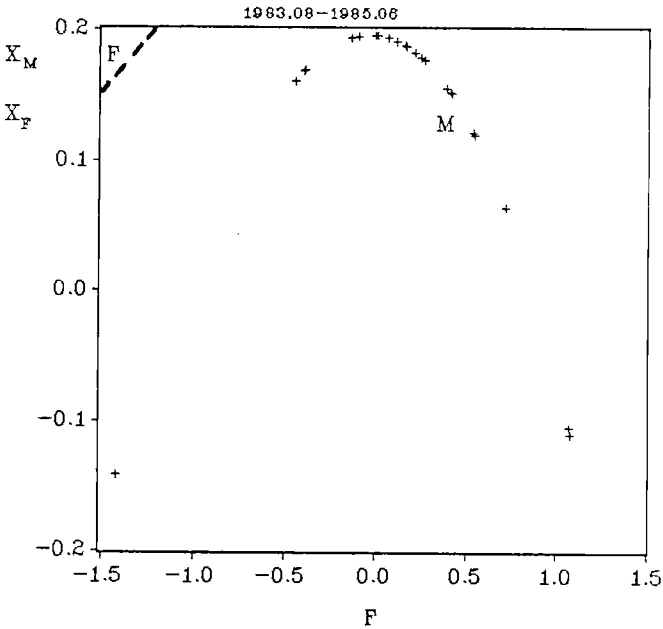

Figure 3d:
Free and Managed Depreciation Rates:

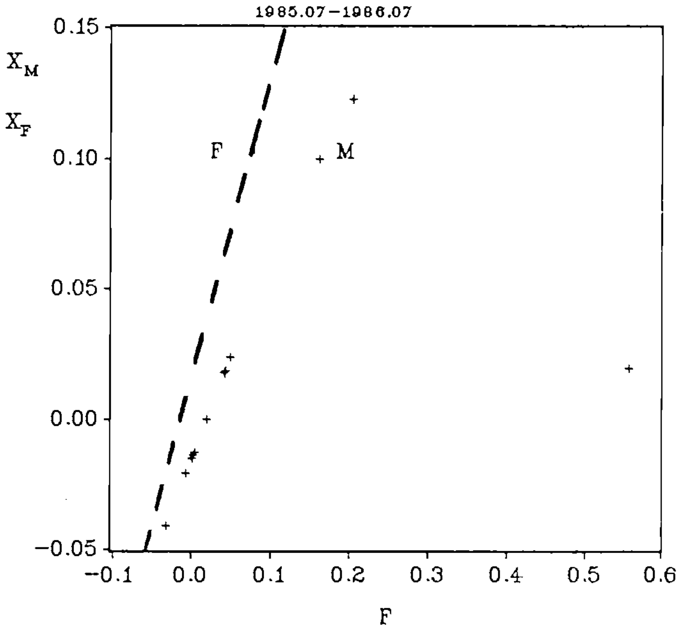

Figure 3e:
Free and Managed Depreciation Rates:

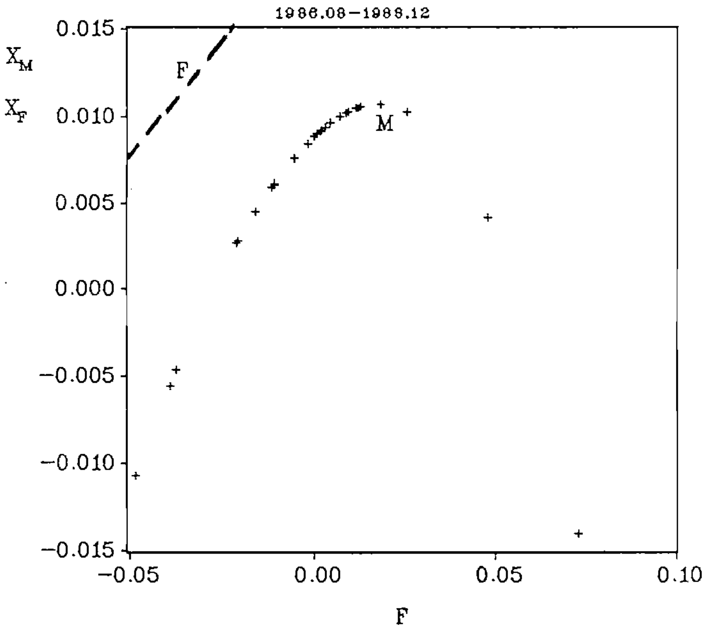

Figure 3f:
Free and Managed Depreciation Rates:
1989.01–1990.06

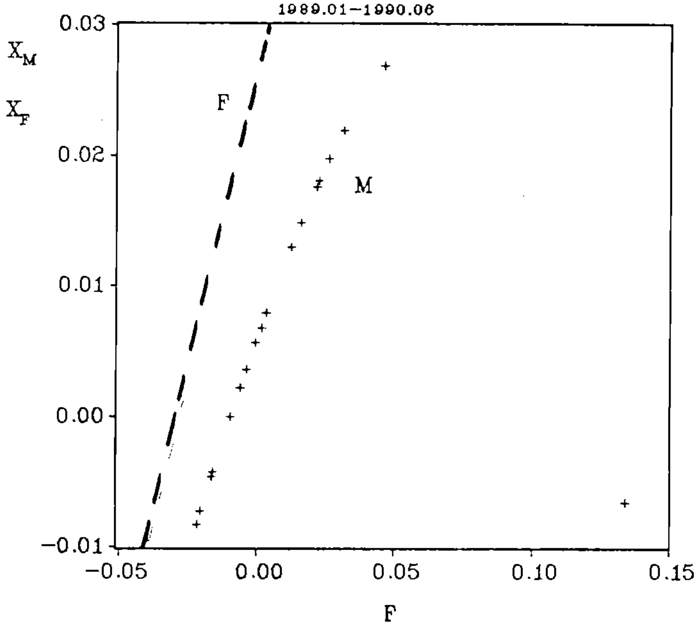

Figure 4:
Domestic Interest Rate Vs. Upper Bound Foreign
Rate of Return (Chachd Vs. Patam)

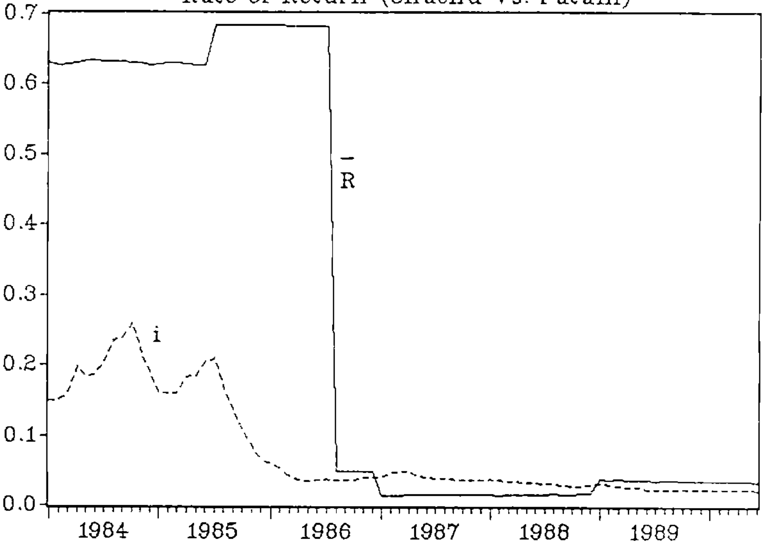

Figure 4a:
Domestic Interest Rate Vs. Upper Bound Foreign Rate of Return (Chachd Vs. Patam)

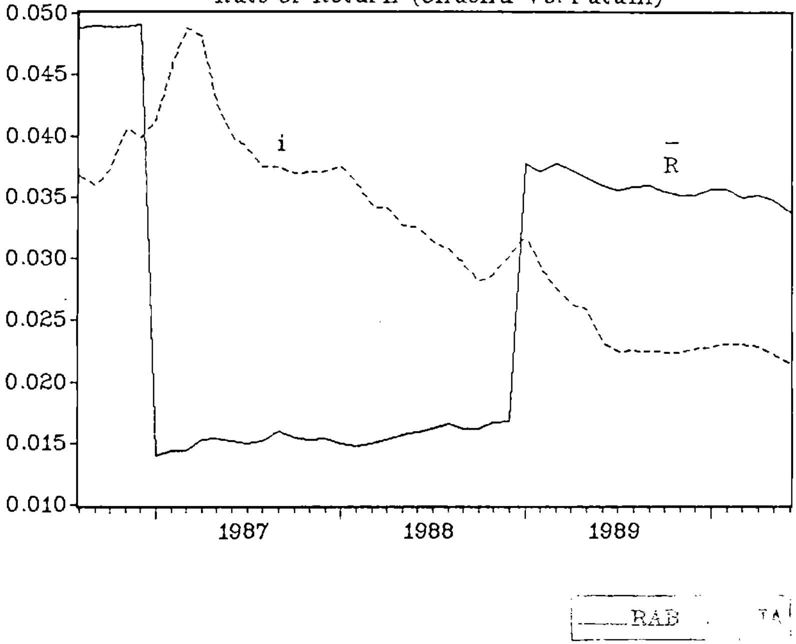

Figure 5:
Domestic Interest Rate Vs. Upper Bound Foreign
Rate of Return (Makam Vs. Banks' Stocks)

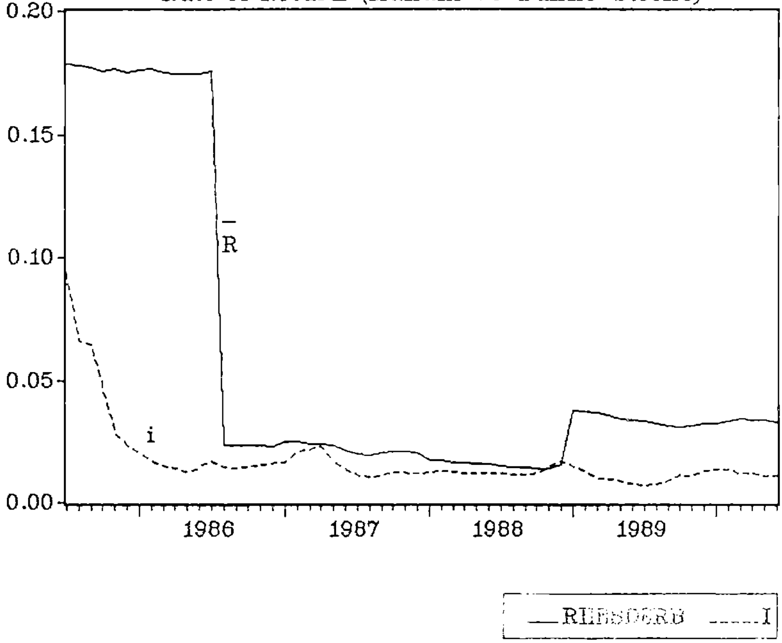

Figure 5a:
Domestic Interest Rate Vs. Upper Bound Foreign
Rate of Return (Makam Vs. Banks' Stocks)

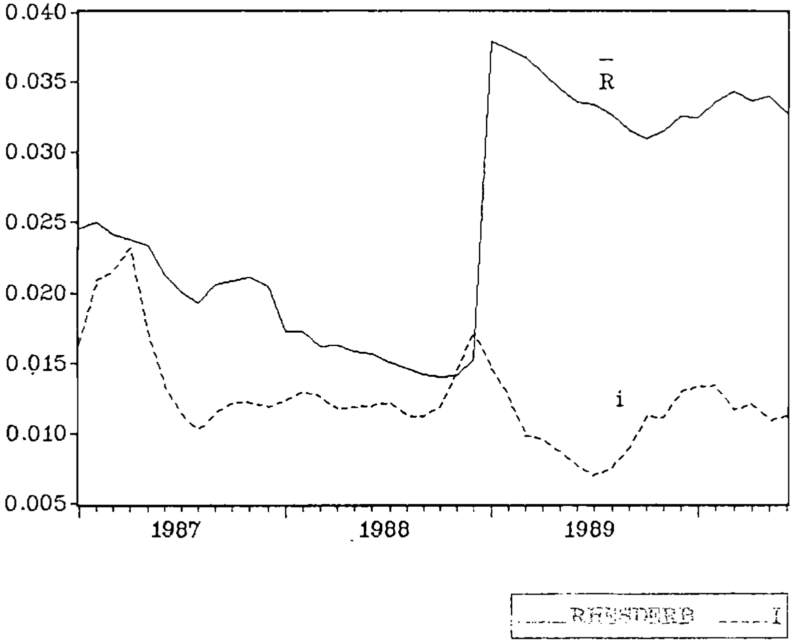

Figure 6:
Probability Of a Discrete Devaluation (v=17%)

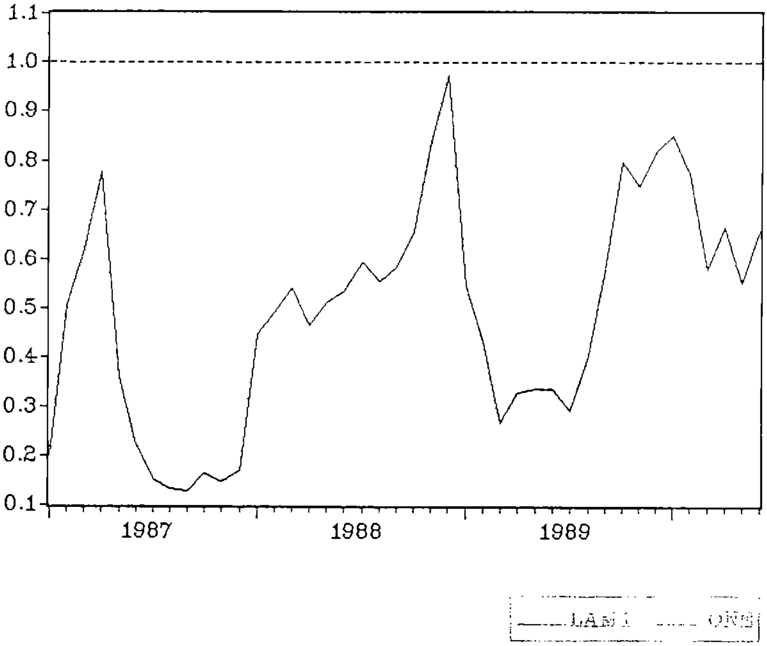

Figure 6a:
Probability of a Discrete Devaluation (left scale) and
Actual Devaluation (right scale)–percents per month

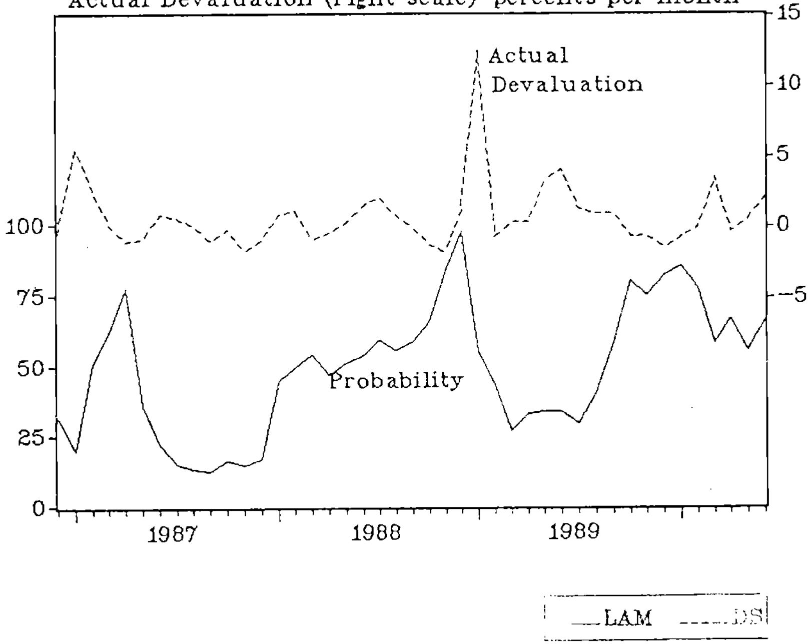

Figure 6b:
Probability Of a Discrete Devaluation ($v=\bar{x}$)

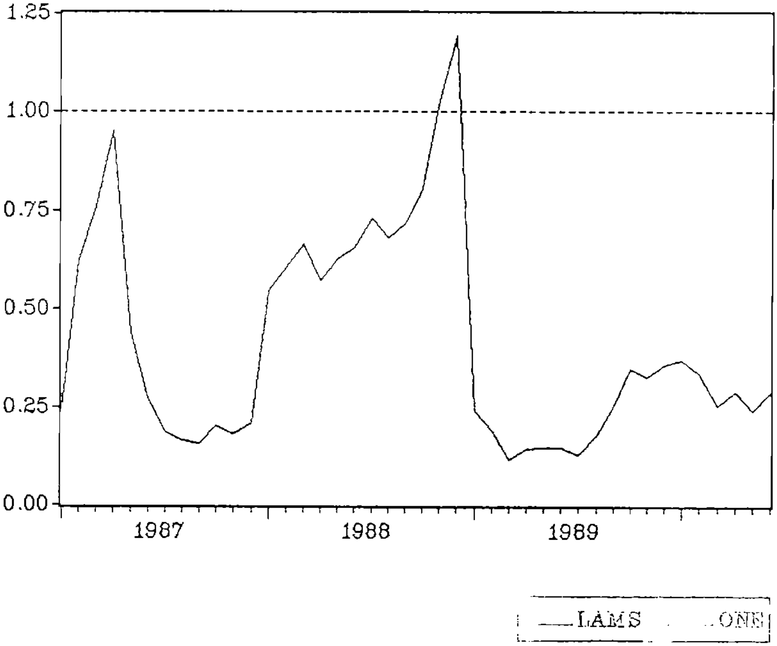

Figure 7:
Probability of Devaluation (left scale) and Foreign Currency Purchases (right scale–million of U.S. $)

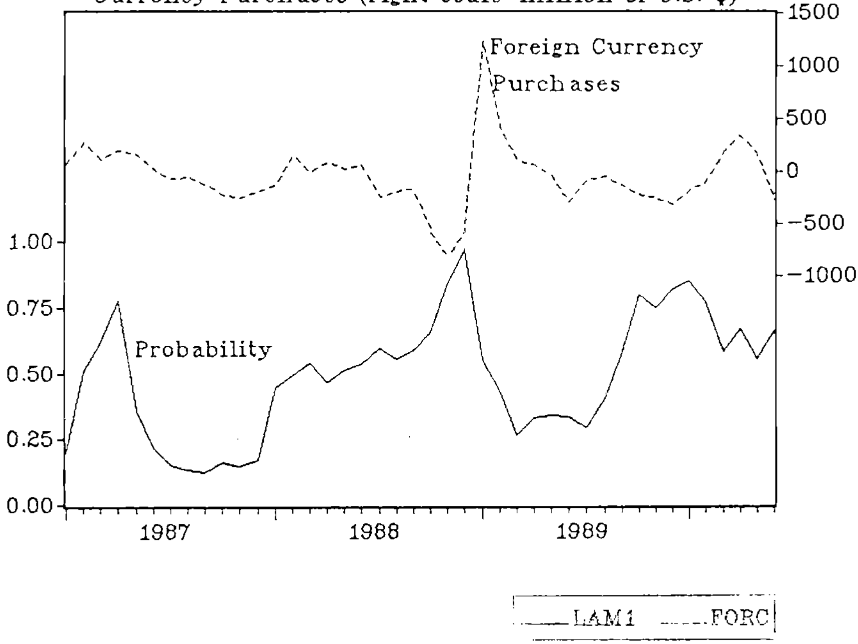

Figure 8:
Upper Bound Expected Inflation Vs. Actual Inflation
(Three Months ahead) - Annual Terms

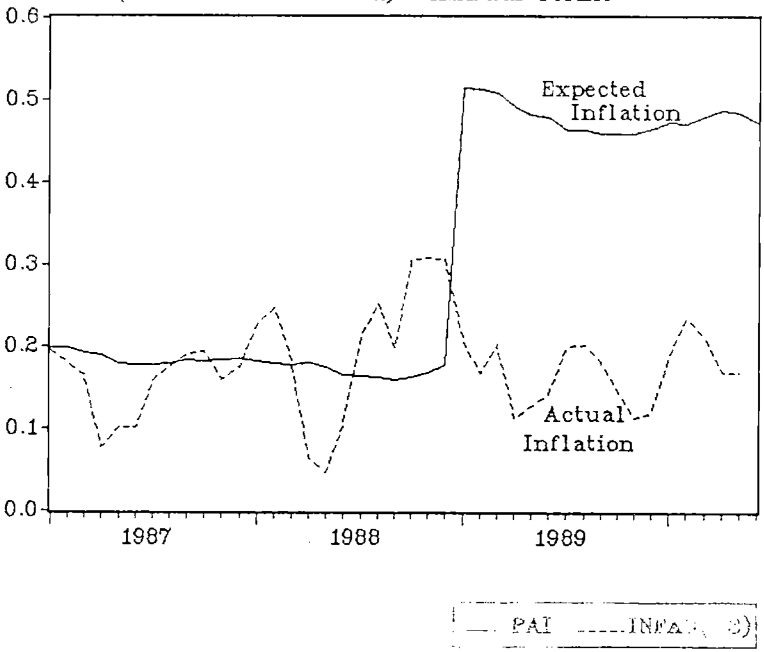

Figure 9:
Discrete Interventions and The Exchange Rate Behavior