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IMF WORKING PAPER

WP/90/61

INTERNATIONAL MONETARY FUND

Research Department

Targeting the Exchange Rate: An Empirical Investigation

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Authorized for Distribution by Jacob A. Frenkel

July 1990

Abstract

The purpose of this paper is to implement empirically the new theory of exchange rate targeting. The theory formulates an expectations induced relationship between the exchange rate and the fundamental subject to random shocks and target zone constraints. By using monthly data for a representative small-open economy (Israel in the 1980s) the empirical analysis identifies the special roled played by policy and market fundamentals in the behavior of the exchange rate.

JEL Classification Numbers:

132, 431

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Contents

Summary

An upper barrier to exchange rate movements is commonly set during inflationary episodes of small open economies. By influencing market expectations, such a policy can systematically change the equilibrium relationship between the exchange rate and market fundamentals (such as money market factors). This paper separates out the effects on the behavior of the exchange rate that arise from market fundamentals from those that arise from exchange rate targeting.

The paper implements empirically an analytical framework developed in the recent target-zone literature. The theory's main prediction is that the upper barrier shifts downward the entire schedule representing the relationship between exchange rate depreciations and the rate of change of market fundamentals; it also reduces fluctuations in the rates of depreciation.

The empirical analysis is conducted on monthly data of a representative small open economy under inflationary conditions (Israel from the late 1970s to the late 1980s). The analysis yields plausible estimates of the extent to which managed depreciations deviate from the free float rates of increase of the exchange rate that are constructed in the model.

I. Introduction

In many inflationary episodes the monetary authorities attempt to set upper limits on the exchange rate movements without holding the exchange rate completely fixed. By affecting expectations such policies change systematically the equilibrium relationship between the exchange rate and fundamental factors. A challenging problem in such circumstances is to separate out the effects on the behavior of the exchange rate, which arise from the market fundamentals, from those which arise from policy interventions.

The new target-zone literature has been able to formulate in a rather simple way the expectations-induced relationship between the exchange rate and the fundamental, subject to random shocks. 1/ The theory's main prediction is that the upper barrier 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 new theory. The paper provides an empirical analysis of the exchange rate policy in a representative small-open economy under inflationary conditions (Israel: 1978-89). This period, which is characterized by high and variable inflation rates, intensive exchange rate targeting and fluctuating interest differentials (reflecting varying expectations) seems suitable for testing the target zone theory. In the paper we implement a variant of the theory adapted for inflation proned economies. The empirical results conform to the model's predictions and are statistically significant.

The paper is organized as follows. In Section II we outline the key features of the target-zone exchange-rate theory and present a variant of the theory which is suitable to inflationary environments. Section III provides an overview of the foreign exchange market in Israel during the period under investigation. In Section IV we implement the analytical framework of Section II to the data. Section V concludes the paper.

II. The Analytical Framework

Consider a stylized log-linear model of exchange-rate behavior. 2/ At any point of time the exchange rate is determined by:

(1) $$s(t) = v(t) + \delta E[ds(t)]/dt \qquad , \delta > 0,$$

where

1/ See Krugman (1987, 1988, 1989), Flood and Garber (1989), Froot and Obstfeld (1989), Miller and Weller (1988) and Svensson (1989).

2/ See Krugman (1989), and Svensson (1989).

s = exchange rate

v = fundamental

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

E = expectations operator.

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

(2) $v(t) = m(t) + q(t) - c - \alpha y(t) + \delta i^*(t) - \varepsilon(t)$, $\alpha > 0$,

where

m = money supply

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

p = domestic price level

p^* = world price level

c = 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

ε = money demand disturbance.

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 also depends positively on the expected rate of depreciation, $E[ds(t)]/dt$.

Equation (1) implies that the rate of change of the exchange rate behaves as follows:

(1a) $x(t) = f(t) + \delta E[dx(t)]/dt$

where

x = rate of exchange-rate depreciation

f = rate of change of the fundamental.

In the context of an inflationary economy it is plausible to specify that the monetary authorities place upper bounds on the rate of depreciation instead of the exchange rate level. Accordingly, we assume that the monetary authorities enforce an upper bound on x(t).

The rate of change of the fundamental is assumed to follow a Brownian motion with drift:

(3) $df(t) = \mu dt + \sigma dz$

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

The solution 1/ to the differential equation of the exchange rate depreciation as a function of the rate of change of the fundamental, obtained from equations (1a) and (3), is given by:

(4) $x(f) = f + \delta\mu + Ae^{\tau f} + Be^{\beta f}$

where $\tau > 0$, $\beta < 0$, A and B are the integration parameters.

The economic interpretation of equation (4) is that the first term, $f + \delta\mu$, represents the effect of the rate of change of the fundamental on the exchange-rate depreciation, while the second term, $Ae^{\tau f} + Be^{\beta f}$, represents the deviation of the exchange rate depreciation from this rate, due to the exchange-rate management by the central bank.

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

(5) $x_F(t) = \delta\mu + f(t)$.

Thus, the 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 we assume that the monetary authority places an upper barrier to the rate of depreciation. Various interventions in the foreign exchange market or the domestic bond market by the central bank take place so as to prevent the depreciation rate

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1/ The solution is derived in Appendix I.

from exceeding this upper limit, $\bar{x}$. The management rules are assumed to be known to the private sector. Since no lower limit is placed, the no-bubble condition must imply that B = 0 (see Appendix I). Hence the rate of depreciation under the managed exchange-rate regime, x_M, is given by:

(6) $x_M(t) = \delta\mu + f(t) + Ae^{\tau f(t)}$.

Comparing equations (5) and (6), and using (7), reveals that the rate of depreciation under the managed exchange-rate regime never exceeds the free-float depreciation rate.

The value of the constant A is determined from the so called "smooth pasting condition", i.e., $x_M'(\bar{f}) = 0$, which simply reflects the fact that near the upper limit there exists only one-sided risk in exchange rate fluctuations. 1/

Differentiating equation (6) and evaluating the derivatives around

$f = \bar{f}$ yields:

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

Finally, substituting equation (7) into equation (6) yields a relation ship between the upper barrier depreciation rate $\bar{x}$ and the upper bound on the rate of change of the fundamental $\bar{f}$ which is given by:

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

To summarize, we specify an equilibrium rate of depreciation which can be decomposed to terms 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.

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 small open economy for empirical assessments of the effects of foreign exchange interventions, under inflationary conditions. Table 1 presents indicators of the

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1/ We assume that there exists a zero subjective probability of discrete devaluation. See Bertola and Caballero (1989) for an extension which allows for realignments; in which case the "smooth pasting" condition is modified.

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 bids. 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 the 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 the implementation of 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. Following the policy 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 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

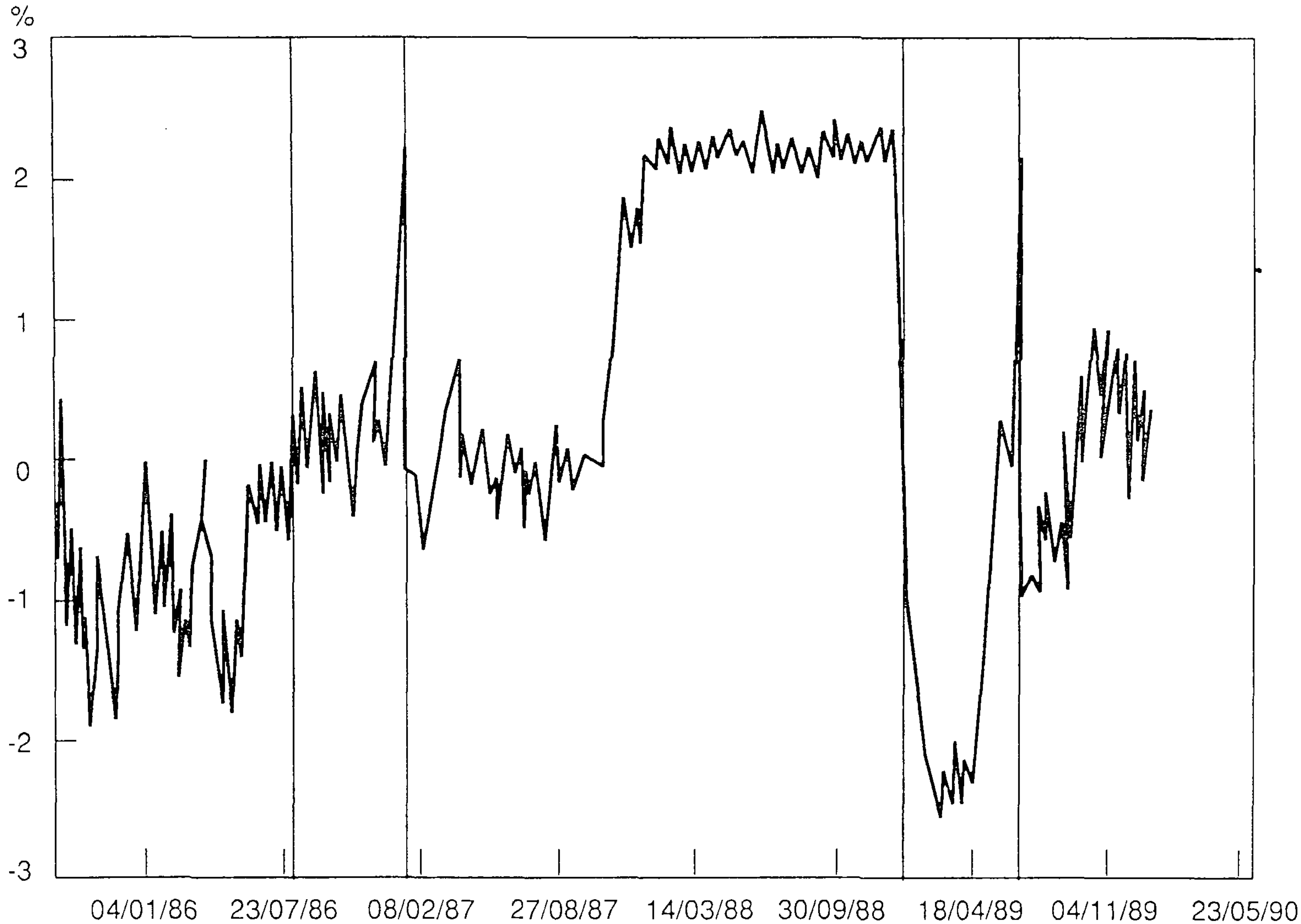
Table 1. Foreign Exchange Market Indicators in Israel, 1978-89 1/

Balance of Payments Indicators (In millions of U.S. dollars)						Price Indicators (Quarterly % Change)		
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
	(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	15.87	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



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 GDP percentage point 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 took place over the 1986-88 period.

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 to 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 upper barriers on exchange rate fluctuations, possibly because of its 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 the 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 abovementioned description of episodes we argue, however, that there have been enough possibilities to circumvent the controls so that there have been capital mobility to a large extent.

IV. Empirical Application

In this section we implement a variant of the target zone exchange rate theory on the Israeli data. The estimation of the model is carried out in three stages. 1/

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 while expectations are assumed to be unbiased. Accordingly, the demand for money is given by:

$$(9) \quad m_t - s_t = c + \alpha y_t - \delta E(s_{t+1} - s_t) + w_t$$

1/ The application is based on an approximation to discrete time of the model.

where w is a residual (which is equal to ε - q in equation (2)).

Second, using the estimates of c, α, and w, we derive the drift (μ) and variability (σ) parameters of the rate of change of the fundamental ($v = m - c - \alpha y - w$) from the first differencing of f. The variability measure, σ, is the standard error of the drift-adjusted periodic changes in f. At this stage we calculate the root of the characteristic equation, τ, from equation (10). 1/

$$(10) \quad \hat{\tau} = [-\hat{\delta}\hat{\mu} + (\hat{\delta}^2\hat{\mu}^2 + 2\hat{\delta}\hat{\sigma}^2)^{1/2}]/\hat{\delta}\hat{\sigma}^2$$

where a "hat" indicates an estimate of the parameter.

Third, using $\hat{\tau}$ and $\hat{f}$ we estimate the intervention parameter, A, in equation (4) from the following equation:

$$(11) \quad x_t - \hat{f}_t - \delta\mu = Ae^{\hat{\tau}\hat{f}} + u_t$$

where u_t is a residual. Note that although equation (4) is deterministic (with the value of B set equal to zero by the no-bubble condition) we allow in equation (11) a stochastic deviation from the deterministic relationship, to capture errors in measurement which may result from deviations from PPP.

The model is implemented on monthly data for the period 1978:06 - 1989:07 in Israel. 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.

The time series of expected future exchange rates (see the righthand side of equation 9) consists of the official and the black market data. Demand for money is estimated by using instrumental variables for y_t and $E(s_{t+1} - s_t)$. Table 2 reports the empirical results.

1/ See equation (A.5) in Appendix I.

Figure 2
Upper Bound and Managed Rates of Depreciations
(Percents per month)

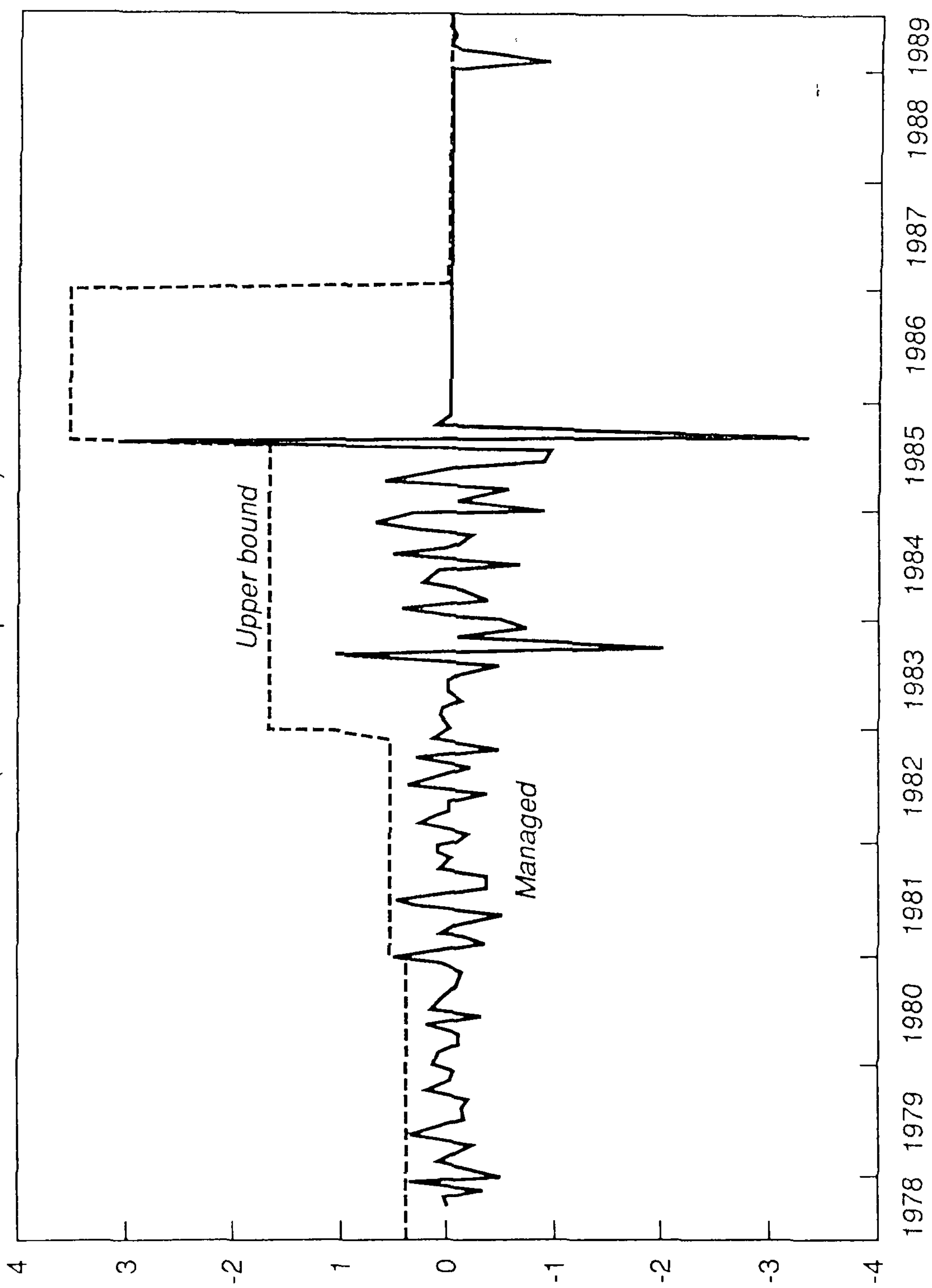


Table 2: Estimation 1/

Demand for Money: 2/

$$m_t - s_t = \underset{(2.35)}{-10.129} + \underset{(4.31)}{3.964 y_t} - \underset{(6.14)}{0.0945 E(s_{t+1} - s_t)} + \underset{(5.23)}{1.426 D_1} + \underset{(7.17)}{2.148 D_2},$$

$$R^2 = 0.886, \quad AR(1) = \underset{(10.65)}{0.68} \quad D.W. = 2.03$$

Rate of Change of the Fundamental:

Period i	Drift (μ_i)	Variability (σ_i)	Root (τ_i)
1978:06-1980:12	-0.004	0.391	11.819
1981:01-1982:12	0.003	0.521	8.825
1983:01-1985:07	-0.046	1.334	3.473
1985:08-1986:12	0.082	2.517	1.815
1987:01-1989:07	0.001	0.059	77.074

Depreciation under the Managed Exchange-Rate Regime:

$$x_t - f_t - \delta\mu_i = \underset{(-5.82)}{-0.0003 e^{\tau_i f_t}}$$

$$R^2 = 0.411, \quad MA(1) = \underset{(-4.48)}{-0.436}, \quad D.W. = 2.00$$

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}, $(s_t - s_{t-1})$, $(s_{t-1} - s_{t-2})$, $(s_{t-2} - s_{t-3})$, and dummy variables which capture discrete changes of the regime, D_1 for October 1983 and D_2 for July 1985.

The first equation in Table 2 describes the demand for money. The estimates for the output elasticity, $\alpha = 3.96$, and the interest rate semi-elasticity, $\delta = -0.09$, lie in the confidence intervals of estimations of the demand for money in Israel. 1/ The behavior of the rate of change of the fundamental (capturing changes in money supply and money demand) is estimated for five subperiods which correspond to the changes in the economic environment described in section III. The drift measure, which reflects the average rate of growth in the excess supply of money, ranges from -0.4 percent per month to 8 percent per month. The variability measure exhibits significant variations across periods, and is positively correlated with the drift (in absolute value).

Using equation (11), the intervention coefficient is given by $A = -0.0003$. As the theory predicts, the intervention coefficient (which is determined by the upper bound set by the authorities on exchange-rate depreciations) is negative, and statistically significant.

The estimates in Table 2 can be used to calculate the depreciation rates of free-float, x_F, the managed exchange, x_M, and the upper-bound depreciation rate, $\bar{x}$. The free-float depreciation rate is calculated from equation (5) using the estimates for δ, μ, and f. The managed depreciation rate is obtained from equation (6). The upper-bound depreciation rate is calculated from equations (7) and (8).

Figure 2 describes the sample paths of the derived upper-bound and managed depreciation rates, over the period 78:06 - 89:07. As suggested by the theory the managed depreciation rate lies always below the upper bound which is set by the monetary authorities to limit exchange rate fluctuations. Interestingly, figure 2 shows that in the period 1978-82 there are binding limits on the fluctuations of the exchange rate, even though the exchange rate is officially declared as being determined to a large extent by market forces. The figure indicates relatively weak constraints on the rates of depreciation in the high (and accelerating) inflation period of 1982 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 two subperiods: mid 1985 to end of 1986 and 1987 to 1989. The figure shows that in the first subperiod the depreciation ceilings are not binding, reflecting possibly the effect of the excessive devaluation that took place at the initial stage of the stabilization program and the weak credibility of the new exchange rate policy. The figure demonstrates that the second subperiod may reflect the possiblility that the exchange rate policy has become more credible since it shows that the freeze is almost fully binding.

The M curve in Figures 3a-3e portray the relationship between managed depreciations and the rate of change of the fundamental (see equation (6)). The F curve, shown as a 45 degree line, describes a similar relationship for the free float exchange rate (see equation (5)). These

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1/ See, for example, Leiderman and Meron (1985).

Figure 3a

FREE AND MANAGED DEPRECIATIONS,
JUNE 1978 - DECEMBER 1980

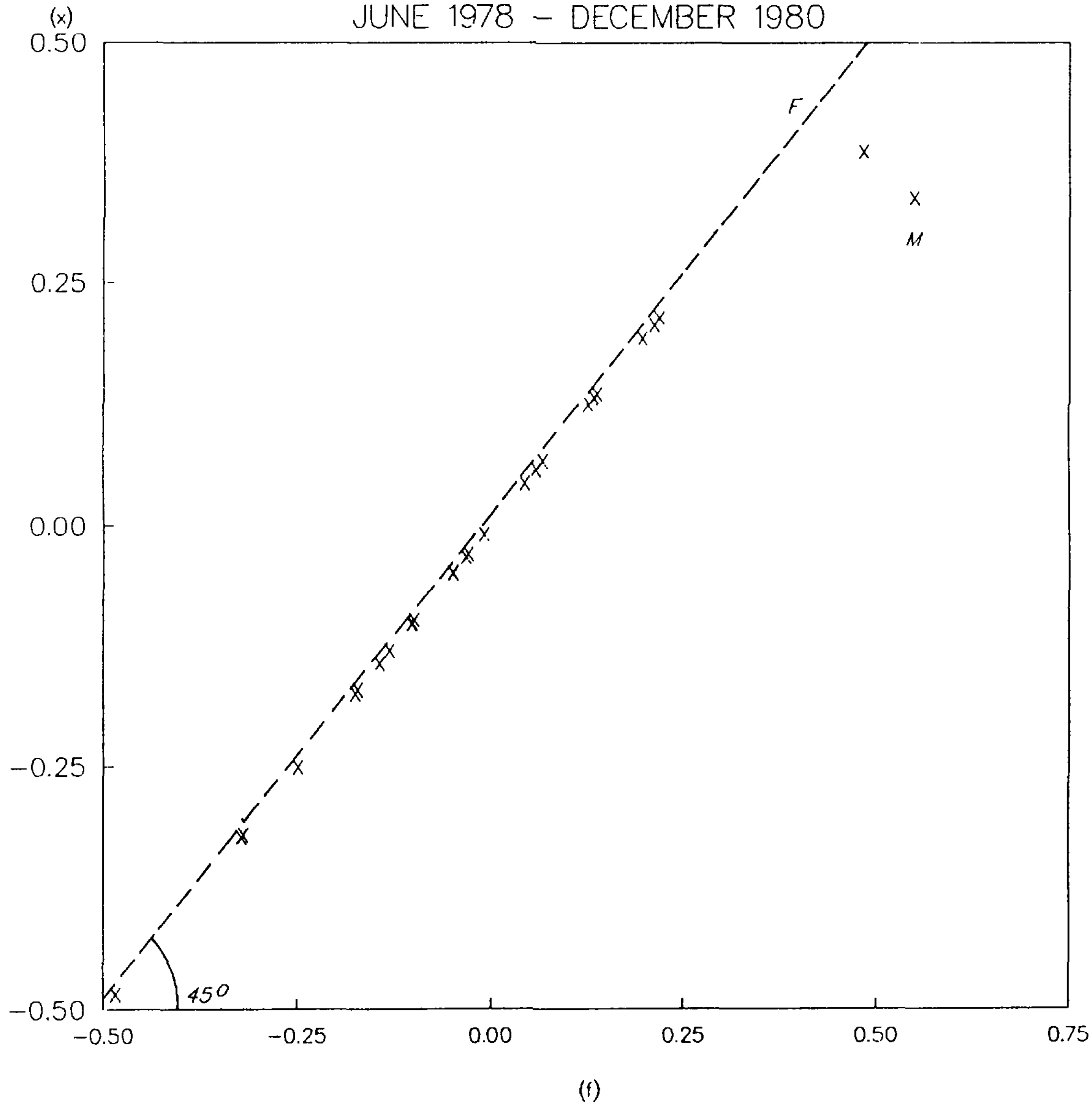


Figure 3b

FREE AND MANAGED DEPRECIATIONS, JANUARY 1980 – DECEMBER 1982

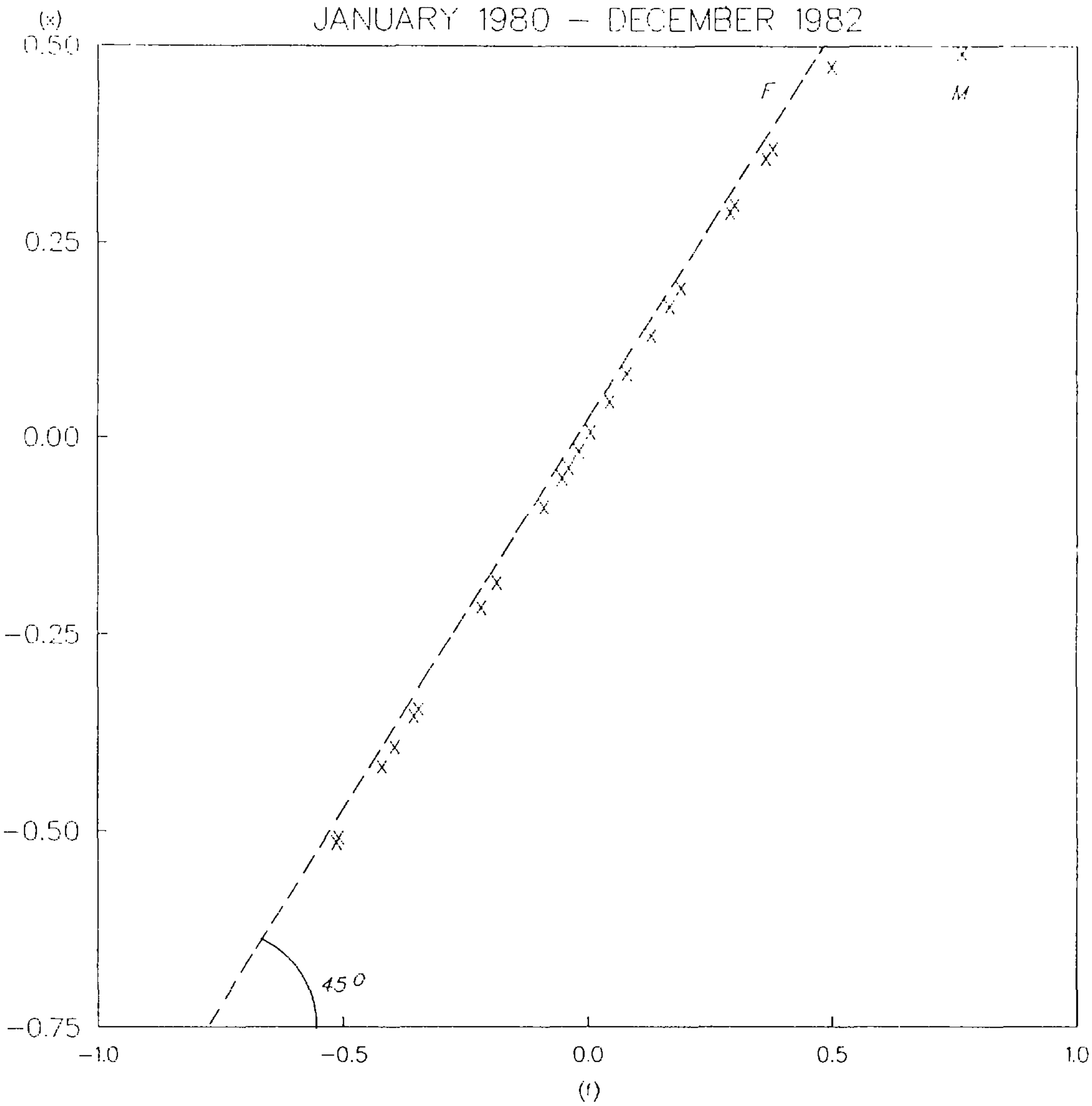


Figure 3c

FREE AND MANAGED DEPRECIATIONS, JANUARY 1983 – JULY 1985

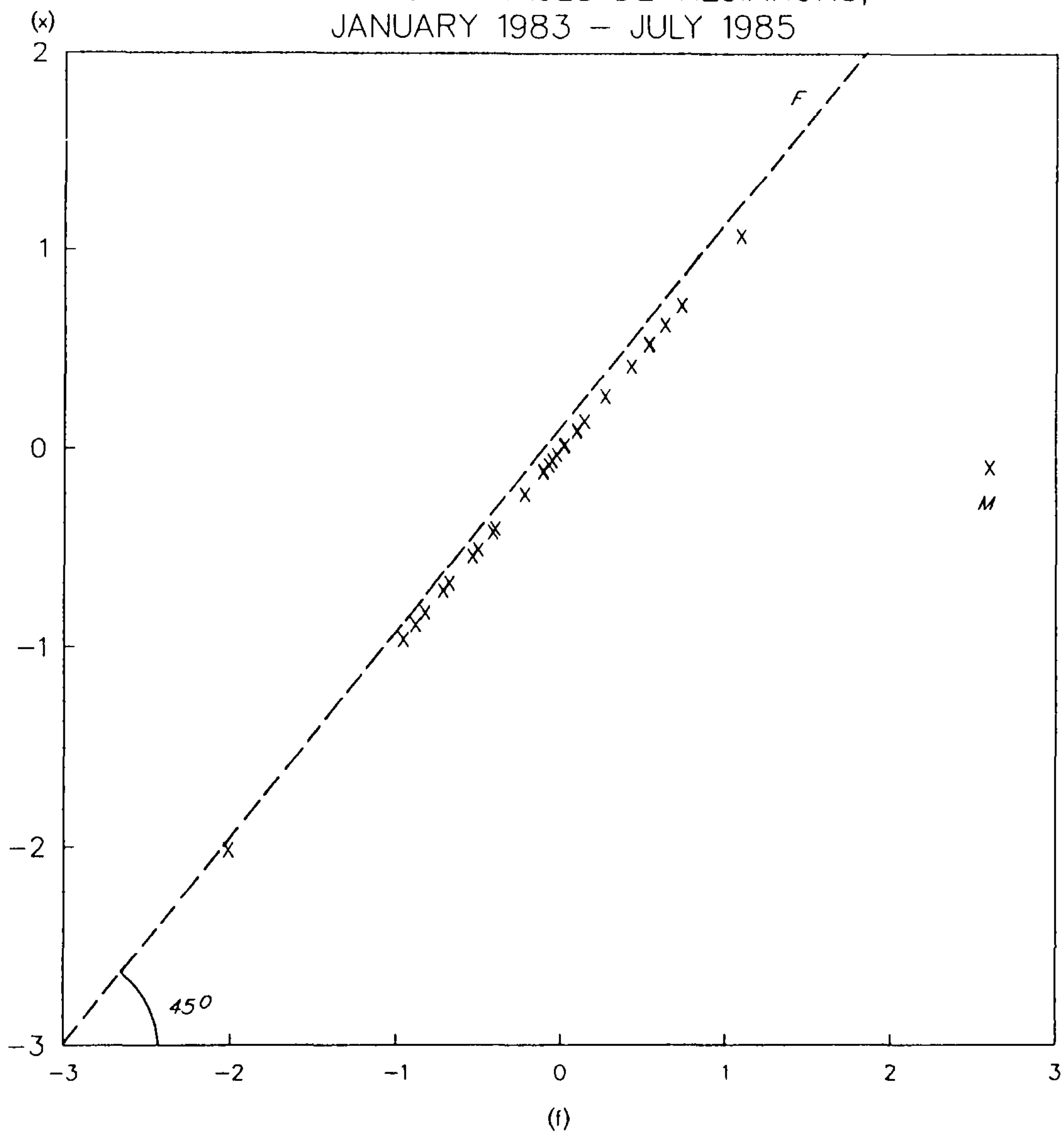


Figure 3d

FREE AND MANAGED DEPRECIATIONS, AUGUST 1985 – DECEMBER 1986

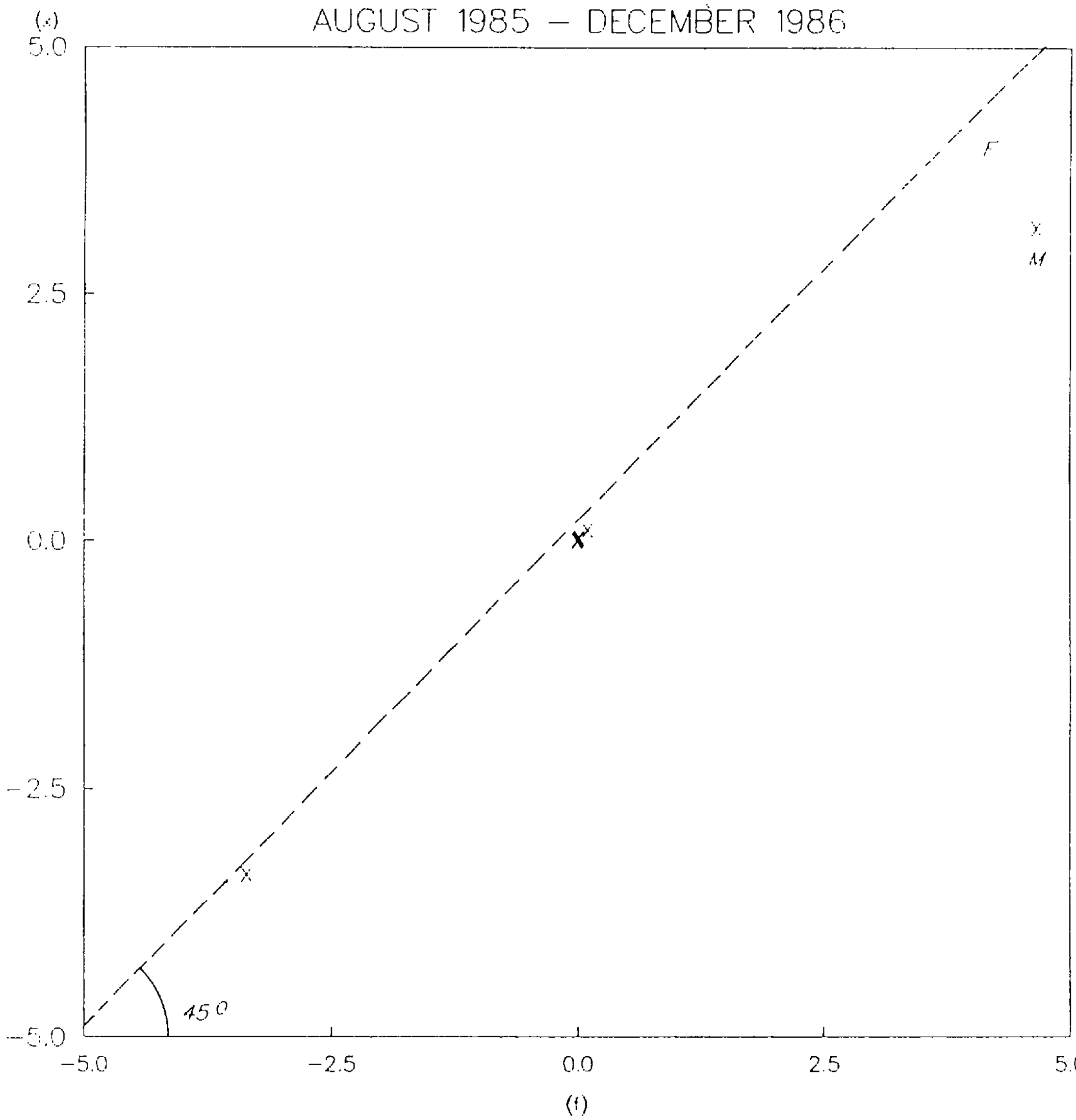
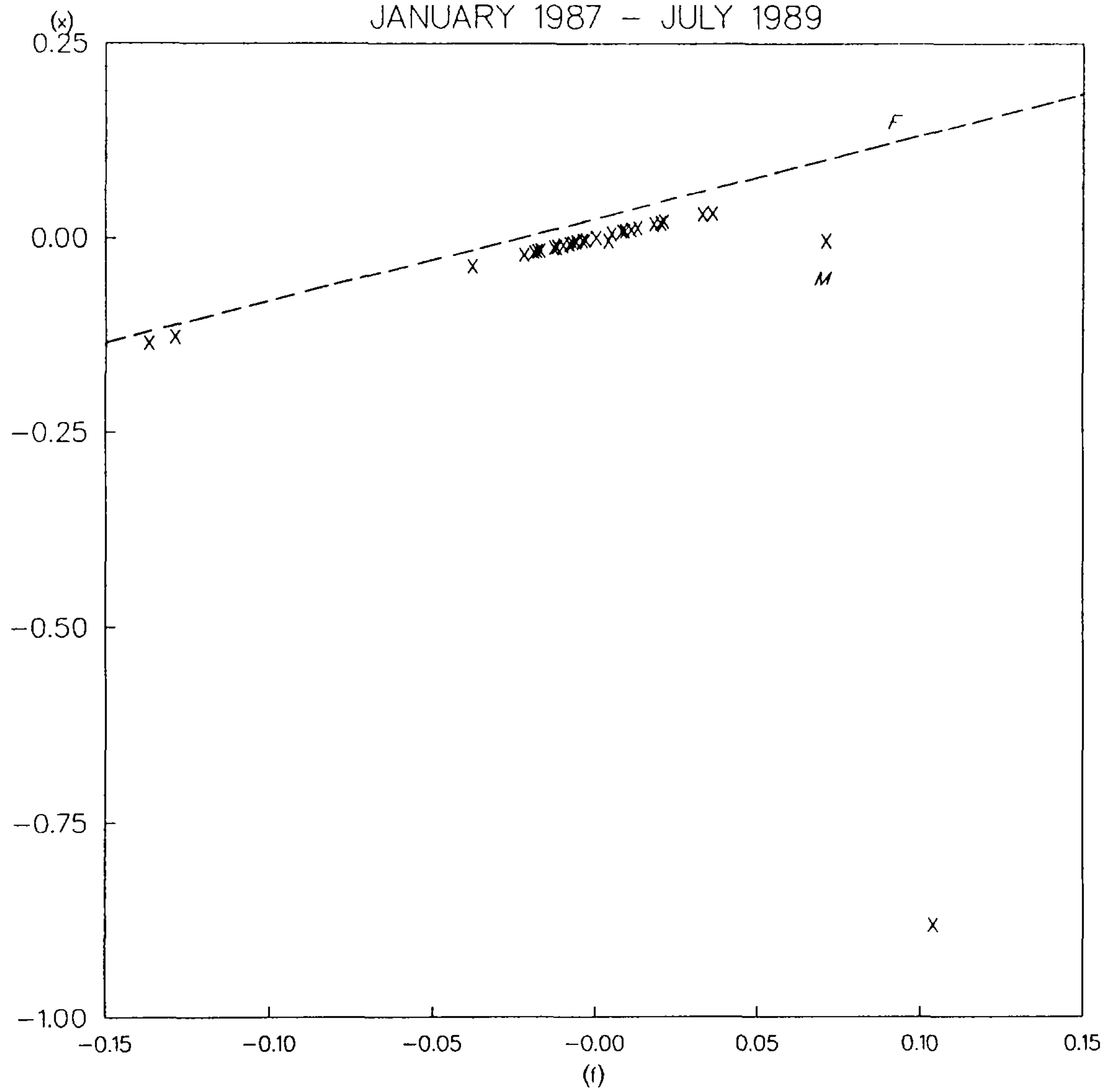


Figure 3e

FREE AND MANAGED DEPRECIATIONS, JANUARY 1987 - JULY 1989



figures are the empirical counterpart of the main analytical geometrical device, used in the theory of target zone exchange-rates as developed by Krugman (1988, 1989) and extended by Flood and Garber (1989), Froot and Obstfeld (1989) and Svensson (1989). As this theory suggests, the relationships between the M curve and the F curve 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 will hold down the rate of change of the price of foreign exchange relative to what it would have been in the absence of interventions and that the standard deviation of the exchange rate depreciations is reduced. In other words, the upper barrier stabilizes exchange rate depreciations within the *target zone*.

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

c) 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 in addition to small sterilized interventions in the foreign exchange market the underlying intervention policy has been characterized also by discrete changes in the fundamental. The lowest point on the bending downward segment of the M curve corresponds to such discrete interventions in the fundamental (see Appendix II).

V. Conclusion

Target zone exchange rate theory is shown to be useful for an empirical analysis which separates the effects on exchange rate behavior of the market fundamental from the effects of policy. The implementation of the theory to our small open economy 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 policymakers attempt to stabilize the exchange rate at the expense of increased turbulence in the financial capital markets. 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.

Exchange Rate Behavior Within the Target Zone

In this appendix we derive the pattern of exchange rate depreciations specified in equation (4). We first express the depreciation rate as a function of the rate of change of the fundamental, x = x[f]. We then apply Ito's Lemma to get

(A.1) $dx(f) = x'(f)df + .5x''(f)(df)^2.$

Substituting equation (3) into (A.1) taking expectations and dividing thorough by dt yields:

(A.2) $E[dx(f)]/dt = x'(f)\mu + .5x''(f)\sigma^2.$

Substituting (A.2) into equation (1) and rearranging terms yields the second order differential equation for x(f), as follows:

(A.3) $(\delta/2)\sigma^2 x''(f) + \delta\mu x'(f) - x(f) = - f$

The general solution for the second-order differential equation is:

(A.4) $x(f) = f + \delta\mu + Ae^{\tau f} + Be^{\beta f}$

where $\tau > 0$ and $\beta < 0$ are the roots of the associated characteristic equation:

(A.5) $(\delta/2)\sigma^2\tau^2 + \delta\mu\tau - 1 = 0.$

The term $f + \delta\mu$ in equation (A.4) represents the specific solution and the term $Ae^{\tau f} + Be^{\beta f}$ represents the homogenous solution, and A and B are constants of integration.

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 depreciations will never exceed a specified upper limit $x\overline{2}$. The monetary authority chooses the pair ($\underline{f}$, $\overline{f}$) so that whenever the rate of change of the fundamental reaches f there is a discrete intervention, that shifts f from point A to point B (see Figure 4) so as to satisfy the value-matching condition. The intervention rule "positions" the exchange rate depreciation curve to be tangent to the $\overline{x}$ line at point C.

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Figure 4
Discrete Interventions and Exchange Rate Behavior