The Effectiveness of Intervention in India: An Empirical Assessment

Sitikantha Pattanaik and Satyananda Sahoo*

The empirical assessment conducted in this paper suggests that intervention operations of the Reserve Bank have been effective in containing exchange rate volatility of the Rupee, even though the degree of influence does not appear to be very strong. Estimated results also indicate that intervention operations may not be very effective in influencing the exchange rate levels. India's stated exchange rate policy fully recognises these aspects and as a result, intervention operations are not used either for driving the exchange rate to any particular level or for keeping the exchange rate contained within any pre-decided range of volatility. Such an intervention strategy reflects the commitment to a market determined exchange rate regime where the Central Bank normally does not interfere with the market dynamics as long as the range of factors that influence the level and volatility of the exchange rate do not give rise to disorderly conditions in the market.

JEL Classification: C2, C3, F31

Key words: Intervention effectiveness, Volatility, Exchange rate

Introduction

The objective of this paper is to assess empirically the effectiveness of intervention operations in the foreign exchange market in India by drawing on the methodologies commonly applied in the empirical literature on the subject. In undertaking such a study, the unavoidable challenge that one encounters is the inability to construct the right counterfactuals, *i.e.*, what could have happened to the exchange rate, both in terms of its level and volatility, in the absence of intervention. The second major difficulty arises from interpreting the objective of countering disorderly market conditions, "a goal that eludes a simple, precise or even impartial definition" (Humpage, 1996). Some even question the rationale behind interventions in an efficient market condition on the ground that fundamental changes are better anticipated and priced by the market, and unless a Central Bank retains some information superiority that allows it to interpret fundamentals differently from the market, it must explain transparently why it intervenes to enhance the effectiveness. The very fact that most Central Banks operating with managed flexible regimes have shifted their stated exchange rate goal from "ensuring exchange rate consistent with the fundamentals" to "ensuring orderly conditions in the market" also lends credence to this argument. Another charge that is generally levelled against empirical studies on the effectiveness of intervention is that they fail to recognise the presence of a dynamic game between the Central Bank and the market players, that requires close and constant monitoring of the activities of market players - rather than fundamentals - for conducting intervention. According to Neely (1997), more than 90 per cent of the dealers use some form of technical analysis (involving identification of trends and reversal of trends, local maxima and minima, *etc.* through charting or mechanical trading rules such as the "filter rule", "trading range break rule" or "moving average" and "oscillators" class rules) and over short horizons, technical analysis clearly predominates fundamental analysis. No empirical analysis, therefore, can truly assess the effectiveness of any Central Bank intervention. Recognising these limitations, this paper only

presents an assessment of the effectiveness of intervention operations in India by using the standard techniques employed in the empirical literature on the subject.

India's exchange rate regime since March 1993 can be characterised as "managed floating with no fixed target" (Jalan, 2000). Using measures of Exchange Market Pressure (EMP) and Index of Intervention Activity (IIA), Patra and Pattanaik (1998) had viewed the exchange rate of the Indian Rupee to be largely managed, though market determined. In a managed flexible regime, particularly when the barriers to cross-border trade and finance are less pervasive and are expected to be liberalised further as a part of the overall reform process, the usual instruments of policy for ensuring orderly market conditions could comprise: (i) direct foreign exchange market interventions, (ii) monetary interventions, generally taking the form of high interest rates, and (iii) use of administrative measures, including capital controls as "last resort". Pattanaik and Mitra (2001) studied the effectiveness of monetary interventions in relieving the pressure on the exchange rate of the rupee during major episodes of disorderly corrections of the exchange rate in the post-March 1993 period and concluded that the interest rate defence of the exchange rate was effective in India.

In this paper, the emphasis is laid entirely on examining the effectiveness of interventions, even though it is difficult to disentangle the effect of direct intervention on the exchange rate from those of the monetary and other administrative measures, particularly when all three are used during occasional phases of significant pressures on the exchange rate. With this broad objective, Section I presents a brief account of the important features of the present day exchange rate regime in India. Important considerations that often determine the effectiveness of intervention are encapsulated in Section II. In view of the large volume of empirical literature that exists on the subject of effectiveness of intervention and given the fact that the experience with regard to the efficacy of and the force behind direct foreign exchange market interventions in "effectively leaning against the wind" has been quite mixed, a detailed review of the empirical literature has been avoided by presenting only important findings of these studies in Annexure I. Section III sets out the methodologies commonly applied in the empirical literature to study the effectiveness of intervention. Applying some of these methodologies, Section IV offers an assessment of the effectiveness of the intervention operations in stabilising the exchange rate of the Indian rupee. Concluding observations are set out in Section V.

Section I
Features of the Indian Exchange Rate Regime

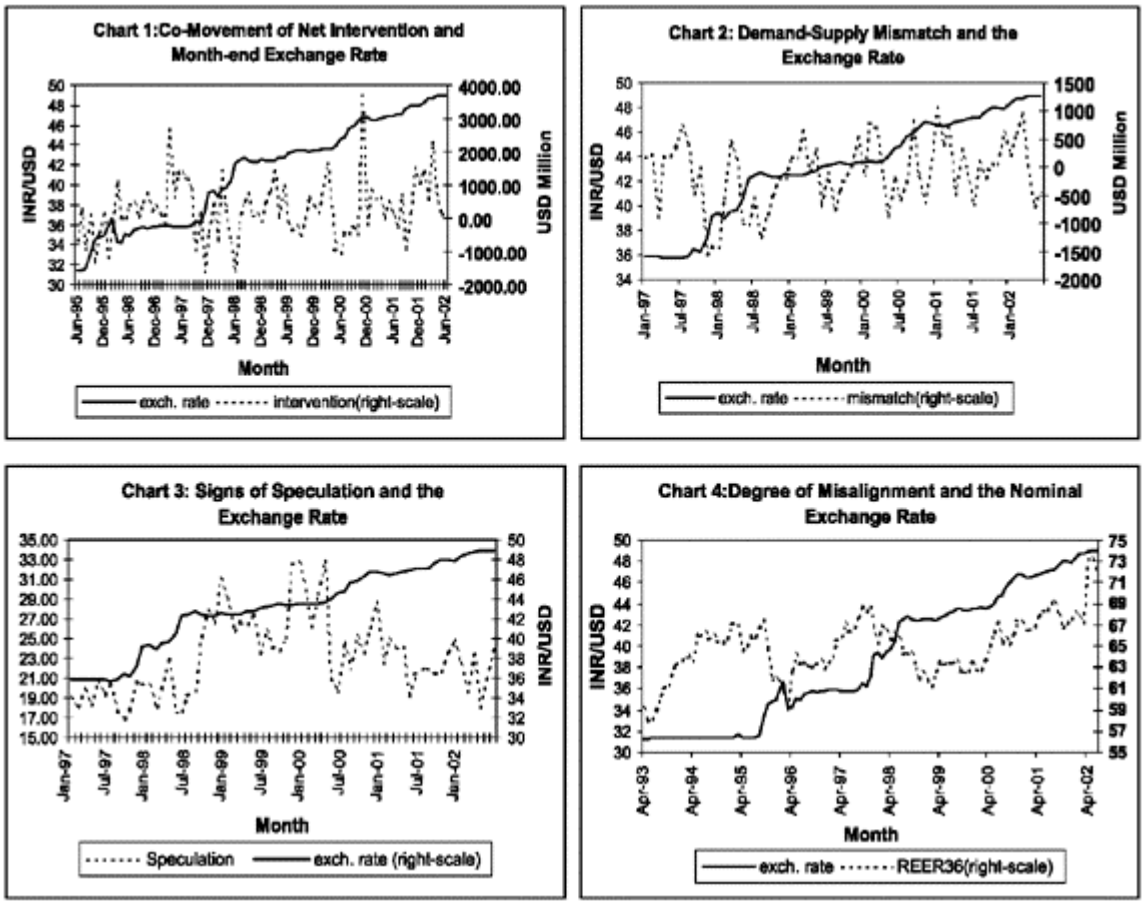
Since March 1993, India has been operating with a managed flexible regime, where the management objective is not to achieve any explicit or implicit target for the exchange rate but to contain volatility by ensuring orderly market conditions. The regime could be interpreted as "more flexible" during normal market conditions with the accent shifting to "management" when the market turns disorderly. While in case of the former, intervention could be viewed as "passive", in case of the latter, intervention is "active". In other words, the objective behind passive intervention could be to "avoid a nominal appreciation" whereas in case of active intervention, the objective is to "avoid disruptive market corrections". Furthermore, during phases of active intervention, a combination of "leaning with the wind" and "leaning against the wind" may be applied, depending on the perceptions about the extent of accumulated

misalignment at the beginning of any episode of exchange market pressure. The policy of leaning with the wind may apply when the correction for the perceived misalignment is ensured by the market forces in an orderly manner. On the other hand, when the market correction turns disorderly – as reflected in heightened volatility – or when the market gets driven primarily by destabilising speculation, pursuing a policy of leaning against the wind becomes inevitable. Though interpretation of misalignment by the market and the authorities at times could vary, both the market and the authorities seem to have referred to the real effective exchange rate (REER) in identifying misalignment over the medium to long-run (Pattanaik, 1999). According to Jalan (2000), "…From a competitive point of view and also in the medium-term perspective, it is the REER which should be monitored….in the short-run, there is no option but to monitor the nominal rate." One unique feature of the Indian regime is that despite attracting net capital inflows of about US $ 89 billion during 1992-2001, and the resultant reserve accretion by about US $ 54 billion (excluding valuation effects) after meeting the financing gap in the current account of about US $ 35 billion, the nominal exchange rate depreciated from Rs. 24.47 per US dollar at the beginning of 1992 to Rs. 48.74 by March 2002. The misalignment arising on account of the positive inflation differential was thus largely corrected by nominal depreciation, despite significant surplus conditions in the market which, left to market forces, could have ensured a large nominal appreciation and the associated significant real misalignment. Nominal appreciation, if allowed, could have, of course, triggered its own corrective mechanism, but that would have represented a different regime altogether whose advantages and disadvantages may be difficult to compare with the present regime due to the typical problem involved in constructing counterfactuals involving exchange rates.

Passive intervention operations in India, thus, not only prevented large accumulation of misalignment but also enabled significant build up of foreign exchange reserves. In emerging market economies, irrespective of their exchange rate regimes, maintaining a comfortable reserve level has generally emerged as an integral element of the policy for external management in the recent years. The monetary management problems associated with such capital inflows induced reserve build up often create additional complications while operating with a managed flexible regime (Pattanaik, 1997). Even when the objectives assigned to monetary policy, exchange rate policy, and official reserve policy could be different, the direct implications of one for the other suggest the need for a coordinated approach. The exchange rate regime, thus, has implications for the monetary regime.

Unlike passive intervention, active intervention operations have enabled the authorities to absorb the shock to the foreign exchange market arising from temporary supply demand mismatches, particularly the leads and lags, and also helped in containing destabilising speculation which often fuels and feeds on volatility. The co-movement of active intervention and the exchange rate of the rupee – particularly of the turning points and local peaks – is depicted in Chart 1. The impact of any supply demand mismatch in the underlying market - as proxied by the difference between merchant purchase and sales turnover - on the exchange rate is shown in Chart 2. The relationship between speculative positions and disorderly exchange market conditions is graphically presented in Chart 3. Inter-bank to merchant turnover ratio is used as a proxy for speculative position because, given the over-night position limits and absence of any limits on intra-day positions, speculative inter-bank intra-day positions (or day trading) can raise the inter-bank turnover in relation to the underlying merchant turnover. Whether nominal exchange rate

behaviour during episodes of significant exchange market pressures reflects corrections for accumulated real appreciation in the previous period can be inferred from Chart 4. The extent of monthly real appreciation depicted in Chart 4 relates to the deviation of the 36-country trade based REER from the level prevailing in March 1993 (following the approach used in the Annual Report of the Reserve Bank of India for 1996-97).



In assessing the appropriateness of an exchange rate regime in the context of the well known impossible trinity, it is often argued that the *first best* policy option could be one where countries with independent monetary policy and open capital account embrace a flexible exchange rate system. For the developing countries, however, pursuance of the *first best* approach generally involves two unavoidable costs: First, in the face of surges in capital flows flexible regimes would give rise to nominal appreciations; riding over the positive inflation differentials the real appreciation could be substantial, eroding thereby the country's external competitiveness. External sector sustainability of a developing economy is highly dependent on the export performance and hence, an exchange rate policy that could threaten the external viability may not be in the interest of such economies. Second, due to lack of market efficiency and thinness of markets, flexible regime may entail unduly large volatility. In such markets agents fail to distinguish between "news" and "noise" and do not price information efficiently. Due to market thinness, some dominant players could even move the market one way. With no restrictions on capital transactions, speculators could potentially take positions in excess of a country's foreign exchange reserves and thereby influence the market at their whim.

The general policy preference, therefore, has been in favour of the *second best* approaches. Retention of capital controls during the phase of gradual transition to the *first best* represents one variant of the *second bes*t approach. Countries like India which pursue this variant of the *second best* approach, emphasise orderly liberalisation of capital transactions and regulation of capital flows consistent with the financing needs and absorptive capacities of the economy for reducing vulnerability to exchange rate crises. According to this approach, judicious controls are akin to dams which "do not stop, but only temper the flow of water from the top of a mountain… without the dams there are floods that bring with them death and property destruction. By contrast, with the dam, not only is the death and destruction reduced, but the water itself can be channelled into more constructive uses" (Stiglitz, 1999).

Section II
Factors Influencing the Effectiveness of Interventions

In the theoretical literature on the subject of intervention effectiveness, one comes across a host of arguments explaining why intervention in general turns ineffective. The simplest of such arguments are that: (i) If exchange rate is primarily decided by the demand and supply positions in the foreign exchange market, only a large volume of intervention relative to the turnover in the foreign exchange market can make an intervention successful. But, the amount used by the Central Banks to intervene generally represents only a small proportion of both daily market turnovers and demand-supply mismatch; (ii) If the exchange rate is interpreted as the relative price (value) of national money (at least in the medium to long-run – as per the monetary approach to exchange rate), non-sterilised interventions can always change the supply of money in relation to demand in one country and thereby influence the exchange rate. But again, the change in the stock of money resulting from intervention may not be very significant. Moreover, intervention operations in general are sterilised – to ensure that intervention operations remain money supply neutral - and hence, the non-sterilised channel of intervention is not very important empirically; and (iii) If the exchange rate is viewed as the relative price of financial assets denominated in different national currencies (*i.e*., the asset market approach to exchange rate determination), sterilised interventions could affect the exchange rate by altering the supply of domestic bonds *vis-a-vis* bonds denominated in foreign exchange. In relation to the large stock of publicly traded domestic and foreign bonds, the change in the demand-supply position caused by sterilised intervention operations may, however, be very marginal.

An assessment of intervention effectiveness, thus, involves clear identification of the transmission channels. From the stand point of a Central Bank, both sterilised and non-sterilised intervention channels are important because while the former has implications for the interest rate scenario, the latter can influence the monetary base and hence, the aggregate money stock. Non-sterilised and sterilised interventions essentially rely on the monetary channel and the portfolio balance channel, respectively. Non-sterilised intervention purchases (sales) give rise to higher (lower) money stock, which in turn lead to exchange rate depreciation (appreciation) as per the monetary approach to exchange rate. As per this approach, any money stock mismatch resulting from non-sterilised interventions may get reflected in change in the exchange rate, both under flex-price and sticky-price conditions. The argument against the use of non-sterlised intervention is that it is akin to open market operations (with the only difference that foreign,

rather than domestic assets are exchanged). In essence, therefore, it is more like a monetary policy instrument rather than an instrument for attaining the exchange rate objective. Moreover, non-sterlised intervention generally operates as a constraint to independent conduct of monetary policy whereas sterilisation helps in regaining monetary policy independence. Not many Central Banks may even tolerate large variability in short-term money market rates resulting from non-sterilised intervention, particularly in view of the fact that short-term interest rate is being increasingly relied upon by them as the primary operating instrument of monetary policy.

Sterilised interventions, which are money supply neutral, do not influence the exchange rate through monetary disequilibrium. Instead, by altering the relative supply of domestic and foreign bonds, such interventions engineer a portfolio reallocation in the market in response to the divergence of the rates of return on domestic and foreign assets. The assumption of perfect asset substitutability that underlies the monetary approach has to be relaxed in the portfolio balance channel for sterilised intervention to work. If assets are assumed to be perfect substitutes, agents would not be concerned about the relative supplies of assets since their primary concern will be only the total size of the portfolio. Agents will be insensitive to transactions involving exchange of foreign bonds for domestic bonds resulting from sterilised intervention operations undertaken by a Central Bank. In turn, if assets are assumed to be imperfect substitutes, agents would continuously reallocate their portfolios among domestic and foreign bonds based on expected return changes resulting form intervention induced changes in relative supplies of domestic bonds. Under sterilised intervention, the crucial variable that one has to examine is the excess return or risk premium that domestic bonds must offer in order to induce the agents to willingly hold the altered (higher/ lower volume of) domestic bonds. The risk premium (RP) can be approximated by ($RP = r – r^* - e^e$), where r and r* represent nominal returns on domestic and foreign bonds, respectively and e^e is the expected change (appreciation/depreciation) of the exchange rate. Condition of uncovered interest rate parity (UIP) would suggest that a currency fetching higher (lower) interest rate must necessarily depreciate (appreciate) to equalise return on assets denominated in different currencies. Presence of risk premium, however, may complicate the empirical assessment of UIP. Empirical tests of the existence/absence of risk premium actually examine a joint (null) hypothesis of “no risk premium” and “foreign exchange market efficiency”. Rejection of the null, therefore, does not explain whether the foreign exchange market is inefficient or whether there is evidence of the presence of risk premium. Acceptance of the joint null, in any case, cannot validate the presence of portfolio balance channel. Given the difficulty in inferring results from the joint hypothesis, how could one explain the portfolio balance channel? One option could be to explore alternative effects of sterilisation by rewriting the risk premium (RP) equation as:

$$RP= r – r^* - [(E^e- E)/E]$$

where $e^e = [(E^e- E)/E]$, E and E^e represent levels of spot and expected exchange rates (domestic currency units per unit of foreign currency), respectively.

Any increase in the supply of domestic bonds resulting from sterilised intervention purchases would increase the risk premium; *i.e.*, only by offering higher return agents can be induced to willingly hold the higher supply of domestic bonds. In practice, this increase in risk premium would get reflected either in: (i) an increase in r, or (ii) a decline in r*, or (iii) a decline in E^e , or

(iv) an increase in E, or (v) a combination of all four. r* is least likely to be affected by sterilised intervention operations undertaken by any emerging market economy. Regarding the effect on r, there could be two views. One view is that sterilised interventions do not alter the monetary base and, therefore, r should remain unaffected. Another view, which relies on the values of offset coefficients to explain how sterilisation does not solve the monetary management problem arising from surges in capital flows, suggests that only by offering higher interest rates a Central Bank can sell more domestic bonds in exchange of the foreign exchange purchased by them to mop up the capital flows induced surplus in the foreign exchange market. If interest rates remain unchanged and expected exchange rate level also remains unchanged, the only possible outcome resulting from sterilised purchase (sale) of foreign exchange could be depreciation (appreciation) of the domestic currency. One may argue that during surges in capital flows the objective behind sterilised intervention would be to prevent a nominal appreciation, rather than to ensure a depreciation following the portfolio balance channel. It is difficult to offer any valid counter argument because of the problem of empirical testing of the joint hypothesis already mentioned above as also the lack of success in establishing strong empirical relationship between time varying risk premia and the relative changes in asset supplies brought about by sterilised interventions.

In view of the growing recognition that "direct" effects of intervention on exchange rates are either statistically insignificant or quantitatively unimportant, greater emphasis has been laid on "indirect" channels, which operate by altering market expectations and triggering forced position shifts. In terms of this approach: (i) intervention can be used as a signaling device – *i.e.*, to signal a Central Banks monetary policy intentions. To establish the credibility of signals, interventions should be followed up by monetary policy actions; (ii) Intervention can also be used to signal authority's perceptions about a fundamentals justified "fair/right" value of the currency and thereby contribute to anchor market expectations. For this channel to be successful, the Central Bank must have established a track record of superior assessment of fundamentals through its regular publications and other channels of communication with the market participants. Information superiority resulting from non-transparent dissemination of information could also enable the Central Bank to view the fundamentals differently from the market; and (iii) When noise-traders drive the rate far beyond the "fair" value and accumulate large overbought/oversold positions, intervention could be used as a "surprise", forcing the traders to unwind their positions. In the context of the effectiveness of the signaling channel, there is a vast literature on "secret" *versus* "reported" interventions and the related issues of information superiority and time consistent behavior of the Central Banks. A comprehensive review of such studies has been avoided in this paper. Only some important findings of empirical studies are reported in Annexure-I.

Despite the presence of known arguments against the effectiveness of intervention, it continues to be a major instrument for achieving the exchange rate objective, even though the magnitude and frequency of interventions vary widely across countries. In the post Bretton Woods period, even the IMF recognised the role of intervention when it adopted the "Principles for the Guidance of Member's Exchange Rate Policy" on April 29, 1977 with the following provisions:

i) A member shall avoid manipulating exchange rates or the international monetary system in order to prevent effective balance of payments adjustment or to gain an unfair

competitive advantage over other members.

ii) A member should intervene in the exchange market if necessary to counter disorderly conditions which may be characterised *inter alia* by disruptive short-term movements in the exchange value of its currency.

iii) Members should take into account in their intervention policies the interests of other members, including those of the countries in whose currencies they intervene.

An exact interpretation of "disorderly condition", however, is almost non-existent in the literature. Rosenberg (1996) noted that the interpretations could vary depending on the stated objectives behind intervention, such as:

i) Simple smoothing operations to limit potentially erratic short-run fluctuations in exchange rates;

ii) Operations to counter excessive speculation or market overreaction to changes in economic fundamentals;

iii) Trend-breaking operations to put an end to a persistent uptrend or downtrend in a currency's value;

iv) Operations to counter excessive risk aversion;

v) Exchange rate targeting operations designed to rigidly peg a currency's value to some specific level or range;

vi) Resistance to exchange rate movements that exceed some threshold rate of change;

vii) Intervention only to prevent large and persistent misalignments of exchange rates that might harm long-term international competitiveness; and

viii) Trend-indicating operations to help push a currency's value in a desired direction.

The stated objectives, thus, leave considerable scope for ambiguity. Some ambiguity, however, may be necessary because the sources of exchange rate volatility / misalignment could be too many and the importance of each could vary over time. According to Rosenberg (1996), the disorderly conditions may arise because: (i) the market may not be using all available information efficiently, (ii) the market may be using a defective model to predict the future path of the exchange rates, (iii) although the market may be using the correct model, its perceptions about the future may be seriously flawed, (iv) the market may be placing undue emphasis on extraneous information that is not quantitatively important in terms of the medium or long-term trend in exchange rates, or (v) the market may be subject to persistent mood swings, constantly shifting from excessive optimism to excessive pessimism. The ambiguity in the stated objective behind intervention, therefore, in a sense recognises the uncertainty about the alternative sources of exchange rate volatility and also helps Central Banks in retaining some element of discretion so that similar market developments need not be followed up with similar reactions. There may, however, be a trade-off between ambiguity and scope for time inconsistent behaviour by the Central Banks. Constructive ambiguity, which is a common feature of the intervention strategies of most Central Banks, essentially reflects a realisation of the great uncertainty against which an intervention operation has to be conducted, and in the absence of information superiority, it largely indicates the intention of a Central Bank rather than its ability to attain the stated objective.

Section III

Methodologies for Empirical Tests

In the empirical literature on the effectiveness of intervention, a number of alternative methodologies have been applied, all of which cannot be tested for India due to non-availability of daily data on intervention. In India, intervention data are available on a monthly basis and, therefore, only such methodologies that can be applied to monthly data are emphasised here. Other methodologies that cannot be applied have only been mentioned to highlight the future scope for empirical research in this area.

One of the early attempts to examine the effectiveness of intervention relied on profitability criterion. Friedman (1953) noted that "there should be a simple criterion of success – whether the agency makes or loses money". Edison (1993) proposed the test of profitability as:

$$\Pi_t = \sum_{i=1}^{t} \left[Intv_i \, (e_t - e_i) + e_t \, (r_t^* - r_t) \sum_{i=1}^{i} Intv_i \right] \qquad (1)$$

where profit (II_t) is a function of the intervention purchase (or sale) of US dollars at e_i in relation to the end period exchange rate e_t and the interest rate differentials (*i.e.,* the difference in the rate of return on rupee and dollar deposits). According to this methodology, positive II_t would indicate success of intervention operations. Bank of England also recognised the role of profit when its Quarterly Bulletin for December 1980 reported that " … intervention has been largely confined to smoothing out fluctuations in the rate –for example, selling sterling when it is strong in demand, with the aim of buying it back at a profit quite soon, perhaps even the same day".

The most commonly applied tests, however, use simple regressions in which either levels of exchange rates or their volatility are explained by levels of interventions. As per Almekinder's (1994) regression test:

$$e_t - e_{t-1} = a_0 + a_1 \text{ Interventions}_{(t \text{ to } t-1)} + a_2 (e_{t-1} - e_{t-2}) + u_t \qquad (2)$$

where the coefficient a_1 should be positive for interventions to be effective and a_2 should be positive if there is a "following the trend" pattern in the exchange rate.

The above OLS regression assumes that the direction of causality runs only from intervention to exchange rate even though in reality intervention may have to be undertaken in response to observed behaviour of the exchange rate. Recognising the simultaneity problem, Almekinders and Eijffinger (1994) suggested the following simultaneous equation systems:

$$e_t - e_{t-1} = a_0 + a_1 \text{ Interventions}_{(t \text{ to } t-1)} + a_2 (e_{t-1} - e_{t-2}) + u_t \qquad (3)$$

$$\text{Interventions}_{(t \text{ to } t-1)} = b_0 + b_1 (e_t - e_{t-1}) + b_2 (e_{t-1} - e_{t-2}) + \in_t \qquad (4)$$

where a_1 should be positive and b_1 should be negative.

In the system of equations, the second one is a typical Central Bank reaction function and, therefore, variables representing deviations of actual exchange rate from any explicit/implicit exchange rate

targets can also be included in the regression equation. Several other factors (X_1) influencing both intervention and exchange rate could also be used as additional explanatory variables in the above equations. Following Black (1980), Argy (1982) and Keneray and MacDonald (1986), the reaction function could be estimated as :

$$\text{Intervention}_t = \alpha_0 + \alpha_1 (\%\ \text{change in exchange rate})_{(t-1\ \text{to}\ t)} + \alpha_2\ \text{Intervention}_{(t-1)} + \alpha_3\ (\text{deviation of current exchange rate from PPP or FEER, the latter two representing targets, if any}) + \alpha_4\ (\text{actual volatility in excess of tolerable volatility}) + u_{1t} \quad (5)$$

where $\alpha_0 > 0$ implies a policy of reserve build up through intervention purchases.

As opposed to the tests relying on exchange rate levels, some studies also examine the impact of intervention on volatility. As per the test suggested by Bonser-Neal (1996):

$$\text{Exchange rate volatility} = \beta_0 + \beta_1\ \text{Interventions} + \beta_2\ (\text{macro-economic indicators}) + u_{2t} \quad (6)$$

where the macro-economic indicators could include deviation of REER from PPP, deviation of actual money growth from target, volatility in equity markets, industrial production and export performance, as well as lagged exchange rate volatility to capture the feedback effects. An intervention coefficient β_1 that is negative and statistically significant suggests that intervention helped in reducing volatility and, therefore, must be stabilising. The simultaneity argument mentioned in case of tests using exchange rate levels also apply in this case.

Besides the above alternative approaches, one also comes across other methodologies like the Fausten's (1995) test of co-integration among the exchange rate, the targeted level of exchange rate (if any, say in relation to REER or FEER based misalignment), and the control variable at the disposal of the authorities (*i.e.*, interest rate and/or intervention purchases/sales).

This paper applies the above methodologies to assess the effectiveness of intervention operations in India. Other methodologies which can be tested using daily (or even higher frequency) intervention data include: Engle's ARCH and Bollerslev's GARCH models to forecast volatility - both in sample and out of sample - so as to assess whether interventions can be effected in a forward looking manner, Bonser-Neal and Tanner (1996) type GARCH estimates of conditional volatility using implied volatility from currency option markets as proxy for ex-ante volatility, and Galati and Melick (1999) type Logit / Probit models. Due to non-availability of data, this paper does not attempt to apply these techniques for assessing the intervention effectiveness in

India.

Section IV
An Empirical Assessment of Intervention Effectiveness in India

In India, monthly data on intervention operations in the spot market are available from June 1995. In applying the Friedman's test of profitability to assess the effectiveness of intervention, however, one must recognise that in the absence of information on transaction-wise details of intervention purchases and sales it is almost impossible to arrive at the true profit/loss figure associated with a Central Bank's intervention operation. We, therefore, follow the approach adopted by Pilbeam (1991) to approximate the profit figure (II_t) as per the following equation by separately estimating the exchange rate related profit/loss and the interest rate related profit/loss.

$$\Pi_t = \sum_{i=1}^{t} \left[Intv_i \, (e_t - e_i) + e_t (r_t^* - r_t) \sum_{i=1}^{i} Intv_i \right] \qquad (7)$$

Here the assumption is that, if the Central Bank can purchase foreign currency at an appreciated rate and sell at a depreciated rate, it can make profits (*i.e.,* the principle of buy low and sell high). While acquiring foreign currencies through intervention purchase, however, a Central Bank may have to also compare the returns on domestic and foreign assets. If the domestic interest rate scenario can fetch a higher return on domestic assets than foreign assets, by accumulating reserves through intervention purchases it may incur some interest rate related loss, with the magnitude of loss depending on the extent of interest rate differential prevailing at any point of time. The steps to calculate the respective gains/ losses are set out below:

i) Convert the monthly US dollar intervention purchases/sales at the monthly average exchange rate into rupees.
ii) Convert the cumulative US dollar intervention at the end period exchange rate into rupees.
iii) Calculate the exchange rate related gain/ loss at any point of time as the difference between (b) and (a).
iv) For arriving at the interest rate related gains/losses, first estimate the monthly average cumulative intervention balances for every month. A simple approximation could be the average cumulative balance of two consecutive months.
v) Apply the interest rate differential (annual interest rates converted into monthly rates) to the monthly cumulative balance.
vi) Convert the cumulative interest gain/loss expressed in US dollars over months by the end of a particular period at the end period exchange rate into rupees.
vii) Combine the exchange related gains/losses and the interest rate related gains/losses to arrive at the total profit/loss figure associated with intervention.

In adopting this approach, as suggested by Edison (1993) and Pilbeam (1991), one cannot avoid the following unrealistic assumptions: (i) all interventions are made in US dollar, (ii) interventions are spread out evenly throughout the month, (iii) profits and losses on intra-month trading are ignored, (iv) all interest rate gains/losses are converted at the end of the period into

rupees, and (v) net cumulative intervention can be closed at the end of any period at the end-period exchange rate without altering the exchange rate. These unrealistic assumptions suggest that any attempt to estimate the intervention related profits would only be fraught with errors.

However, such estimates can provide some broad indication over a period of time, if not at any particular point of time, about the profitability pattern. Keeping this in view, the estimated gains/ loses associated with interventions operations in India over a span of more than seven years are presented in Table 1.

Table 1: The Profitability of Intervention Operations in India

Year	Cumulative Interventions [In US dollar Million]*	Exchange rate related cumulative profits(+)/loss(-) [In Rupees Million]	Interest rate related** cumulative Profits(+)/loss(-) [In Rupees Million]	Total cumulative Profits (+)/loss(-) [In Rupees Million]
1996-97	7,447	4,251.1	- 4,287.4	-36.3
1997-98	11,316	44,453.3	- 28,987.2	15,466.1
1998-99	13,158	76,199.1	- 55,333.1	20,866.0
1999-2000	16,407	92,382.2	- 91,026.8	1,355.3
2000-01	18,763.68	1,36,951.8	- 143,673.6	-6,721.0
2001-02	25,826.70	1,81,245.6	- 178,711.7	2,533.9
2002-03 (April- June)	26,629.95	1,83,127.5	- 185,093.3	-1,965.8

*Cumulative since June 1995.
** Interest rate on 91 day Treasury Bill (TB) in India minus 3 month LIBOR.

As could be seen from Table 1, it is difficult to make an assessment about intervention effectiveness from the estimated end-year profit positions since in different years contrasting positions are obtained for India. As noted by Pilbeam (1991), authorities may make profit when net interventions are close to zero and as the levels of net interventions increase, profitability may decline and over time they may even incur net losses. However, when cumulative interventions are large, they need not reflect only the exchange rate objective, as reserve accumulation policy may at times be guided by a host of factors, including of course the exchange rate objective. In such cases, despite the known opportunity costs of holding high reserves and the associated net loss, reserve accumulation policy may continue in the interest of other objectives to be achieved through a high reserve policy. Furthermore, recognising the problem of possible large errors that may be associated with estimates of intervention profitability, we turn to other methodologies that are more commonly used in empirical literature.

Applying ordinary least square(OLS) regressions of the type suggested by Almekinder (1994) and Bonser-Neal (1996), we obtain the following results for India.

i) DEPR = 0.28 – 0.0002 INTV
(5.25)* (-3.97)*
$\overline{R}^2$ = 0.15 , DW = 1.92

ii) DEPR = 0.12 – 0.0003 INTV +0.02 MISALIGNMENT
(0.09) (-4.19)* (1.41)
$\overline{R}^2$ = 0.16 , DW = 1.95

iii) DEPR = 0.36 – 0.0002 INTV – 0.02 INTGAP
(5.24)* (-4.15)* (-1.79)***
$\overline{R}^2$ = 0.17 , DW = 1.93

iv) VOLA = 0.17 – 0.0005 INTV
(8.67)* (-4.22)*
$\overline{R}^2$ = 0.17 , DW = 1.49

v) VOLA = 0.12 – 0.0008 INTV + 0.01 INTGAP
(4.48)* (-3.78)* (2.68)**
$\overline{R}^2$ = 0.27, DW = 1.96

*,**,*** significant at 1, 5 and 10 per cent, respectively.

In the above equations, DEPR refers to monthly change in the exchange rate (*i.e.*, difference between two consecutive end-month Rupee/US dollar rate) and VOLA represents volatility of daily exchange rate during a month (*i.e.*, standard deviations of daily rates). INTV is the net monthly intervention. To capture the possible impact of certain fundamental variables on the exchange rate (both in terms of level and volatility), we use INTGAP (*i.e.*, the difference between 91 day Indian tresury bill and 3 month LIBOR) and MISALIGNMENT (*i.e.*, deviation of the REER from its March 1993 level, as explained in Section-I).

First three estimated equations suggest that the intervention coefficients are wrongly signed, implying that intervention operations may not be effective in influencing the exchange rate levels or the extent of change in the exchange rate during a month. The last two equations, however, suggest that intervention operations can be effective in lowering exchange rate volatility. The intervention coefficients in the volatility equations are correctly signed and statistically significant. Thus, given the Reserve Bank's exchange rate objective of ensuring orderly conditions in the market (*i.e.,* to contain volatility and not to achieve any particular level of exchange rate), intervention in India can be viewed as an effective instrument.

All the estimated equations suggest that certain fundamentals like interest rate gaps and degree of misalignment could have some influence on both degree of change in exchange rate as well as

volatility. Exchange rate may depreciate more when the misalignment is higher (exhibiting thereby a positive relationship). Similarly, higher interest rate gap would create expectations of a depreciation of domestic exchange rate as per the condition of uncovered interest rate parity (explaining a positive relationship of both volatility and change in exchange rate with interest rate differential). While the respective fundamental variables are correctly signed, in some of the equations they do not turn out to be statistically significant. Since the objective of this paper is to assess the effectiveness of intervention, we do not attempt to study the relevance of fundamentals in great detail.

Recognising the problem of simultaneity highlighted by Almekinders and Eijffinger (1994), we estimated the volatility equation again in a simultaneous framework along with an intervention reaction function of the Central Bank. This framework is more realistic in the sense that volatility not only responds to intervention operations but it also triggers intervention action by the Central Banks. The results of Two-Stage Least Square (TSLS) regressions presented below suggest that volatility often triggers intervention actions but such interventions may not always be effective in reducing volatility.

$$\text{INTV} = 529.3 - 2859.6\ \text{VOLA} + 17.9\ \text{MISALIGNMENT}$$
$$(1.56) \quad (-2.16)^{**} \quad (0.91)$$
$$\bar{R}^2 = 0.12,\ \text{DW} = 1.83$$

$$\text{VOLA} = 0.14 - 0.0001\ \text{INTV} + 0.25\ \text{VOLA}(-1)$$
$$(1.82)^{***} \quad (-0.67) \quad (1.23)$$
$$\bar{R}^2 = 0.22,\ \text{DW} = 2.02$$

,* significant at 5 and 10 per cent, respectively.

In the Central Bank reaction function, the volatility coefficient is of the expected sign and is also statistically significant. In other words, when volatility increases (*i.e.*, + VOLA), intervention sales will increase (*i.e.*, – INTV). Hence, the negative relationship is obtained. In the volatility equation, the intervention coefficient is of expected sign, though not statistically significant. Hence, estimates generated in the simultaneous framework do not corroborate the findings of simple OLS.

Following the approach suggested by Fausten (1995), an alternative to the results obtained through OLS and TSLS could be conducted by exploring the possible existence of a co-integration between exchange rate levels/volatility and interventions. ADF test statistics reported in Table 2 indicate that all the three relevant variables, *i.e.*, DEPR, VOLA and INTV are of the same order of integration. Johansen trace statistics reported in Table-3 indicate the presence of one co-integrating relationship between VOLA and INTV and two such relationships between DEPR and INTV. The estimated equations as set out below validate the OLS results, implying that intervention operations in India have been effective in containing volatility, if not the exchange rate levels/extent of change in exchange rate during any month.

VOLA = 0.32 – 0.0005 INTV
DEPR = 0.28 – 0.0003 INTV
DEPR = 5.96 – 0.017 INTV

Table 2: Stationarity Test Statistics (June 1995 to June 2002)

	ADF Test Statistics
INTV	-4.18*
VOLA	-2.59***
DEPR	-5.08*

*,*** imply significance at 1 and 10 per cent levels, respectively, for 4 lags.

Table 3 : Johansen Trace Statistics

Between VOLA and INTV

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.214288	28.39483	19.96	24.60	None **
0.107537	9.101611	9.24	12.97	At most 1

Between DEPR and INTV

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.303370	46.00819	19.96	24.60	None **
0.192330	17.08809	9.24	12.97	At most 1 **

The Co-integrating vector with a constant and four lags.

It may be noted that almost all the estimated equations for India exhibit better fit in relation to similar other empirical studies conducted elsewhere. In the OLS and TSLS specifications, low values of the R^2 in fact turn out to be higher than what one finds in other similar empirical studies. Most importantly, a positive constant term in the reaction function equation corroborates the continuous reserve accretion feature that has characterised the intervention operations in India.

SectionV
Concluding Observations

The empirical assessment conducted in this paper suggests that intervention has been quite effective in India as an instrument to achieve the stated exchange rate objective of ensuring an orderly exchange market. There is little evidence in the empirical tests conducted for India that can validate any possibility of intervention influencing the exchange rate levels on a sustained

basis. Exchange rate volatility, as measured by the standard deviations of daily exchange rates over months, however, responds to intervention operations in the expected direction, even though the magnitude of the impact appears to be not very strong. The findings of this paper indicate that in the present day managed float regime of India, intervention can serve as a potent instrument of exchange rate management only at the margin, that too only for managing the magnitude of volatility and not to remove volatility completely. In fact, India's stated exchange rate objective already recognises this aspect, as it neither aims at driving the exchange rate to any particular level nor tries to keep the exchange rate contained within any pre-decided range of volatility. Due to the generalised surplus conditions prevailing in the market, passive intervention purchases have dominated the intervention operations in India. Active intervention has been resorted to only during occasional phases of strong exchange market pressures. It is possible, therefore, that the effectiveness of active intervention in lowering volatility may be much less in relation to passive intervention operations conducted during normal conditions. But that need not be viewed as the inability to contain volatility since, first of all, in a market determined regime the exchange rate must necessarily exhibit some volatility, reflecting the market clearing process. Most importantly, if at every sign of greater volatility the Central Bank reacts with aggressive interventions, the expected market correction for any misalignment may never materialise. Any empirical assessment of the effectiveness of intervention, therefore, cannot account for the entire range of factors, whether stated or unstated, that may be guiding the actual intervention strategy of a Central Bank. Empirical exercises can at best provide only some broad indications about the effectiveness of intervention in a country.

Empirical literature reviewed in this paper covering the exchange rates of advanced countries over different time horizons generally suggest that interventions have not been very effective in the past, either in having any lasting impact on the exchange rate or in lowering the exchange rate volatility. Similar empirical studies on emerging markets are, however, very rare. Given that the type of exchange rate regime pursued by a country, the depth and sophistication of the foreign exchange market, and the regulatory controls on the type and volume of foreign exchange transactions can significantly condition the impact of intervention, it may not be appropriate to assess the performance of intervention in an emerging market keeping in view the empirical findings obtained mostly for advanced countries. The findings of this paper for India suggest that intervention can contain volatility. If the Central Bank decides to loose reserves over the intervention cycle, it can even affect the exchange rate levels. Interventions are, however, carried out only to smooth out temporary mismatches as reflected in the fact that reserve losses incurred during disorderly market conditions are recouped during normal conditions. Such an intervention strategy essentially establishes the commitment of the Central Bank to a market determined regime, where it does not interfere with the market dynamics as long as the market forces continue to determine the course of the exchange rate in an orderly manner.

References

Adams, Donald and Dale Henderson (1983), "Definition and Measurement of Exchange Market Intervention", *Staff Studies 126*, Board of Governors of the Federal Reserve System, Washington DC.

Almekinders, G.J. (1995), *Foreign Exchange Intervention: Theory and Evidence*, Elgar Publication.

Almekinders, G.J. and S.C.W. Eijffinger (1994), "The Ineffectiveness of Central Bank Intervention", *Center for Economic Research Discussion Paper No. 94101*, December.

Andrew, Robert and John Broadbent (1994), "Reserve Bank Operations in the Foreign Exchange Market: Effectiveness and Profitability", *Research Discussion Paper No.9406*, Reserve Bank of Australia, November.

Argy, V. (1982), " Exchange Rate Management in Theory and Practice", *Princeton Studies in International Finance*, No.50.

Baillie, R.T. and William P. Osterberg (1997), " Why Do Central Banks Intervene?", *Journal of International Money and Finance*, Vol.16, No.6.

Blundell-Wignall, A and P.R. Masson (1985), "Exchange Rate Dynamics and Intervention Rules", *IMF Staff Papers*, March.

Bonser-Neal, Catherine (1996), " Does Central Bank Intervention Stabilise Foreign Exchange Rates?", *Federal Reserve Bank of Kansas City Economic Review*, First Quarter.

Bonser-Neal, Catherine and Glenn Tanner (1996), "Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence from the Options Market", *Journal of International Money and Finance*.

Boothe, Paul, Kevin Clinton, Agathe Cote, and David Longworth (1985), "International Asset Substitutability: Theory and Evidence for Canada", Ottawa, Bank of Canada.

Bossaerts, P. and Hillion P. (1991), " Market Microstructure Effects of Government Intervention in the Foreign Exchange Market", *Review of Financial Studies*, 4, 513-541.

Corrado, C. and Taylor D. (1986), "The Cost of a Central Bank Leaning Against A Random Walk, "*Journal of International Money and Finance*, 5, 303-314.

Cuddington, J.T. (1991), "Comparing the Intensity of Exchange Market Intervention with Frenkel and Aizeman's index of Managed Float", *Journal of International Economics*, 31, 383-386.

Danker, Deborah J, Richard A. Haas, dale W. Henderson, Steven A. Symansky and Ralph W. Tryon (1987), "Small Empirical Models of Exchange Market Intervention: Applications to Germany, Japan and Canada", *Journal of Policy Modeling*, 9, Spring.

Dominguez, Kathryn (1993), "Does Central Bank Intervention Increase the Volatility of Foreign Exchange Rates?", *NBER Working Paper No. 4532*, November.

Dominguez, K. and Frankel, J.A. (1993), "Does Foreign Exchange Intervention Work?", *American Economic Review*, 83, 1356-1369.

Dooley, Michael P.(1982), "An Analysis of Exchange Market Intervention of Industrial and Developing Countries", *IMF Staff Papers*, June.

Dooley, Michael P, Donal J. Mathieson and Liliana Rojas-Suarez (1997), "Capital Mobility and Exchange Market Intervention in Developing Countries", *NBER Working Paper No. 6247*, October.

Eaton, Jonathan and Stephen J Turnovsky (1984), " The Forward Exchange Market, Speculation and Exchange Market Intervention", *NBER Working Paper* No.1138, November.

Edison, Hali J. (1993), "The Effectiveness of Central Bank Intervention: A Survey of the Literature After 1982", *Princeton Special Papers in International Economics No. 18*, July.

Fausten, D. K. (1995), " The Effectiveness of Exchange Rate Intervention in Post-float Australia", *Economica Internationale*, November.

Feldstein, M. (1986), " New Evidence on the Effects of Exchange Rate Intervention", *NBER Working Paper* No. 2052.

Frenkel, M., C. Pierdzioch and G. Stadtman (2001), "The Foreign Exchange Market Interventions of the European Central Bank", *BNL Quarterly Review*, No.218, 249-287.

Friedman, Milton (1953), " The Case for Flexible Exchange Rates", in *Essays in Positive Economics*, Chicago.

Galati, Gabriele and William Melick (1999), " Perceived Central Bank Intervention and Market Expectations: An Empirical Study of the Yen/Dollar Exchange Rate, 1993-96", *BIS Working Papers, No.77*, October.

Ghosh, A. (1992), "Is it signalling ? Exchange Intervention and Dollar DM Rate", *Journal of International Economics*, 32, 201-220.

Goodhart, C.A.E. and T. Hesse (1993), "Central Bank Foreign Exchange Intervention Assessed in Continuous Time", *Journal of International Money and Finance*, Vol.12, No.4, August, 368-89.

Hsieh, D.A. (1989a), "The Statistical Properties of Daily Exchange Rates", *Journal of International Economics*, 24, 129-145.

Hsieh, D.A. (1989b), "Modeling Heteroscedasticity in Daily Foreign Exchange Rates", *Journal of Business and Economic Statistics*, 7, 307-317.

Huang, Juann (1995), "Intervention Strategies and Exchange Rate Volatility: A Noise Trading Perspective", *Federal Reserve Bank of New York Working Paper No. 9515*, June.

Humpage, Owen F. (1989), "US Intervention: Assessing the Probability of Success", *Federal Reserve Bank of Cleveland Working Paper No. 9608*, Sept.

Jalan, Bimal (2000), "Development and Management of Foreign Exchange Markets: A Central Banking Perspective", Inaugural Remarks at the 21st Asia pacific Congress held in New Delhi on December 1.

Jorion, Philippe (1995), "Predicting Volatility in the Foreign Exchange Market", *Journal of Finance*, June, 50, 507-528.

Kaminsky, Graciela and Karen Lewis (1993), "Does Foreign Exchange Intervention Signal Future Monetary Policy ?", *NBER Working Paper No. 4298*.

Karunaratne, N.D. (1995), " The Effectiveness of Intervention in Post-float Australia", *Economica Internationale*.

Kearney, Colm and Ronald MacDonald(1986), " Intervention and Sterilization under Floating Exchange Rates: The UK 1973-1983", *European Economic Review*, 30, April.

Kim, S. J. and J. Sheen (2002), "The Determinants of Foreign Exchange Intervention of Central Banks: Evidence from Australia", *Journal of International Money and Finance*, vol.18, No.5.

Klein, Michael and Karen Lewis (1991), "Learning About Intervention Target Zones", *NBER Working Paper No. 3674*.

Klein, M.W. (1993), "The Accuracy of Reports of Foreign Exchange Intervention", *Journal of International Money and Finance*, 12, 644-653.

Leahy, M.P. (1995), " The Profitability of US Intervention in the Foreign Exchange Market", *Journal of International Money and Finance*, Vol.14, No.6, Dec.

Lewis, K.K. (1995), "Are Foreign Exchange Intervention and Monetary Policy Related and Does it Really Matter?", *Journal of Business*, 68, 185-214.

Loopesko, Bonnie (1984), "Relationships Among Exchange Rates, Intervention and Interest Rates: An Empirical Investigation", *Journal of International Money and Finance*.

Neely, Christopher and Paul Weller (1997), "Technical Analysis and Central Bank Intervention", *Federal Reserve Bank of St. Louis*, January 23.

Obstfeld, Maurice (1988), "The Effectiveness of Foreign Exchange Intervention: Recent Experience", *NBER Discussion Paper No. 2796*.

" (1983), " Exchange Rates, Inflation, and the Sterilization Problem: Germany 1975-1981", *European Economic Review*, 21, March.

Pattanaik, Sitikantha (1999), " REER: The Leading Indicator", *Reserve Bank of India Occasional Papers*, Vol.20, No.2, Monsoon.

" (1997), " Target and Instruments for the External Sector with an Open Capital Account", *Economic and Political Weekly*, Vol. XXXII, No. 40, October 4.

Pattanaik, Sitikantha and A.K. Mitra (2001), " Interest Rate Defence of Exchange Rate: Tale of the Indian Rupee", *Economic and Political Weekly*, Vol. XXXVI, Nos. 46 and 47, Nov.24.

Patra, M.D. and Sitikantha Pattanaik (1998), " Exchange Rate Management in India: An Empirical Evaluation", *Reserve Bank of India Occasional Papers*, Vol.19, No.3, Sept.

Pilbeam, Keith (1991), *Exchange Rate Management: Theory and Evidence*, MacMillan.

Rogoff, Kenneth (1984)," On the Effects of Sterilised Intervention: An analysis of Weekly Data", *Journal of Monetary Economics*, 14, Sept.

Rose, Andrew K. (1996), " Explaining Exchange Rate Volatility: An Empirical Analysis of the Holy Trinity of Monetary Independence, Fixed Exchange Rates, and Capital Mobility", *Journal of International Money and Finance*, Vol.15, No.6.

Rosenberg, Michael R. (1996), "Central Bank Intervention and Determination of Exchange Rates", in *Currency Forecasting*, Irwin Professional Publishing, London.

Sarno, Lucio and M. P. Taylor (2001), "Official Intervention in the Foreign Exchange Market: Is It Effective and, If So, How Does It Work?", *Journal of Economic Literature*, Vol.39, 839-868.

Spencer, P. (1985), " Official Intervention in the Foreign Exchange Market", *Journal of Political Economy*, Vol.93, 1019-1024.

Stiglitz, Joseph E. (1999), " Lessons from East Asia", *Journal of Policy Modeling*, 21(3).

Taylor, D. (1982), "Official Intervention in the Foreign Exchange Market", *Journal of Political Economy*, 90, 356-368.

Turnovsky, Stephen J. (1985), "Exchange Market Intervention under Alternative Forms of Exogenous Disturbances", *NBER Working Paper No. 1289*, April.

Annexure-I
Effectiveness of Central Bank Intervention: Empirical Evidence from Select *S*tudies

Authors (Year)	***Empirical Findings***
Kim, S. J. and J. Sheen (2002)	Intervention operations of the Reserve Bank of Australia (RBA) during 1983 to 1997 were guided by five major considerations, *viz.* trend corrections in exchange rate, volatility smoothing, US-Australia overnight interest rate differentials, profitability and foreign currency reserve inventory. Intervention related profits of RBA were normally close to zero from 1983 to 1988

	and in the subsequent years major losses were sustained upto 1997.
Frenkel, M. C. Pierdzioch and G. Stadtman (2001)	Using the very short intervention record of the European Central Bank, the study concluded that interventions were not effective. While intervention had some effect on the level of the exchange rate in the intra-daily exchange rate data, those effects were only minor and got reversed on the trading day following the intervention.
Sarno, Lucio and M. P. Taylor (2001)	By reviewing the existing literature, the study concluded that studies of the 1990s are largely supportive of intervention effectiveness whereas those of the 1980s largely rejected the hypothesis that intervention could be effective.
Galati, G. and Williams Melick (1999)	The paper examined how market expectations affected the likelihood of Central Bank intervention and, in turn, how intervention affected market expectations. It concluded that the Bank of Japan and the Fed responded quite differently. Most importantly, interventions increased market uncertainty regarding future movement of spot rates.
Paolo Vitale (1997)	In a market micro-structure framework, the results of this study showed that in some circumstances sterilized intervention may represent an instrument to influence exchange rate.
Baillie, R. and W.P. Weferberg (1997)	Using daily intervention data from July 6, 1986 to March 1, 1990 for the G-3, the paper studied the intervention effectiveness in the US$/DM and US$/Yen spot markets and concluded that interventions may tend to increase volatility rather than calming disorderly conditions.
Bonser-Neal (1996)	Using daily intervention data for the G-3 over 1985 to 1991 the study concluded that interventions typically had little effect on exchange rate volatility and in some cases interventions even increased volatility.
Karunaratne, N.D. (1995)	This study contradicted the Juttner and Tonkin (1992) findings that Reserve Bank of Australia's interventions were futile and ineffective and out-rightly damaging to Australia's macro-economic performance. It also contradicted the RBA claims that its sterilised interventions were mainly for "leaning against the wind" since there were instances of sporadic heavy doses of intervention since mid-80s aimed at achieving a variety of stabilisation goals.
Huang, Juann (1995)	US interventions reduced both yen/dollar and DM/ dollar exchange rate volatilities during 1985-86, but increased them during 1987-89. These results make sense in a noise trading framework where the effectiveness of sterilised intervention may depend critically on the shrewdness of intervention strategies.
Almekinders and Eijffinger (1994)	Using daily data from February 23, 1987 to October 31, 1989, they found that interventions conducted by the Bundesbank and the Federal Reserve were not successful at systematically reversing unwanted movements in the respective exchange rates. [They contradicted the findings of Dominguez and Frankel (1993)].
Catte, Galli and Rebecchini (1994)	This study identified 19 episodes of coordinated intervention and found that all episodes were successful in temporarily reversing the trend movement in the US dollar.
Weber (1994)	Sterilised intervention, whether coordinated or not, has no lasting effect on exchange rates.

Andrew and Broadbent (1994)	According to this study, whether any intervention is stabilising or not cannot be directly observed since the behaviour of the exchange rate in its absence is unknown. Using Friedman's "profit tests", it showed that RBA profited from its intervention operations, indicating that interventions were stabilising.
Dominguez, K.M. (1993)	Using GARCH models on $/DM and $/yen daily data over the period 1985 to 1991, the study concluded that publicly known interventions generally decreased volatility. Secret intervention operations by both the Fed and the Bundesbank increased exchange rate volatility.
Dominguez and Frankel (1993)	Using daily data they showed that even sterilised interventions can influence the exchange rates, particularly when known to the markets.
Ghosh A. (1992)	The study supported the view that sterilised intervention operating through the portfolio channel is statistically significant but quantitatively unimportant. To materially influence the exchange rate, substantial intervention is required so as to operate through the portfolio balance channel.
Klein and Lewis (1991)	They found that neither the Federal Reserve nor the Bundesbank had used intervention as a signal of future policy changes. Intervention did not consistently precede policy changes, and a large number of policy changes were not preceded by intervention in the post- Plaza period.
Pilbeam, Keith (1991)	Interventions by the Bank of England, which were mostly sterilised, had no significant exchange rate effects. The authorities made profits when net intervention was close to zero. They generally lost money, when net cumulative interventions turned out to be large.
Dominguez, K. M. (1989)	Coordinated intervention is generally statistically significant and of the correct sign and is reported to be quantitatively more important than non-coordinated intervention.
Humpage (1989)	The study concluded that: (1) systematic intervention had no apparent impact on exchange rates, (2) intervention can have a short-term effect if it provides new information to the market, and (3) distinction between coordinated and non-coordinated intervention is not important.
Obstfeld Maurice (1988)	Sterilised intervention, in itself, played an un-important role in promoting exchange rate realignment. The signaling channel worked occasionally due to the readiness of the authorities to adjust monetary policy promptly to counteract unwelcome exchange market pressures.
Danker *et al.* (1987)	None of the alternative models could confirm that sterilised intervention can be effective.
Kearney & MacDonald (1986)Kearney & MacDonald (1986)	They concluded that sterilised intervention does appear to have a substantial (quantitatively important) effect on the exchange rate.
Dominguez (1986)	The study examined whether a relationship existed between intervention and weekly money surprises. During periods when the Fed's anti-inflation credibility was high, there was evidence that money supply surprises were positively correlated with intervention. When credibility was high, intervention had a significant positive impact on the exchange rate.
Blundell-Wignall & Masson (1985)	Estimates of portfolio balance equations indicated that sterilised intervention had a statistically significant but quantitatively unimportant effect. When the purpose of intervention is to limit

	exchange rate overshooting, evidence provides little justification for such actions.
Boothe *et al*. (1985)	Examining the effectiveness of sterilised intervention by Bank of Canada, the study showed that movements in estimated risk premiums were not related to asset stocks. Thus, intervention could only be effective if it can influence expectations.
Rogoff (1984)	Estimated impact of relative asset supplies on exchange rates was found to be insignificant and of the wrong sign.
Loopesko (1984)	In at least one sub-sample period, sterilised intervention was found to be effective through the portfolio balance channel for 5 of the 6 exchange rates examined. However, when all sub-sample periods were examined, one-half of the cases did not support the existence of a portfolio balance channel. Evidence suggested that coordinated intervention may have a significantly greater impact on exchange rates than non-coordinated intervention.
Obstfeld (1983)	Simulation experiments suggested that the Bundesbank's ability to influence the DM/U.S.$ exchange rate using sterilised intervention was very limited.

* Sitikantha Pattanaik is Assistant Adviser and Satyananda Sahoo is Research Officer in the Department of Economic Analysis and Policy of the Bank. They are grateful to the anonymous referees for their useful suggestions. The views expressed in the paper are those of the authors and not of the institution to which they belong.