# Exchange Rate Dynamics: An Indian Perspective

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Based on monthly data from January 1996 to March 2002 on exchange rate, net purchase by the Reserve Bank of India, data on open market operations in the debt market and Nominal Effective Exchange Rate (NEER), the paper develops a Generalised Autoregressive Conditional Heteroskedastic (GARCH) model for USD/INR exchange rate. Major conclusions of the paper are the following: (i) central bank intervention reduces volatility in the market; (ii) open market operations in the debt market in the case of sterilised intervention reduces volatility in exchange rate and (iii) NEER plays a dominant role on return and volatility. Besides, results indicate that USD/INR exchange rate and NEER are cointegrated.

JEL classification: E58; F31

Key words: Central Bank Intervention; Cointegration; GARCH; Nominal Effective Exchange Rate; Open Market Operations.

## Introduction

Wide ranging literature is available on the effectiveness of central bank intervention in the foreign exchange market. Most of the central banks use sterilised intervention as part of their foreign exchange market operations. The dispute on the effectiveness of sterilised interventions is unresolved ever since the so-called Jurgensen report (Jurgensen, 1983). Even though empirical literature finds weak evidence in this regard, central banks continue to use this instrument as a major policy tool.

Another related issue on which there is no clear cut solution is the effect of intervention on volatility in foreign exchange market. Fatum and Hutchison (1999), Doroodian and Caporale (2001), among others, used GARCH framework to analyse the problem and found that interventions enhanced volatility in some of the markets. However, using an event study methodology commonly used in finance, Fatum (1999) concluded that sterilised intervention is indeed effective. Humpage (1996) studied DEM/USD rates using binary choice models on daily data and found that intervention is systematically associated with exchange rate movements. In a series of papers, Dominguez and Frankel emphasised the signaling effect of intervention that would work on expectation of institutional investors. Ito (2002) studied the effectiveness of central bank operations in the USD/ JPY market; he made interesting observation to the effect that intervention strategy adopted by Dr.Sakakibara, when he was Director General of International Finance Bureau, Bank of Japan, was distinctively different and highly successful.

In a related study, Bofinger and Wollmershaeuser (2001) found that many countries classified by International Monetary Fund (IMF) as "independent float" are actually "managed float"; the major difference between independent and managed float is the active intervention by the central bank. In other words, pure float or independent float remains a theoretical proposition with active intervention being done by central banks without such intervention being in the public domain.

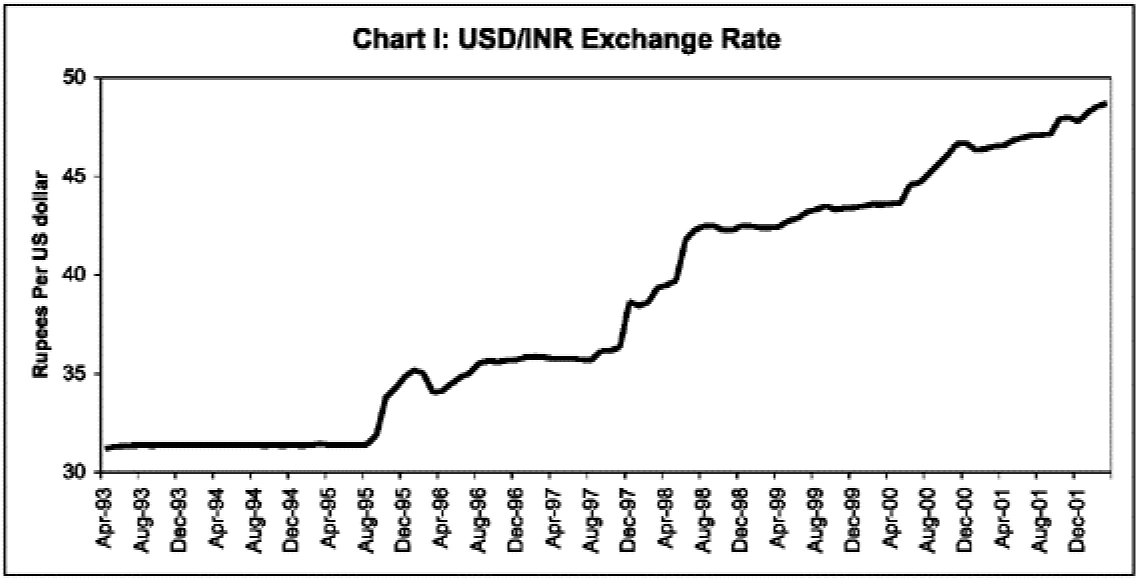
As Bofinger and Wollmershaeuser (2001) pointed out, literature on intervention is mainly on a few developed countries and thus it would be difficult to generalise these results to developing countries such as India. One of the major difficulties in studying the problem for other countries is lack of data on central bank intervention operations. Bhattacharya and Weller (1997) developed a theoretical model to study behavioural pattern of central banks and found supporting evidence in 'hiding one's hand' while concluding that secrecy about the scale of an intervention operation is always desirable. However, this hampers progress in further research in the field as the data requirements can be satisfied only in the case of some of the developed countries.

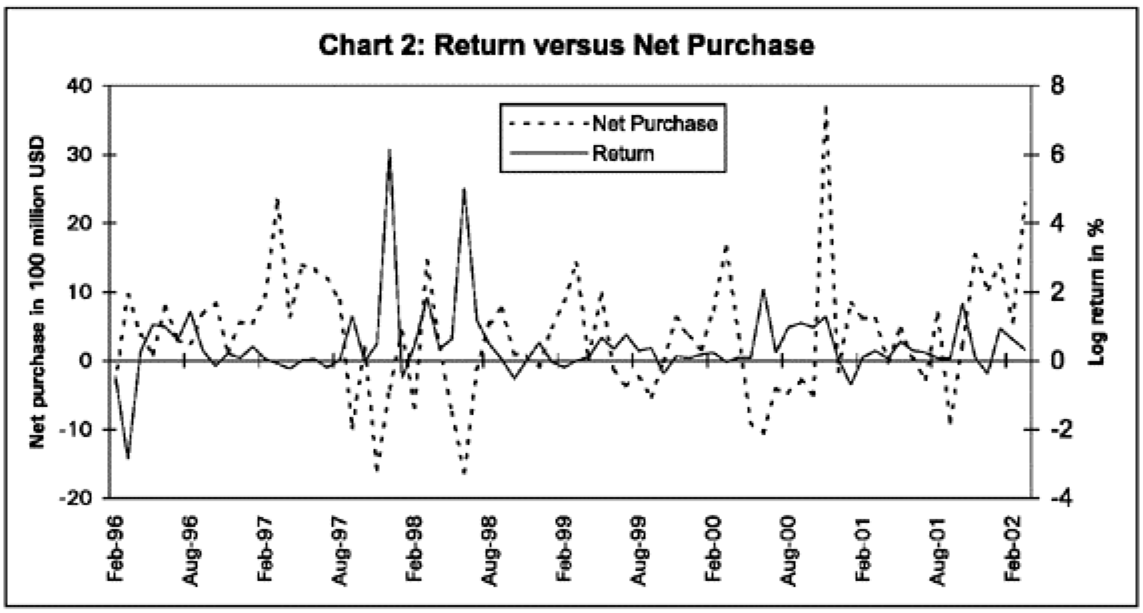
Against the above background, based on monthly data from January 1996 to March 2002 on exchange rate of the Indian rupee (INR), net purchase by the Reserve Bank of India, data on open market operations in the debt market and Nominal Effective Exchange Rate (NEER), this paper develops a Generalised Autoregressive Conditional Heteroskedastic (GARCH) model for USD/INR exchange rate. Analysis of data is undertaken in Section I, followed by the model results in Section II. The paper concludes with major observations.

## Section I
## Analysing the Data

In India, the Reserve Bank of India (RBI) has been regularly publishing its total market purchase and sale on a monthly basis; this is inclusive of forward and swap market operations on value date basis. The paper first reviews the monthly published data from January 1996 to March 2002 and then develops a GARCH model for log return on USD/INR rate. This of course is not enough to study the impact of RBI interventions in the market and the short-term effect essentially gets smoothed out while using the aggregate monthly data. Nevertheless, it enables us to give a panoramic view of its policies adopted in the USD/INR market at the macro level. In addition to intervention data, we also use Nominal Effective Exchange Rate (NEER) as independent variable in the model; details are given in Section II.

Plotting the movement of USD/INR exchange rate from April 1993 to March 2002, it is clear that ever since the Indian rupee became 'fully float', there were longer stable periods as coupled with occasional periods for greater exchange rate volatility (Chart 1). Being a developing market, the Reserve Bank of India necessarily has to intervene in the market to relieve the pressure either from excessive appreciation or from volatile depreciation of its currency. The major objectives of exchange rate management by the Reserve Bank of India inter alia include containing undue volatility in the foreign exchange markets and meeting temporary demand-supply mismatches due to lump sum demand or lag effect.




In order to study whether RBI adopts a 'leaning-against-the-wind' policy at least at the macro level or not, we plot log return in percentage (*i.e.*, __ln (INR(t))*100, where INR(t) is the price of one USD in Indian Rupee and _ is the difference operator) and the Reserve Bank of India intervention in USD million in Chart 2. This plot indicates an interesting pattern: most of the time, whenever return moves downward, net purchase moves upwards and vice versa and the correlation between the two is -0.28, which is statistically significant. This justifies the common perception that, at least at the macro policy making level, the central bank adopts a 'leaning-against-the-wind' policy. This can be explained further: whenever INR is depreciating the Reserve Bank of India provides USD to the market and whenever INR is appreciating the Reserve Bank of India absorbs USD from the market, resulting in negative relationship between the two variables. We may explain this negative relationship further from the stated policy objective of the Reserve Bank of India: "... the prime objective of the Reserve Bank is to manage volatility with no fixed target for the exchange rate which is determined by market forces" (RBI Annual Report, 2001-02, page 10). From the stated objective, we may infer that the Reserve Bank of India stand is against volatility and not necessarily against any particular trend in the market. This means that when INR is depreciating against USD, it will continue to depreciate but the objective is only to temper the rate at which it is depreciating. Similarly, when INR is appreciating the Reserve Bank of India may try to temper the speed of appreciation. In both the cases, the relationship between the two variables is negative. One hypothetical example in an INR appreciating scenario may help in understanding this better. Suppose that the rate opens at Rs.48.57 against USD and assume that it is the closing rate of the previous day also. The rate moves to Rs.48.50 per USD at some occasion during the day and at this time point the Reserve Bank of India purchases USD from the market and the rate moves to Rs.48.53 per USD, due to reduced supply of the US dollar in the market. Thus, if the time of intervention is known, the relationship between net purchase and return before and after intervention will be positive. However, suppose that the rate closes at Rs.48.53 per USD so that compared to the previous day close, return is negative and still net purchase is positive, yielding a negative relationship. In such a scenario, the Reserve Bank of India is not against a particular trend in the market but only against volatility and negative relationship is natural. A similar argument may be given in a depreciating scenario too. Thus, we may reach the following conclusions, depending on data availability:

i) If the time of intervention is known, the Central Bank intervention may be termed successful if the relationship between the return before intervention and after intervention and net purchase during the intervention period is positive. Based on this, Almekinders and Eijffinger (1994) have argued that within a GARCH model setup, coefficient of the intervention variable should be positive in the mean equation and negative in the variance equation.

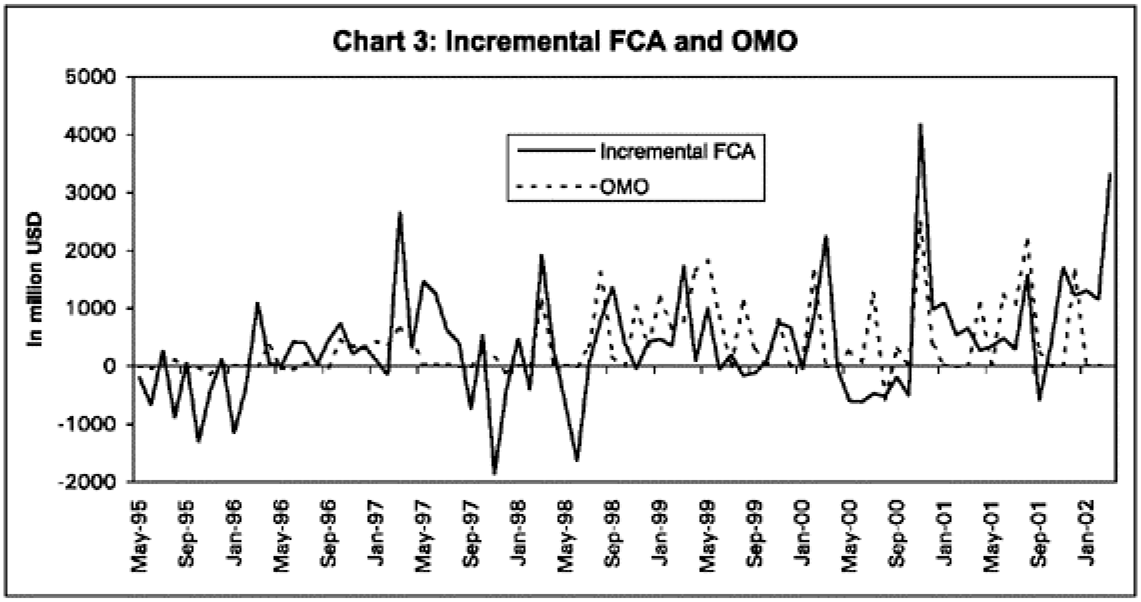
ii) However, when the time of intervention is largely unknown, but total intervention amount is known, then the relationship between the two is likely to be negative. This is especially true for currencies with uni-directional movements like INR and also when data are available only on monthly basis.

These issues are further explored in Section II.

Based on the curve for net purchase of USD from Chart 2, a few more observations on the nature of interventions could be made. During January 1996 – March 2002, maximum monthly net purchase occurred in November 2000 at USD 3.69 billion while the minimum net purchase occurred in June 1998 amounting to USD -1.63 billion. Average monthly net purchase during the period was USD 0.35 billion with a standard deviation of 0.87. While net monthly purchase of more than USD 0.9 billion occurred 20 per cent of the times during the period, that below USD -0.9 billion occurred only during 5.33 per cent.

Another important aspect of the Reserve Bank's market operation is with regard to the sterilisation operation and its effect on exchange rate. The Reserve Bank has been publishing data on open market operations (OMOs) in the money market on a monthly basis. In order to control impact of foreign exchange interventions on money markets, it may be possible that the liquidity added or depleted is absorbed back or pumped into the market by the Reserve Bank.

One way of getting a picture on the combined operation is to look at incremental Foreign Currency Assets (FCA) during a month and the corresponding OMO figures. Chart 3 plots these two variables. It is interesting to note the co-movements of these variables. During the whole period, the correlation between them is 0.37 and, during January 1998 to May 2001, the correlation is 0.46, indicating that during the periods of high increase in FCA, OMO was also high. Even though it is not possible to separate out the effects of OMO due to 'liquidity operations' and 'sterilisation operations', there seems to be an overall relationship between the increase in FCA and the OMO.




The monthly data published by the Reserve Bank on its foreign exchange market interventions have some limitations. The published data are purchase, sale during the month and outstanding net forward sales and purchases at the end of the month. The purchase and sale are inclusive of swaps and forwards, which do not influence the spot market directly but influence it through expectations. Strictly speaking, only spot, forward and swap interventions with cash flows within the month are to be considered for the analysis. However, given the published data, it is neither possible to obtain spot intervention data nor possible to make crude adjustments. For instance, forwards maturing in a specific month may be high but the overall net position may be much lower. Thus, analysis given here is subject to these limitations.

## Section II
## Model Specifications and Results

The objective of the present section is to explore the relationship among major variables in the context of exchange rate management using a GARCH model, especially with respect to the effectiveness of intervention activities of central banks. GARCH models have been used in such situations by Almekinders and Eijffinger (1994), Fatum and Hutchison (1999), Doroodian and Caporale (2001), Ito (2002), among others. Independent variables considered here are Nominal Effective Exchange Rate (NEER), Real Effective Exchange Rate (REER), Net Purchases (NetP) and Open Market Operations (OMOs) by the central bank. Dependent variable in the GARCH set up is log return on exchange rate of Indian Rupee (INR); to be precise, let INR(t) denote price of one US Dollar in INR, then log return is defined as _ln(INR(t)). Both ln(INR) and ln(NEER) have unit roots, as reported in Table 1 below based on weighted symmetric (WS) and Dicky-Fuller (DF) unit root tests. Thus modeling based on differenced log series for these two variables are justified.

**Table 1: Unit root tests for NEER and USD/ INR exchange rate**

| **Test** | **ln(NEER)** | | **ln(USD)** | |
|---|---|---|---|---|
| | **Test Statistic** | **P-Value** | **Test Statistic** | **P-Value** |
| WS Test | -1.8194 | 0.7599 | -1.8432 | 0.7467 |
| DF Test | -1.5821 | 0.7994 | -2.6338 | 0.2646 |

Relationship among the variables can be broadly specified in the following regression model:

$$\Delta \ln(INR(t)) = f(\Delta \ln(NEER(t), \ln(REER(t)), OMO(t), h(t)) + \varepsilon(t)$$

where $\varepsilon(t)$ is distributed as Normal(0, h(t)) and h(t) is the volatility parameter; h(t) is modeled in a GARCH framework as

$$h(t) = g(\text{lags of } \varepsilon(t)^2, \Delta \ln(NEER(t)), \ln(REER(t)), OMO(t)).$$

Preliminary model with all variables included both in mean and in variance equations is given by

$$\ln(INR(t)) = \underset{(-1.68)}{-0.35} + \underset{(1.38)}{0.01}\, NetP(t) - \underset{(-0.27)}{0.00}\, OMO(t) \underset{(-2.27)}{-0.50}\, \Delta \ln(NEER(t))$$

$$+\underset{(1.12)}{0.23} \ln(REER(t)) + \underset{(-2.22)}{0.80}\, h(t)^{0.5} + \varepsilon(t)$$

$$h(t) = 0.25 + 0.99\,\varepsilon(t-1)^2 - 0.02\,NetP(t) - 0.03\,OMO(t) - 0.24\,\Delta\ln(NEER(t))$$
$$(3.08)\quad(17.26)\quad(-2.32)\quad(-3.04)\quad(1.69)$$
$$-\,0.23\,\ln(REER(t))$$
$$(-1.85)$$

$R^2$=0.39; D.W. =2.14.

Clearly, the model requires modification by dropping insignificant variables from both the equations. After deleting least significant variable one at a time, we arrived at the following model:

$$\ln(INR(t)) = -0.29 + 0.01\,NetP(t) - 0.27\,\Delta\ln(NEER(t)) + 0.79\,h(t)^{0.5} + \varepsilon(t)$$
$$(-1.39)\quad(1.19)\quad(-7.42)\quad(2.16)$$

$$h(t) = 0.24 + 1.00\,\varepsilon(t-1)^2 - 0.02\,NetP(t) - 0.03\,OMO(t) - 0.24\,\Delta\ln(NEER(t))$$
$$(3.20)\quad(26.36)\quad(-2.25)\quad(-3.67)\quad(1.79)$$
$$-\,0.24\,\ln(REER(t))$$
$$(-2.04)$$

$R^2$=0.38; D.W. =2.01.

Major observations from this equation are the following:

1. NetP is not significant in the mean equation, even though it has correct sign in the sense of Almekinders and Eijffinger (1994).
2. NEER has significant impact on the mean equation.
3. All major variables that we are considering have significant impact on the volatility of returns. Particularly, NetP, REER and OMOs have significant impact on volatility equation.

If we drop the insignificant NetP from the mean equation, even REER in the volatility equation becomes insignificant and the modified model is as follows:

$$\ln(INR(t)) = -0.07 - 0.24\,\Delta\ln(NEER(t)) + 0.56\,h(t)^{0.5} + \varepsilon(t)$$
$$(-3.07)\quad(-3.50)\quad(2.67)$$

$$h(t) = 0.27 + 0.74\,\varepsilon(t-1)^2 - 0.02\,NetP(t) - 0.01\,OMO(t)$$
$$(7.09)\quad(16.58)\quad(-6.76)\quad(-1.79)$$

$R^2$=0.36; D.W. =2.02.

Based on this final model, we may observe the following:

1. REER does not appear at all.
2. Both NetP and OMOs have significant influence on the behaviour of volatility in the market.
3. Also NEER plays a significant role in mean equation, indicating its influence on expectations.

The negative coefficients of NetP and OMO have important policy implications. The pronounced policy of the central bank in exchange rate management is that its main objective is volatility containment and orderly market conditions. The final equation captures this effectively: Net purchases by the central bank reduce volatility in the market, which is in alignment with the pronounced policy. Besides, even the sterilisation operations assist in containment of volatility. Thus it may be said that the central bank is successful in its policy objective.

Since the final model indicates that NEER and not REER plays major role in exchange rate dynamics of Indian Rupee, it is desirable to see whether the relationship between NEER and exchange rate is true in long term perspective too. In order to study long term relationship between exchange rate and NEER we tested for cointegration of these variables after log transformation. Engle-Granger cointegration test statistic value was -3.41 with P-value 0.12, indicating that these two variables are cointegrated. Thus, these variables move in tandem in the long run, which further reinforces the general perception on the role of NEER in the exchange rate.

## Section III
## Concluding Remarks

The paper explores effectiveness of the central bank intervention on USD/INR exchange rate. It was found that the central bank adopts a policy of 'leaning-against-the-wind' at macro level, as reflected in negative correlation between exchange rate return and net dollar purchases by the central bank; it is further reinforced through the GARCH models. However, it cannot be interpreted as a policy against appreciation or depreciation of the domestic currency; instead, it reflects a stand against volatility in the market. In fact, the GARCH model effectively captures the central bank policy of volatility containment, indicating that RBI is successful in achieving the objectives of intervention policies. It was also found that log-differenced NEER has significant effect on return; besides, movement of NEER is indicative of the direction of USD/INR exchange rate in the sense of long term relationship captured through cointegration.

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