Central bank intervention and exchange rate behaviour : empirical evidence for India

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Keywords: Causality-in-variance, central bank, exchange rate, India, intervention
JEL classification: F31, E58

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Central Bank Intervention and Exchange Rate Behaviour:

Empirical Evidence for India

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Abstract

This paper examines the causal relationship between central bank intervention and exchange rate returns in India. Using monthly data from December 1997 to December 2011, the empirical results derived from the CCF approach of Cheung and Ng (1996) suggest that there is causality-in-variance from exchange rate returns to central bank intervention, but not *vice versa*. These findings are robust in the sense that they hold in cases where the returns were measured from either the spot rate or the forward rate. Therefore, the results of this paper suggest that the Indian central bank has intervened in the foreign exchange market to respond to exchange rate volatility, although the volatility has not been influenced by central bank intervention in the form of net purchases of foreign currency in the market.

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1. Introduction

The main objective of this paper is to empirically analyze the causal relationship between central bank intervention and exchange rate returns in India. India has experienced a transformation of its exchange rate regime during the past several decades. From 1947 to 1991, the fixed exchange regime was adopted, and under this, the Indian rupee was initially pegged to gold, and then to the British pound sterling in December 1971 and to a basket of currencies in September 1975. Subsequently, against the background of the balance of payment crisis in June 1991, India implemented economic and financial liberalization, as a part of which it decided to shift to the market-determined exchange regime in March 1993. As the nominal exchange rate was set at a predetermined level against the dollar for a while thereafter, however, it has only been since 1995 that the rupee has begun to exhibit relatively volatile two-way movements.

Under the managed float regime, the Reserve Bank of India (RBI), which is the Indian central bank, announced that the exchange rate is largely determined by the demand and supply conditions in the market (Jalan 1999, 1126). The bank has also stated that the exchange rate policy is guided by the need to reduce excess volatility but not to affect the level, prevent the emergence of destabilizing speculative activities, help maintain an adequate level of reserves, and develop an orderly foreign exchange market (*ibid*., 1126), and these have basically remained unchanged since the late 1990s. For these purposes, the RBI has undertaken sale and purchase operations in the foreign exchange market and has sterilized these operations, as do the central banks in many other countries. This activity is epitomized by the introduction of the Market Stabilization Scheme by the government in April 2004, under which the RBI was empowered to issue government Treasury bills and dated securities exclusively for sterilization purposes so as to manage liquidity appropriately.

As sterilized intervention leaves the monetary base unchanged, there is as yet no consensus on whether and to what extent this type of intervention affects the exchange rate, although some literature states that even when sterilized, central bank intervention is assumed to influence the exchange rate movement through various channels such as the portfolio balance channel, the signaling channel, and the noise-trading channel (e.g. Dominguez and Frankel 1993, Hung 1997, Mussa 1981). In this context, there have been several empirical studies conducted on India which generally suggest that the RBI's intervention has served as a useful instrument in reducing the extent of exchange rate volatility.

We have taken a slightly different approach to analyzing central bank intervention and the exchange rate; this paper aims to examine volatility spillover between the exchange rate and central bank intervention in India. More specifically, applying the causality-in-variance test based on the cross correlation function (CCF) approach by Cheung and Ng (1996) and using monthly data from December 1997 to December 2011, we examine whether there is a causal relationship from exchange rate returns to central bank net purchases of foreign currency on the one hand and from net purchases to exchange rate returns on the other hand.

This paper is organized as follows. In the next section, we review the recent movement of both the exchange rate and net purchases and survey the relevant literature. The third section gives a brief explanation of the CCF approach, while the fourth section provides the definitions, the sources and the properties of the data. The fifth section presents the empirical results, and the final section summarizes the main findings of this study.

2. Literature Review

Figure 1 shows the movements in net purchases of US dollars by the RBI as well as the nominal exchange rate of the Indian rupee to US dollar. From this figure, it seems that the Indian central bank has been active in purchases and sales of foreign currency since around 2002. From 2003 to 2008, the RBI tended to purchase the dollar from the market during the appreciation period, which was primarily caused by the surge in capital inflow. This trend suddenly reverted in the latter half of 2008. Significant selling pressure on the rupee was triggered following the so-called “Lehman shock”, against which the RBI increased net sales of dollars so as to reduce undue volatility. Subsequently, after no intervention from January 2010 to August 2011, the central bank was again faced with a continuous fall in rupee value, attributed to the euro-zone debt issue as well as the deteriorating macroeconomic fundamentals of India. Since the end of 2011, when the rupee fell to its lowest level on record against the dollar, the RBI has resumed large-scale intervention operations in the foreign exchange market.

So far, the empirical literature concerned with central bank intervention and the exchange rate has been generally in the context of advanced countries such as the US and Europe. In the Indian context, there are still limited studies on this topic, although a growing body of literature has begun to examine the empirical relationship, mostly by investigating the effect of intervention on exchange rate.[1]

For example, Unnikrishnan and Ravi Mohan (2001) estimate the general autoregressive conditional heteroscedasiticy (GARCH) model to explore the effectiveness of the RBI's intervention activities. In their model, the rupee/dollar exchange rate returns are explained by net purchases and open market operations by the central bank as well as by real and nominal effective exchange rates. Using monthly data from January 1996 to March 2002, they find that central bank intervention reduces exchange rate volatility, indicating that the RBI is successful in achieving the objectives of its intervention policies. Recognizing the potential simultaneity problem, Pattanaik and Sahoo (2001) estimate the simultaneous equation systems in which the dependent variable is either exchange rate volatility or net interventions. Their result indicates that exchange rate volatility often causes intervention actions, but that intervention may not always be effective in reducing volatility. Based on other results from different specifications, however, they conclude that the intervention operations of the RBI have been effective in containing exchange rate volatility, though the degree of influence does not appear to be very strong. Also, Harendra, Narasimhan and Murty (2008) empirically investigate the effects of central bank intervention on the exchange rate level and volatility using monthly data from April 1995 to December 2006. From the empirical result of the GARCH (1,1) model, they find that the RBI intervention is effective in reducing volatility in the foreign exchange market instead of reversing the trend movement of the exchange rate. This finding is consistent with those in the above-mentioned literature. Finally, Goyal and Arora (2012) analyze the impact on the exchange rate mean and volatility of conventional monetary policy measures including interest rates, intervention and other quantitative measures, and of central bank communication, using dummy and control variables in an EGARCH framework. From the results obtained with daily and monthly data, they state that market intervention and communication not only affect exchange rate volatility but also the exchange rate mean despite a policy statement that there is no target level for the exchange rate.

Unlike the reviewed literature, we discard the assumption that intervention may influence the exchange rate, and we examine the relationship between these two variables.

[1] Edison et al. (2007) and Afzal (2010) have also analyzed the link between intervention and the exchange rate in several Asian countries including India. They use foreign exchange reserves as the proxy variable of central bank intervention.

Specifically, we test the causality-in-variance between net purchases of dollars by the RBI and the returns of the exchange rate of the rupee against the dollar, applying the causality-in-variance test based on the CCF approach.

3. The CCF approach

The CCF approach was developed by Cheung and Ng (1996) to examine the causality-in-variance between variables. This approach is based on the residual cross correlation function and is composed of a two-stage procedure (Cheung and Ng 1996, 34). The first stage involves the estimation of univariate time series models that allows for time variation in conditional variances. In the second stage, the resulting series of residuals and squared residuals standardized by conditional variance are constructed, respectively. The CCF of the squared standardized residuals is used to test the null hypothesis of no causality in variance. This approach is summarized as follows:[2]

Suppose that there are two stationary time-series, X_t and Y_t, and that three information sets are defined by $I_{1t} = \{X_{t-j}; j \geq 0\}$, $I_{2t} = \{Y_{t-j}; j \geq 0\}$, and $I_t = \{X_{t-j}, Y_{t-j}; j \geq 0\}$. Y_t is said to cause X_t in variance if

$$E\{(X_t - \mu_{x,t})^2 \mid I_{1t-1}\} \neq E\{(X_t - \mu_{x,t})^2 \mid I_{t-1}\} \tag{1}$$

where $\mu_{x,t}$ is the mean of X_t conditioned on I_{1t-1}. Similarly, X_t causes Y_t in variance if

$$E\{(Y_t - \mu_{y,t})^2 \mid I_{2t-1}\} \neq E\{(Y_t - \mu_{y,t})^2 \mid I_{t-1}\} \tag{2}$$

where $\mu_{y,t}$ is the mean of Y_t conditioned on I_{2t-1}. We encounter feedback in variance if X_t causes Y_t in variance, and *vice versa*.

The concept defined in Equations (1) and (2) is too general to test empirically. Hence we need an additional structure to represent the general causality concept applicable in practice. Suppose X_t and Y_t can be written as

$$X_t = \mu_{x,t} + h_{x,t}^{0.5}\,\varepsilon_t \tag{3}$$

$$Y_t = \mu_{y,t} + h_{y,t}^{0.5}\,\xi_t \tag{4}$$

where $\{\varepsilon_t\}$ and $\{\xi_t\}$ are two independent white noise processes with zero mean and unit variance, and $h_{x,t}$ and $h_{y,t}$ are the conditional variances of X_t and Y_t, respectively. For the causality-in-variance test, let U_t and V_t be squares of the standardized innovations, given by

[2] Here, we refer to Cheung and Ng (1996), Hong (2001), and Hamori (2003).

$$U_t = (X_t - \mu_{x,t})^2 h_{x,t}^{-1} = \varepsilon_t^2 \tag{5}$$

$$V_t = (Y_t - \mu_{y,t})^2 h_{y,t}^{-1} = \xi_t^2 \tag{6}$$

As both U_t and V_t are unobservable, we must use their estimates, $\hat{U}_t$ and $\hat{V}_t$ to test the hypothesis of no causality-in-variance.

Next, we compute the sample cross correlation coefficient at lag i, $\hat{r}_{UV}(i)$, from the consistent estimates of the conditional mean and variance of X_t and Y_t. This gives us

$$\hat{r}_{UV}(i) = C_{UV}(i)(C_{UU}(0)C_{VV}(0))^{-0.5} \tag{7}$$

where $C_{UV}(i)$ is the i-th lag sample cross covariance given by

$$C_{UV}(i) = T^{-1}\sum(\hat{U}_t - \bar{\hat{U}})(\hat{V}_{t-i} - \bar{\hat{V}}), \qquad i = 0,\ \pm 1,\ \pm 2,\ \ldots \tag{8}$$

and similarly where $C_{UU}(0)$ and $C_{VV}(0)$ are defined as the sample variance of U_t and V_t, respectively.

Causality-in-variance of X_t and Y_t can be tested by examining the squared standardized residual CCF, $\hat{r}_{UV}(i)$. Under the condition of regularity, it holds that

$$\begin{pmatrix} \sqrt{T}\hat{r}_{UV}(i) \\ \sqrt{T}\hat{r}_{UV}(i') \end{pmatrix} \xrightarrow{L} AN\left(\begin{bmatrix} 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\right), \qquad i \neq i' \tag{9}$$

where T is the number of observations. This test statistic can be used to test the null hypothesis of no causality-in-variance. To test for a causal relationship at a specified lag i, we compare $\sqrt{T}\hat{r}_{UV}(i)$ with the standard normal distribution. If the test statistic is larger than the critical value of normal distribution, we reject the null hypothesis.

4. Definitions, Sources and Properties of Data

For empirical analysis, we use monthly data on the exchange rate and net purchases. Net purchases is defined as the difference between purchases and sales of the dollar by the RBI. This includes spot, swap and forward transactions in the foreign exchange market, representing millions of dollars. The data was obtained from various issues of the Monthly Bulletin published by the RBI. The exchange rate is the nominal exchange rate of the Indian rupee against the US dollar. Since the RBI undertakes intervention in spot and forward segments, we consider both the spot rate and forward rate and use logarithmic values for each rate. The forward rate was calculated from the monthly average spot exchange rate and the one-month forward premium.[3] The spot rate was obtained from IMF (2012), and the forward premium is from RBI (2011) and the RBI web page.

India officially announced a shift to a market-determined exchange system in March 1993. As is clear from Figure 1, however, the rupee to dollar rate was initially fixed at a pre-determined level for a while and has begun to exhibit fluctuation since the middle of the 1990s. In addition, as the governor of the RBI, B. Jalan explicitly stated that the central bank does not have a fixed target or band around the exchange rate and that it is prepared to intervene in the market to dampen excessive volatility when necessary. He was appointed governor at the end of November 1997, and since then under successive governors up to the present, the RBI's stance on exchange rate policy has basically remained unchanged. Accordingly, the empirical research in this paper was performed using monthly data from December 1997 to December 2011.

To check the properties of the data, an augmented Dickey-Fuller (ADF) test was carried out for each variable. As can be seen in Table 1, the results indicate that net purchases does not have a unit root at the conventional level, whereas the exchange rate in either the spot or the forward market has a unit root at the conventional level and does not have a unit root in the first difference.[4, 5] Therefore, net purchases was found to be stationary, and the exchange rate was integrated at the order of one.

5. Causality Test Results

The first step in the CCF approach is to estimate the univariate time series model for each variable that allows for time variation in both conditional mean and conditional variance. Unlike Cheung and Ng in which a GARCH model was adopted, an AR-EGARCH model was applied here to obtain conditional mean and conditional variance for the variable concerned, y_t.[6] Models (10) and (11) are AR (m) and EGARCH (p, q), respectively.

$$y_t = \pi_0 + \sum_{i=1}^{m} \pi_i y_{t-i} + \varepsilon_t, \quad \varepsilon_t | I_{t-1} \sim N\left(0, \delta_t^2\right) \tag{10}$$

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[3] The forward exchange rate is calculated as follows:
FRt = SRt + (SRt * FP/1200)
where FRt is the forward exchange rate at time period t, SRt is the spot exchange rate at time period t, and FP is the forward premium (discount if negative) for one month.

[4] A Phillips-Perron test was also conducted as an alternative unit root test which confirmed that the results are not changed by an ADF test (results not shown).

[5] Even if we do not take the logarithm of the exchange rate, it does not affect the results of the unit root test.

[6] Hamori (2003) summarized the advantages of the EGARCH model over the standard GARCH model.

$$\log \delta_t^2 = \varphi + \sum_{i=1}^{p} \left(\alpha_i |z_{t-i}| + \gamma_i z_{t-i} \right) + \sum_{i=1}^{q} \beta_i \log \delta_{t-i}^2 \tag{11}$$

where π_0 and φ are the constant, ε_t is the error term, δ_t^2 is the conditional variance of ε_t, and z_t is i.i.d. with zero mean and unit variance. Both z_t and δ_t are statistically independent, and $z_t = \varepsilon_t / \delta_t$.

Since y_t is assumed to be stationary, empirical analysis uses net purchases and the exchange rate returns. The exchange rate returns are computed as the first difference of the log exchange rate. Table 2 indicates the estimation results of the AR-EGARCH model for each variable. They are the maximum likelihood estimates and their standard errors. Based on the SIC and residual diagnostics, we determined the appropriate lag order from the maximum lag of 12 for k and 2 for p and q. Table 2 shows that AR (1)-EGARCH (2,2), AR (1)-EGARCH (1,2), and AR (3)-EGARCH (2,1) are selected for the spot exchange returns, the forward exchange returns, and net purchases, respectively. From this table, it can be seen that the coefficients of the ARCH term (α), the GARCH term (β), and the asymmetric effect (γ) are statistically significant in all cases except for the coefficients of α_2 and β_2 for the spot returns.[7]

In the second step of the CCF approach, the squares of standardized residuals were obtained from the estimates of the conditional means and variances in the first step, and the causality-in-variance is tested based on the sample cross correlation coefficients. Table 3 shows the test statistic ($\hat{r}_{\varepsilon\xi}(i)$) to test the null hypothesis of no causality-in-variance between the spot returns or the forward returns and net purchases. 'Lag' in the table refers to the number of periods the exchange returns lag behind net purchases of dollars by the central bank, while 'Lead' refers to the number of periods the exchange returns lead net purchases. The significant test statistics at a specific number of Lag (i) implied that the exchange returns influence net purchases at that point. Similarly, the significant test statistics at a specific number of Lead (i) implies that net purchases influences the exchange returns at that point.

From Table 3, it is found that the exchange returns influenced net purchases at lags 3, 5 and 6, whereas net purchases did not influence the exchange returns. This result holds in cases where the exchange returns were measured as either the spot rate returns or the forward rate

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7 Table 2 also shows the Ljung-Box test statistics ($Q(12)$ and $Q^2(12)$). From this, it was found that the null hypothesis of no autocorrelation up to order 12 is accepted both for standardized residuals and their squares in all cases. Therefore, the diagnostic results statistically support the specification of the selected AR-EGARCH models.

returns. Therefore, our empirical results show that there was unidirectional causality-in-variance from the exchange returns to net purchases in India.

6. Some Concluding Remarks

This paper examines the causal relationship between central bank intervention and exchange rate returns in India. Using monthly data from December 1997 to December 2011, the empirical results derived from the CCF approach of Cheung and Ng (1996) suggest that there is causality-in-variance from exchange rate returns to central bank intervention, but not *vice versa*. These findings are robust in the sense that they hold in cases where the returns were measured from either the spot rate or the forward rate. The results have the following implications.

First, the existence of causality from exchange rate returns to intervention suggests that the Indian central bank has intervened in the foreign exchange market. The RBI announced that it is prepared to intervene in the market to dampen excessive volatility when necessary. Therefore, indeed, the result indicates that the actual intervention operation corresponds to the stated exchange rate policy.

Second, the absence of causality from intervention to exchange rate returns implies that exchange volatility has not been influenced by central bank intervention. Given that the effects of intervention are likely to be short lived in nature, they may be undetectable with low-frequency data, such as the monthly observation in this study. On the other hand, considering the volume of intervention relative to the growing turnover in the market, the effects of intervention may have been too small to be found in India, at least in the form of direct intervention.

Apart from direct intervention, the RBI has attempted to influence the exchange rate volatility through a variety of routes which include non-monetary administrative measures as well as indirect intervention through a few selected public sector banks. Therefore, the second implication does not necessarily negate all the effects of intervention operations.

Finally, most of the previous studies generally assume a causal relationship from intervention to exchange rate movements and conclude that the Indian central bank intervention has served as a useful instrument in reducing the extent of exchange rate volatility. Considering the results in this paper, however, it is plausible to give thought to either reverse causality or the simultaneity problem when examining the effect of intervention on the exchange rate.

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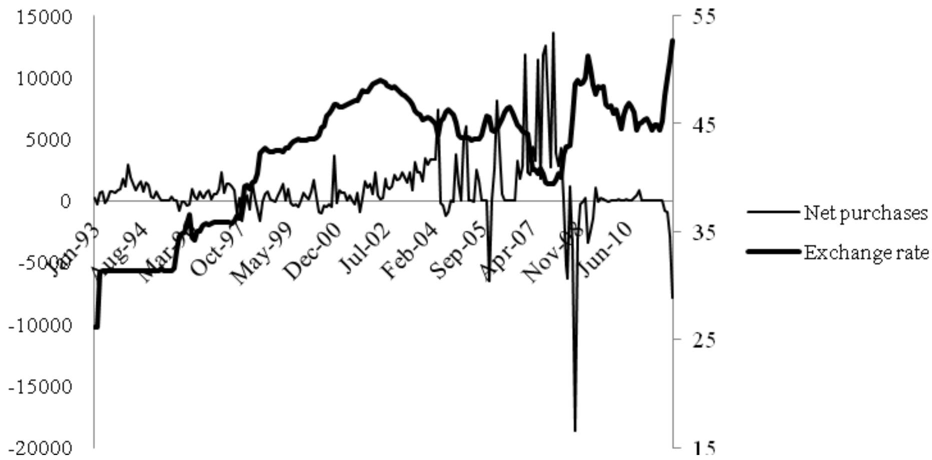
Figure 1 Net Purchases (million US dollars, left axis) and Spot Exchange Rate (rupees per US dollar, right axis)



Source: Compiled by the author from the RBI Monthly Bulletin (various issues) and IMF (2012).

Table 1 Results of Unit Root Test

		Spot rate	Forward rate	Net purchases
Level	None	1.085	1.072	-3.614***
	Constant	-2.550	-2.530	-3.776***
	Constant and Trend	-2.625	-2.610	-3.753**
First Difference	None	-8.506***	-8.513***	—
	Constant	-8.587***	-8.591***	—
	Constant and Trend	-8.547***	-8.550***	—

Note: Significance at the 1% and 5% levels is indicated by *** and **, respectively.

Table 2 Results of AR-EGARCH Models

Variable	Spot returns		Forward returns		Net purchases	
Model	AR(1)-EGARCH(2,2)		AR(1)-EGARCH(1,2)		AR(3)-EGARCH(2,1)	
	Estimates	SE	Estimates	SE	Estimates	SE
AR						
π_0	0.001***	0.000	0.000	0.000	81.758	65.839
π_1	0.404***	0.047	0.500***	0.079	0.483***	0.069
π_2					-0.611*	0.032
π_3					0.011	0.025
EGARCH						
φ	-1.431***	0.522	-1.627***	0.546	0.873***	0.146
α_1	0.857	0.161	0.593***	0.091	0.946***	0.148
γ_1	-0.062	0.138	-0.208**	0.100	-1.197***	0.206
α_2	-0.145	0.094			-0.381**	0.161
γ_2	0.050	0.065			0.778***	0.187
β_1	0.092**	0.035	0.067**	0.028	0.947***	0.010
β_2	0.820***	0.037	0.795***	0.051		
Log Likelihood	524.167		505.792		-1478.702	
Q(12) (P-value)	13.216 (0.354)		16.040 (0.189)		15.246 (0.228)	
Q^2(12) (P-value)	15.768 (0.202)		8.704 (0.728)		4.380 (0.976)	

Note 1: Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Note 2: Both Q(12) and Q^2(12) are a Ljung-Box test statistic for the null hypothesis of no autocorrelation up to order of 12 for standardized residuals and their squares, respectively. The number in parenthesis is the P-value. If this value is less than 0.01, 0.05 and/or 0.10, the null hypothesis is rejected at the 1 %, 5%, and 10% levels, respectively.

Note 3: The standard errors are Bollerslev-Wooldrige robust standard errors, which are robust to departures from normality.

Table 3 Causality in Variance between Exchange Rate Returns and Central Bank Intervention

Lag or Lead	Lag	Lead	Lag	Lead
i	Net purchases and Spot returns (-*i*)	Net purchases and Spot returns (+*i*)	Net purchases and Forward returns (-*i*)	Net purchases and Forward returns (+*i*)
0	0.0702	0.0702	0.0705	0.0705
1	0.0136	0.0142	0.0290	0.0392
2	0.0910	0.0904	0.0940	0.1259
3	0.2613***	-0.0116	0.2752***	-0.0240
4	-0.0298	-0.0645	-0.0274	-0.0276
5	0.1774**	-0.0414	0.1874***	-0.0133
6	0.1917***	-0.0661	0.1455*	-0.0478
7	-0.1027	0.0223	-0.0731	0.0083
8	-0.0667	0.0453	-0.0769	0.0292
9	0.0574	0.0074	0.0890	-0.0174
10	-0.0078	-0.0139	0.0176	0.0051
11	-0.0585	-0.0672	-0.0808	-0.0622
12	-0.0663	0.0147	-0.0388	-0.0066

Note: Significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.