The Interrelationship Between the Stock Markets and the Foreign Exchange Market

by

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THE INTERRELATIONSHIP BETWEEN STOCK MARKETS AND THE FOREIGN EXCHANGE MARKET

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Abstract

This paper investigates the relationship between the volatility of the stock market and that of the nominal exchange rate in India. Using the E-Garch specification proposed by Nelson (1991) it addresses the question whether changes in the volatility of the stock market affects volatility in the foreign exchange market and vice versa. The model specification incorporates asymmetric effects of positive and negative returns surprises on volatility both in the same market as well as spillovers across the two markets. Empirical analysis with one of the major stock market indices supports the hypothesis of such volatility linkages while for the other index there appears to be a spillover from the foreign exchange market to the stock market but not the other way round.

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I INTRODUCTION

The connection between a country's stock market and its foreign exchange market has been a subject of theoretical and empirical investigation for over two decades. The nature and magnitude of the interdependence between stock prices and exchange rates have implications for a number of crucial issues in international finance. First there is the question of whether stock markets price exchange rate risk[1]. The traditional CAPM tells us that exchange rate risk being a firm specific and hence non-systematic risk, should be diversifiable and hence would not be priced by the market. This in turn has implications for a firm's currency exposure management decisions[2]. Second, the presence of exchange risk and its relationship with stock market risk has implications for models of international asset pricing. The extension of the traditional CAPM to a multi-country context under the assumption of integrated capital markets must account for exchange rate risk and its covariance with the world market portfolio[3]. Third, the risk-reward tradeoff of international diversification and therefore management of multi-currency equity portfolios must come to grips with the question of how exchange rate risk and stock price risk interact. With significant rise in cross-border equity investments[3] and in particular investments in emerging markets, this has become a critical issue for fund managers. Finally, the asset market approach to exchange rate determination [Branson (1983), Frankel (1983) among others] regards the equilibrium exchange rate of a currency as the result of the interaction of the demand for and supply of financial assets such as stocks and bonds denominated in that currency. With open capital accounts, the demand for these assets would obviously depend upon, among other things, their risk-return tradeoffs from the point of view of domestic and foreign investors.

A number of researchers have addressed the question of the relation between the levels of stock market returns and exchange rate changes. Studies have been undertaken both for broad market indices, industry indices and individual stocks. Representative examples are Bodnar and Gentry(1993), Bartov and Bodnar (1994), Choi and Rajan (1997), Jorion (1990,1991), Ma and Rao (1990), Apte (1997). By and large, these investigations have failed to discover significant relationship between stock returns and exchange rate changes either at aggregate level such as a market or industry indices or at the level of individual firms. There have also been studies of dynamic linkages between stock returns and exchange rate changes using the cointegration framework. [Ajayi and Mougoue (1996)]. All these studies focus on the first moments i.e. relationship between mean stock returns and exchange rate returns.

The behaviour of volatility of stock returns has been extensively studied using the ARCH-GARCH framework pioneered by Engle (1982) and further developed by Bollerslev (1986), Nelson (1991) and others. As far back as 1976, Black (1976) pointed out that volatility of stock returns changes over time and responds asymmetrically to good and bad news. Representative references are Bollerslev (1987), French, Schwert and Stambaugh (1987), Schwert (1989), Akgiray (1989), and Engle and Ng (1993). A number of researchers have also investigated transmission or spillovers of volatility between different stock markets. [Karolyi (1995), Koutmos and Booth (1995)]. Similarly, there have been investigations of time varying volatility of exchange rates [Jorion (1995)]. A good survey of applications of ARCH-GARCH models in finance can be found in Bollerslev, Chou and Kroner (1992). A good exposition of the basic ARCH-GARCH models and their different variants can be found in Campbell, Lo and McKinley (1997). In a recent paper Kanas (2000) has investigated volatility spillovers between stock returns and exchange rate changes. This is an important question. The variance of returns on a multi-currency portfolio depends on the variances of individual stock market returns, variances of the exchange rates and their pair-wise covariances[4]. If in addition, the stock market and exchange rate variances are interconnected, this would certainly affect the nonsystematic i.e. non-diversifiable risk of multi-currency equity portfolios and hence valuation of stocks by foreign investors which in turn has implications for extending the CAPM to a multi-country context.

The purpose of this paper is to investigate the interrelationship between the volatilities of the Indian stock market and the rupee-dollar exchange rate. It also addresses the question of whether this spillover effect is asymmetric i.e. whether "good" and "bad" news from the stock market has differential impact on the exchange rate and vice-versa. In keeping with the current literature it of course includes ARCH-GARCH effects within each market. In the next section, section II, we describe the data used for the empirical analysis. Section III reports the results of a cointegration analysis of stock prices and exchange rates[5]. In section IV the model which incorporates volatility spillovers between stock and foreign exchange markets is specified. Section V presents the results of estimation of this model and section VI contains concluding remarks.

II THE DATA

The study uses daily closing data on two stock market indices viz. BSE30 (SENSEX), and the NIFTY50 and the daily closing USD/INR exchange rate. The period covered by the data is from January 2 1991 to April 24, 2000. The main limitation of the data is the fact that during the early part of the data series, there are sometimes long gaps due to the stock markets having been closed for several days at a stretch.

Foreign institutional investors were permitted to directly invest in the Indian stock market only after 1997. Since this can be expected to have significant implications for the interrelationship between the stock and forex markets, we have carried out a separate estimation exercise for the sub-sample covering the period March 1998 to April 2000. The stock market data were obtained from the respective exchanges - BSE and NSE - while the historical exchange rate data were supplied by HDFC bank.

III PRELIMINARY DATA ANALYSIS

Table 1 presents some descriptive statistics for the two stock indices and the USD/INR exchange rate. Table 2 presents the same statistics for the stock returns and exchange rate returns series. In all the cases daily returns are computed as log differences of successive observations viz. ($\ln X_t$ - $\ln X_{t-1}$). Because of the data gaps mentioned above, these are not always "daily" returns and hence may impound information which may have arrived during the interval between two successive trading days[6].

As a preliminary check on volatility clustering, the Ljung-Box statistic for 25 lags for the series of squared returns were also computed. They are also reported in Table 2. All of them are significant at 1% level indicating strong autocorrelation among squared returns.

Table 1
Descriptive Statistics : Stock Indices and the Exchange Rate Levels

Statistic	BSE30	NIFTY	USD/INR
Mean	3354.53	934.50	33.32
Std. Dev.	930.73	270.32	6.74
Skewness	-0.304	-0.559	-0.438
Kurtosis	0.292	-0.227	-0.123
Ljung-Box(25)	43627.43	47228.55	50705.43
ADF Statistics*	-2.808	-2.636	-2.842

* The ADF unit root test statistic is for natural logs of the levels of the respective variables. The 5% critical value is -3.41. The test included a trend.

Table 2
Descriptive Statistics : Stock and Exchange Rate Returns

Statistic	BSE30	NIFTY	USD/INR
Mean	0.00075	0.00076	0.00043
Std. Dev.	0.01974	0.01947	0.00556
Skewness	0.529	0.366	11.289
Kurtosis	7.027	8.418	219.797
Ljung-Box(25)	72.57	74.29	92.69
ADF Statistics	-17.00	-18.47	-17.83
Ljung-Box(25) For Squared Returns	559.99	825.21	179.16

The ADF unit root tests with the returns series uniformly fail to reject the hypothesis of stationarity. The (log) levels series have one unit root.

The next step was to examine the dynamic relationship between the (log) levels of the exchange rate and the various stock indices. This was done using the cointegration tests proposed by Johansen and Juselius (1990,1992). The results are reported in Table 3. In each case, the null hypothesis is that the two series (log exchange rate and log of the relevant stock index) are not cointegrated versus the alternative hypothesis of one cointegrating relationship between the two variables.

Table 3
Cointegration Tests for the Exchange Rate and Stock Indices

BSE30-USD/INR		NIFTY-USD/INR	
LMax	Trace	LMax	Trace
23.49	27.90	23.20	27.56
BSE30-USD/INR Sub-Sample			
13.82	14.64		

Critical Values at 10% Significance Levels :
LMax: 10.60 Trace: 13.31

In all the three cases, both the trace and LMax tests support the alternative hypothesis of one cointegrating relationship between the rupee exchange rate and the respective stock index. This implies that in the returns equations to be specified later, an error correction term which captures the departure from long-run equilibrium must be included. A similar procedure was implemented with the BSE30 index and the exchange rate for the sub-sample covering the period April 2, 1998 to April 24, 2000. Here too, presence of one cointegrating vector is indicated.

To summarize, the level series exhibit non-stationarity and stock index and exchange rates are cointegrated. The stock returns and exchange rate returns series show no evidence of unit roots.

IV MODEL SPECIFICATION

The model employed in the present study is an extension of the model proposed by Nelson (1991) which is a member of the extended GARCH family of models and has been designated as E-GARCH or Exponential GARCH model. In the context of models of asset returns, the two main innovations of the E-GARCH model are first, it is possible to allow for asymmetrical response of the conditional variance of asset returns to positive and negative innovations in the returns generating process and second, it ensures non-negative conditional variance without having to impose complicated restrictions on the parameters.

The essential E-GARCH specification can be written as follows:

$$R_t = \boldsymbol{\beta}\mathbf{x}_t + \varepsilon_t \qquad (1)$$

$$\varepsilon_t = \sigma_t z_t \qquad (2)$$

$$E(z_t) = 0 \qquad V(z_t) = 1$$

and $(\sigma_t)^2$ follows the process given by:

$$\ln(\sigma_t^2) = \alpha_t + \sum_{k=1}^{\infty} \theta_k \, g(z_{t-k}) \qquad (3)$$

with the function $g(z_t)$ specified as

$$g(z_t) = \delta z_t + \gamma [\, | z_t | - E | z_t | \,] \qquad (4)$$

Equation (1) specifies the return as a function of a set of variables $\mathbf{x}_t$ with a random disturbance ε_t which has a non-constant variance σ^2_t which in turn depends upon the past values of the disturbances as seen in equations (3) and (4). The specification in (4) permits negative and positive values of z_t to have different impacts on the variance. As specified in (4), the function $g(z_t)$ is linear in z_t with slope $(\delta + \gamma)$ when z_t is positive and $(\delta - \gamma)$ when z_t is negative. Such a specification can account for the observed phenomenon that "bad" news- i.e. returns below expected returns - has greater impact on subsequent volatility than an equal amount of "good" news. Since (3) is an exponential function, the conditional variance would always be non-negative.

The model used in the present study uses the E-GARCH specification in modeling the volatility of stock and exchange rate returns with innovations in stock return affecting its own conditional variance as well as the conditional variance of the exchange rate return and vice versa. The model is set out in equations (5) - (9) below.

$$RS_t = A_{S,0} + \sum_{k=1}^{p} A_{S,k} RS_{t-k} + \sum_{k=1}^{q} A_{E,k} RE_{t-k} + C_S EC_{SE\,t-1} + e_{S,t} \quad (5)$$

$$e_{S,t} / \Omega_{t-1} \sim N\,[0, (\sigma_{S,t})^2]$$

$$RE_t = B_{E,0} + \sum_{k=1}^{m} B_{E,k} RE_{t-k} + \sum_{k=1}^{n} B_{S,k} RS_{t-k} + D_E EC_{ES\,t-1} + e_{E,t} \quad (6)$$

$$e_{E,t} / \Omega_{t-1} \sim N\,[0, (\sigma_{E,t})^2]$$

$$\mathrm{Log}\,\sigma^2_{S,t} = \{F_{S,0} + \sum_{k=1}^{p_s} F_{S,k} \mathrm{Log}\,\sigma^2_{S,t-k} + \beta_{SS}[|z_{S,t-1}| - E|z_{S,t-1}|] + \theta_{SS}\, z_{S,t-1}$$
$$\beta_{SE}[|z_{E,t-1}| - E|z_{E,t-1}|] + \theta_{S,E}\, z_{E,t-1}\} \quad (7)$$

$$\mathrm{Log}\,\sigma^2_{E,t} = \{G_{E,0} + \sum_{k=1}^{p_e} G_{E,k} \mathrm{Log}\,\sigma^2_{E,t-k} + \beta_{EE}[|z_{E,t-1}| - E|z_{E,t-1}|] + \theta_{EE}\, z_{E,t-1}$$
$$\beta_{ES}[|z_{S,t-1}| - E|z_{S,t-1}|] + \theta_{E,S}\, z_{S,t-1}\} \quad (8)$$

$$\sigma_{S,E,t} = \rho_{S,E}\, \sigma_{St}\, \sigma_{Et} \quad (9)$$

In equations (5) and (6) RS_t and RE_t denote, respectively, stock returns and exchange rate returns from t-1 to t. Each return is modeled as depending on lagged values of itself and the other return. In addition, the stock returns equation, equation (5) contains the lagged "disequilibrium" term viz. the error correction term $EC_{SE,t-1}$ from the cointegrating regression of (log of) stock index on (log of) exchange rate while the exchange rate returns equation, equation (6) contains a similar terms from the cointegrating regression of exchange rate on the stock index. The random errors in these equations viz. $e_{S,t}$ and $e_{E,t}$ have conditional variances $(\sigma^2)_{S,t}$ and $(\sigma^2)_{E,t}$, conditional on the information set Ω_{t-1} at time t-1. These are modeled in equations (7) and (8) using the Nelson E-GARCH specification with the added feature that lagged innovations in stock returns (exchange rate returns) affect not only the conditional variance of stock returns (exchange rate returns) but also exchange rate returns (stock returns) with asymmetric impact of positive and negative returns. The own effect is captured by the parameters β_{SS}, θ_{SS}, β_{EE} and θ_{EE} while the cross-market volatility spillovers are captured by the parameters β_{SE}, θ_{SE}, β_{ES} and θ_{ES}. The θ's permit the own and cross effects to be asymmetric. Persistence of volatility or in other words "volatility clustering" depends on the "GARCH" terms viz. $(\Sigma F_{S,k})$ for stock returns and $(\Sigma G_{E,k})$ for exchange rate returns. The terms $z_{S,t}$ and $z_{E,t}$ in these equations denote, respectively, standardized residuals $(e_{S,t}/\sigma_{S,t})$ and $(e_{E,t}/\sigma_{E,t})$. Finally equation (9) specifies the covariance between stock and exchange rate returns. The correlation ρ_{SE} is assumed to be time-invariant.

Equations (5)-(9) specify the general structure of the model. For each specific stock index, the number of lags p,q, m, n, p_s and p_e were decided on the basis of preliminary regressions and the significance of resulting estimates. The final models chosen for maximum likelihood estimation were as follows:

The NIFTY 50 Index

$$RS_t = A_{01} + A_{11}RS_{t-1} + A_{12}RS_{t-2} + A_{13}RS_{t-3} + B_{11}RE_{t-1} + C_{11}EC_{SE,t-1} \tag{10}$$

$$RE_t = A_{02} + A_{12}RS_{t-1} + A_{22}RS_{t-2} + A_{32}RS_{t-3} + B_{12}RE_{t-1} + B_{22}RE_{t-2} + B_{32}RE_{t-3} + B_{42}RE_{t-4} + C_{12}EC_{ES,t-1} \tag{11}$$

$$\text{Log}\,(\sigma^2)_{St} = \{D_{01} + D_{11}\text{Log}(\sigma^2)_{St-1} + D_{21}[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + D_{31}z_{S,t-1} + D_{41}\,[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + D_{51}z_{E,t-1}\} \tag{12}$$

$$\text{Log}\,(\sigma^2)_{Et} = \{E_{01} + E_{11}\text{Log}(\sigma^2)_{Et-1} + E_{21}[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + E_{31}z_{E,t-1} + E_{41}\,[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + E_{51}z_{S,t-1}\} \tag{13}$$

The BSE 30 Index (SENSEX) Full Sample Estimation

$$RS_t = A_{01} + A_{11}RS_{t-1} + B_{11}RE_{t-1} + C_{11}EC_{SE,t-1} \tag{14}$$

$$RE_t = A_{02} + A_{12}RS_{t-1} + B_{12}RE_{t-1} + B_{22}RE_{t-2} + C_{12}EC_{ES,t-1} \tag{15}$$

$$\text{Log}\,(\sigma^2)_{St} = \{D_{01} + D_{11}\text{Log}(\sigma^2)_{St-1} + D_{21}[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + D_{31}z_{S,t-1} + D_{41}\,[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + D_{51}z_{E,t-1}\} \tag{16}$$

$$\text{Log}\,(\sigma^2)_{Et} = \{E_{01} + E_{11}\text{Log}(\sigma^2)_{Et-1} + E_{21}[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + E_{31}z_{E,t-1} + E_{41}\,[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + E_{51}z_{S,t-1}\} \tag{17}$$

The BSE 30 Index (SENSEX) Sub-Sample Estimation

$$RS_t = A_{01} + A_{11}RS_{t-1} + B_{11}RE_{t-1} + C_{11}EC_{SE,t-1} \tag{18}$$

$$RE_t = A_{02} + A_{12}RS_{t-1} + A_{22}RS_{t-2} + A_{32}RS_{t-3} + A_{42}RS_{t-4} + B_{12}RE_{t-1} + B_{22}RE_{t-2} + C_{12}EC_{ES,t-1} \tag{19}$$

$$\text{Log}\,(\sigma^2)_{St} = \{D_{01} + D_{11}\text{Log}(\sigma^2)_{St-1} + D_{21}[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + D_{31}z_{S,t-1} + D_{41}\,[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + D_{51}z_{E,t-1}\} \quad (20)$$

$$\text{Log}\,(\sigma^2)_{Et} = \{E_{01} + E_{11}\text{Log}(\sigma^2)_{Et-1} + E_{21}[\,|\,z_{E,t-1}\,| - E\,|\,z_{E,t-1}\,|\,] + E_{31}z_{E,t-1} + E_{41}\,[\,|\,z_{S,t-1}\,| - E\,|\,z_{S,t-1}\,|\,] + E_{51}z_{S,t-1}\} \quad (22)$$

The log-likelihood function for the E-GARCH specification is given by

$$\text{Log}(\Theta) = -\,0.5(NT)\,\text{Log}(2\pi) - 0.5\sum_{1}^{T}(\log|V_t| + e'_t\,V_{t-1}\,e_t) \qquad (23)$$

Here Θ denotes the parameter vector to be estimated, N is the number of equations, T is the number of data points, e_t denotes the 2×1 column vector with $e_{S,t}$ and $e_{E,t}$ as elements and V_t is the conditional variance-covariance matrix with the conditional variances σ^2_{St} and σ^2_{Et} on the diagonal and the covariance $\sigma_{SE,t}$ off-diagonal.

These models were estimated with the GARCH estimation procedure in RATS using the BFGS (Broyden,Fletcher, Goldfarb and Shanno) algorithm. As can be seen from the equations given above, estimation involves non-linear optimization and the algorithm is very sensitive to starting values of the parameters. Ten iterations of the Simplex algorithm were run to provide the starting values before initiating the BFGS procedure.

V ESTIMATION RESULTS

Since the focus of the paper is on examining the interrelation between volatilities of stock and exchange rate returns, we will present only results pertaining to the conditional variance equations - equations (12) and (13) for NIFTY 50, equations (16), (17) for SENSEX full sample and equations (20), (21) for SENSEX subsample. Full results including those of the returns equations are available from the author.

Table 4
Bivariate EGARCH Model: NIFTY 50 and USD/INR Exchange Rate
(Sample Period: 2/1/1991-24/4/2000)

Parameter	Estimate	Std. Error	t-Value
D01	-9.98669626	0.83029215	-12.02793
D11	0.00439628	0.08556552	0.05138
D21	0.00921377	0.24238015	0.03801
D31	-0.02531982	0.01754861	-1.44284
D41	0.02380320	0.00447302	5.32151
D51	-0.02203088	0.00199475	-11.04446
E01	-15.70551306	0.50210759	-31.27918
E11	0.00684437	0.03026912	0.22612
E21	-0.01601426	0.00048762	-32.84181
E31	0.00992477	0.00062907	15.77687
E41	0.01378210	0.09178939	0.15015
E51	0.02397870	0.01219400	1.96643

These results present an interesting picture. The significant estimate of the parameter D_{41} implies that innovations in exchange rate returns do influence the conditional variance of stock returns. Further, since the parameter D_{51} is also significant, this cross-equation volatility spillover has asymmetric effect. Surprisingly, there is no evidence of autoregressive effect in the conditional variance of stock returns nor any impact of stock returns surprises on the conditional variance. This is indicated by the insignificant estimates of parameters D_{21} and D_{31}. Turning to exchange rate returns, there is evidence of significant evidence of asymmetric ARCH effects - both E_{21} and E_{31} are highly significant but no evidence of autoregression in the conditional variance of exchange rate returns. There is also evidence of spillover from stock returns surprises into the conditional variance of exchange rate returns. Since the parameter E_{51} is significant, this effect appears to be asymmetric. The signs and relative magnitudes of E_{21} and E_{31} indicate that exchange rate return surprises reduce the conditional variance of exchange rate returns but more so when the surprise is negative - a less than expected depreciation of the rupee.

Next we turn to the results with BSE SENSEX covering the same sample period. These are presented in Table 5.

The results with SENSEX are broadly similar to those with NIFTY 50. The GARCH term in the stock returns equation is significant suggesting volatility persistence. Also, like in the case of NIFTY 50, there is volatility spillover from exchange rate returns innovations to the stock market as indicated by the significant value of the estimate of the parameter D_{41} but this effect is not asymmetric since the estimate of D_{51} is not significantly different from zero.

Table 5
Bivariate EGARCH Model: BSE SENSEX and USD/INR Exchange Rate
(Sample Period: 2/1/1991-24/4/2000)

Parameter	Estimate	Std.Error	t-Value
D01	-12.10649202	0.07139159	-169.57870
D11	0.01007225	0.00611568	1.64695
D21	-0.00442026	0.00744624	-0.59362
D31	-1.51410673	1.29330899	-1.17072
D41	0.00119252	0.00007639	15.61138
D51	-0.02789435	0.05646507	-0.49401
E01	-23.67255103	0.05746939	-411.91584
E11	0.00469564	0.00280486	1.67411
E21	0.00119406	0.00008350	14.30019
E31	-0.02042187	0.05275715	-0.38709
E41	-0.00532441	0.00360624	-1.47644
E51	-7.21588086	5.76530608	-1.25160

Turning to the conditional variance of exchange rate returns, there is evidence of volatility persistence as well as ARCH effects of exchange rate returns innovations on their conditional variance but no evidence of any asymmetric effects of negative and positive surprises as also no evidence of any spillover effects from stock returns innovations to the forex market. Finally, Table 6 contains results with the SENSEX for the truncated sample period from March 2, 1998 to April 24, 2000.

Table 6
Bivariate EGARCH Model: BSE SENSEX and USD/INR Exchange Rate
(Sample Period: 2/3/1998-24/4/2000)

Parameter	Estimate	Std. Error	t-Value
D01	-1.5734648	0.1757995	-8.95034
D11	0.0029934	0.1088030	0.02751
D21	-0.0447595	1.7798114	-0.02515
D31	13.0446695	439.9217457	0.02965
D41	-0.0416828	1.3789790	-0.03023
D51	16.0988971	493.7870711	0.03260
E01	-0.0066603	0.1743667	-0.03820
E11	-0.0064024	0.1997587	-0.03205
E21	-0.0611864	1.4661001	-0.04173
E31	-2.9777984	95.3130232	-0.03124
E41	-0.0471495	1.8283482	-0.02579
E51	71.4985930	886.2656999	0.08067

By the start of this period, FII activity on Indian bourses had begun and one would have expected significant spillovers from the foreign exchange market to the stock market and vice versa. It therefore comes as a surprise that the estimates for this period show no evidence at all of such an interconnection. Further, this period also shows no evidence of any ARCH-GARCH effects either in the stock returns or in exchange rate returns.

Diagnostics were performed with the residuals from the two returns equations. With the NIFTY 50 data, the Ljung-Box test with 25 lags shows that residuals from neither equation have any autocorrelation . However, squared residuals from the stock returns equation exhibit autocorrelation. Squared residuals from the exchange rate equation are free of autocorrelation. Similar tests with the BSE SENSEX full sample however indicate that there is significant residual autocorrelation in the estimated disturbances and their squares for both stock returns and exchange rate returns.

VI CONCLUSION

With the globalization of capital markets and liberalization the capital account, investors would be expected to diversify their portfolios across currencies and national stock markets. Since exchange rate risk and its association with the local stock market is an important component of the overall portfolio risk, this trend can be expected to link the stock market and the forex market more closely. Such linkages can be expected to be manifest not only in the behaviour of mean returns in the two markets but also in cross-market volatility spillovers. The evidence presented in this paper does indeed bear out such an expectation. Analysis with one of the major stock indices viz. the NSE Nifty 50 and the rupee-dollar exchange rate supports the hypothesis of returns innovations in one market impacting not only on the conditional variance in the same market but also in the other market. One would have expected such linkages to exhibit themselves all the more strongly after the Indian market was opened up - albeit with restrictions - to foreign institutional investors. Surprisingly, data pertaining to the period following this event do not show up such linkages.

It must be admitted that during the period covered by the data - in particular till April 1993, the exchange rate was not really market determined. Also, certain events in the stock market during 1992 had led to long gaps in the data in the early part of the sample. Hence the conclusions based on the evidence at hand must be treated with some caution and further analysis is needed to strengthen the findings.

Endnotes

[1] Or rather the question should be whether the market views exchange rate risk as a separate source of risk over and above market risk in valuing individual stocks.
[2] See for example Hekman (1989)
[3] A good reference on this is Solnik (1993)
4 It has been estimated that since mid 1980's cross-border equity investment has grown at a rate in excess of 30% per annum. Tesar and Werner (1995).
5 These include pairwise covariances between the individual stock market returns, individual exchange rates and these between exchange rates and stock returns.
6 As usual, the variables are taken in log form.
7 To the extent such information affected both the forex and the stock market and only one of them was closed while the other was open, this would distort the estimated volatility linkages between the two.

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