Correlation and Volatility Transmission across International Stock Markets: A Bivariate GARCH Analysis

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Received: December 5, 2011 Accepted: February 11, 2012 Published: March 1, 2012
doi:10.5539/ijef.v4n3p253 URL: http://dx.doi.org/10.5539/ijef.v4n3p253

Abstract

The study empirically examines correlation and volatility transmission across international stock markets by employing Bivariate GARCH model. The study uses weekly data for five major stock indices such as S&P 500(USA), BSE 30 sensex (India), FTSE 100(U.K), Nikkei 225(Japan) and Ordinary Share Price Index (Australia) from 30th January, 1998 to 30th July, 2011. Long run and short run integrations are investigated through Johansen cointegration and vector error correction models respectively. The results of Johansen test show that long run co-integration is found across international stock indices prices. Further, results suggest that the arrival of external news is simultaneously received by US and Japan stock markets and then transmitted to other Asian and European stock markets. The results of bivariate GARCH model reveal that there is a bidirectional volatility spillover between US and Indian stock markets. This is due to fact that these two economies are strongly integrated through international trade and investment. Finally, results show that a unidirectional volatility spillover from Japan and United Kingdom to India.

Keywords: Johansen cointegration test, Vector error correction model, Bivariate GARCH and volatility spillover

1. Introduction

Under globalization, world financial markets and economics are increasingly integrated due to free flow capital and international trade. Further, globalization has increased co-movement in stock prices across international markets. This co-movement stimulates vulnerability to market shocks. Therefore, shocks originating in one market not only affected its own market but are also transmitted to other equity markets. Hence, any information regarding the economic fundamentals of one country gets transmitted to other markets and thus affects the other's stock markets.

There are differing views concerning how correlation of international stock markets changes over a period of time. One view is that correlations across international stock markets are not constant over time due to changes in economics, political and market environments among countries (Baharumshah, Sarmidi, and Tan (2003) Shamsuddin and Kim (2003) Voronkova (2004), Bekaert and Harvey (2003); Bekaert and Harvey (2000) Errunza and Losq,(1985). Corhay, et al (1995) particularly studied the stock markets of Australia, Japan, Hong Kong, New Zealand and Singapore and found no evidence of a correlation among these markets. Nath and Verma (2003) studied the market indices of India, Singapore and Taiwan and found no correlation between these indices. Cheung and Mak (1992) and Masih and Mash 1997 b) found evidence that international stock markets are strongly correlated. They specifically, found that the US is a global factor affecting both the developed and developing markets. Therefore, there is a need to study cross border interrelation among international stock markets.

The study also investigates volatility transmission across international markets. There are studies which have examined this issue. For instance, Theodossiou et al. 1997, Yiuman Tse and Booth, 1999, Mansor and Mahmoodof, 2003, Savva, 2008, Shiun and Hsueh, 1998 have found significant mean and volatility spillovers from the U.S. market to other international markets. Koutmos and Booth (1995) also examine price and volatility spillovers among US, Japanese and British stock markets in a multivariate EGARCH model. They found significant asymmetric volatility spillovers from NY and London to Tokyo, from Tokyo and NY to London and from London and Tokyo and NY.

However, some studies reveal that there are weaker or no volatility spillover effects from U.S. to Asia [Ng, 2000; Baele, 2002, Bae and Karolyi, 1994]. Ng (2000) studied volatility spillovers between Japan and the US stock markets and found that there is no volatility transmission from the US to Japan. Baele (2002) investigated the time-varying nature of the volatility-spillover effects between the US (global effects) and European stock markets and found volatility spillover from European to the US stock markets.

It may however be pertinent to note that most of the studies have generated evidences which are mixed and inconclusive in nature on this issue. Therefore, the present study proposes to re-examine how common news (external news) drive both the Asia and European stock markets including India and also how these news are transmitted from one market to another.

The correlation and volatility transmission between stock markets is important for risk managers and policy makers for the following reasons. The correlation of stock markets is useful to design a well-diversified portfolio for investors. Changes in international correlation patterns call for an adjustment of portfolios. Policy makers are interested in volatility transmission across markets because of its implications for the stability of the global financial system. For instance, if volatility spillovers are significant between markets, a shock originating from one market may have a destabilizing impact on other markets. Hence, it is important for policy makers to understand the inter relations and volatility spillovers between financial markets.

The remainder of the study is organized as follows. Section 2 provides some empirical evidence on interrelation and volatility transmission across international stock markets. Section 3 describes the methodology and the data used. Section 4 the presents results and discussion. Section 5 provides a summary and conclusion of the study.

2. Some Empirical Evidence

There are studies which have examined correlation and volatility transmission across international stock markets. The empirical evidence however was found mixed [Kanas 1998, Shiun Pan and Hsueh 1998, Ng 2000, Ahmad Zubaidi and Boon Tan 2003, Kaur (2004) Gunasekarage and Power 2005, Victor Fang et al 2006, Mukherjee, and Mishra 2008]. Kanas (1998) examined volatility spillovers across the three largest European stock markets namely, London, Frankfurt and Paris by employing the Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) model. He found that reciprocal spillovers between London and Paris, and between Paris and Frankfurt, and unidirectional spillovers from London to Frankfurt. Finally, his results show that spillovers are asymmetric in the sense that bad news in one market has a greater effect on the volatility of another market than good news. Similarly, Pan and Hsueh (1998) examined the nature of transmission of stock returns and volatility between the U.S. and Japanese futures markets. They used daily opening and closing futures prices on the S&P 500 and Nikkei 225 index from January 3rd, 1989 to December 30th, 1993. Employing the two-step univariate GARCH approach, the results show that there are unidirectional contemporaneous return and volatility spillovers from the U.S. to Japan.

Research studies which have employed the bivariate and multivariate GARCH also found inconclusive results. Ng, (2000) investigated the magnitude and changing nature of the return and volatility spillovers from Japan and the US to the Pacific–Basin markets using bivariate GARCH model. The empirical results show that there are significant volatility spillovers from both the Japanese and US markets to Malaysia, Singapore, Taiwan and Thailand. Kaur (2004) studied the return and volatility spillover between India (Sensex and Nifty) and US (NASDAQ and S&P 500) markets by employing EGARCH models. His results show mixed evidence of return and volatility spillover between the US and the Indian markets. The significant correlation between US and Indian markets was time specific.

Similarly, Gunasekarage and Power (2005) examined return and volatility spillovers from the US and Japanese stock markets to three South Asian capital markets namely, (i) the Bombay Stock Exchange, (ii) the Karachi Stock Exchange and (iii) the Colombo Stock Exchange. Their results show return spillovers in all three markets, and volatility spillovers from the US to the Indian and Sri Lankan markets and from the Japanese to the Pakistani market. Fang et al (2006) investigated the volatility transmission between Stock and Bond Market by using the daily data of stock and bond indices of both the U.S. and Australia during the period from 1998 to 2003. Employing BEKK GARCH (1, 1), they found spillovers between the stock markets of the U.S. and Australia, and the same effects are present in the bond markets of both the countries. Their evidence support that bidirectional information flows between two markets.

Mukherjee and Mishra, (2008) investigated return and volatility spillover among Indian stock market with 12 other developed and emerging Asian countries by applying the Multivariate GARCH model. The study used both daily opening and closing prices from November 1997 to April 2008. The results show that Hong Kong, Korea, Singapore and Thailand are found to be the four Asian markets from where there is a significant flow of information in India. Similarly, among others, stock markets in Pakistan and Sri Lanka are found to be strongly influenced by movements in Indian market.

Employing bivariate VAR model, Savva (2008) investigated the price, volatility spillovers and correlations between the US and the major European stock markets. The study used daily prices S&P 500 (USA), FTSE-100 (UK), DAX-30 (Germany), CAC-40 (France), MIBTEL-30 (Italy) and IBEX-35 (Spain) from August 3rd, 1990 to April 12th, 2005. The estimated results show there is strong co-integration relationship between US and European stock markets. As far as the volatility spillover effects are concerned, the study revealed effects not only from US to Europe but also from Europe to US.

The above review shows that the findings of the various studies have been inconclusive on this issue. In the light of this observation the present study addresses issues related to correlation and volatility transmission across international stock markets.

3. Data and Methodology

3.1 Data

The study has chosen indices from India's four major trading partners; the United States, the United Kingdom, Japan and Australia. The US is India's largest trading partner among others and plays a dominant role in India's trade, accounting for 22.7 per cent of India's exports and around 7.69 per cent of India's imports. India's exports to the US have more than doubled during the period 2000 -01 to 2008-09. During 2000- 01, India's exports to the US at $ 9,301 million and then increased to $ 20,972.3 million in year of 2008-2009. India's exports to the UK also jumped manifold into $ 6,597 million during 2008 -09 as compared to 2000-01 which was $ 2,298.7 million. India's foreign trade with selected partners is given in figure 1. The figures show that India became increasing integrated with other developed countries through foreign trade.

The weekly data were collected from Yahoo Finance and Bombay Stock Exchange of India. The study mainly has chosen the indices from five major countries namely, the United States, the United Kingdom and Japan, Australia and India, to examine volatility transmission across international stock markets. Each index represents one country, such as BSE 30 sensex (India), S&P 500 (the United States), FTSE 100 (United Kingdom), Nikkei 225 (Japan) and Ordinary Share Price Index (Australia). Our weekly data of five indices cover the period from 30th January**,** 1998 to 30th July, 2011. The weekly indices rather than daily data are used for avoiding representation bias from some thinly traded stocks, i.e., the problems of non-trading and non-synchronous trading and to avoid the serious bid/ask spreads in daily data.

3.2 Methodology

The study employs the ADF and PP unit root tests to confirm the stationarity of the process and Johansan cointegration and vector error correction models to examine the long run relationship across international stock markets. The vector error correction model explains the speed of adjustment of the price deviation from long run equilibrium in relation to different stock price indices. The study finally employed bivariate GARCH model to establish the link between variances and covariance of two stock returns.

The main objective of study is to investigate volatility transmission across international stock markets. The Volatility spillovers are important in the study of information transmission because volatility is also a source of information to which investors react and form new expectations regarding risk and return. Angel Liao (2004) argued, volatility or "news" is transmitted through two channels. The first channel is price changes (an increase in the volatility of the variance of returns) whereas the second channel is noise (an increase in the volatility of the variance of the forecast error). Using GARCH models we can predict the effect that news in one stock market has on returns in other markets the next day and through which channel news is conveyed. A significant interaction is evidence of stock market interdependence or integration.

The study follows a two-step procedure. The first step involves estimation of VECM and the second step bivariate GARCH model. Estimating the two models simultaneously in one step is not practical because of the large number of parameters involved. Moreover, although the study focuses more on volatility spillovers (second moment) than cointegration (first moment), the error correction term must be included in the GARCH conditional variance equation.

Otherwise, the model will be misspecified and the residuals obtained in the first step (and, consequently, the volatility spillover results) will be biased.

To investigate volatility transmissions among two markets, a bivariate - GARCH model is employed. To illustrate, let there be two stock markets say one the US and another India. The bivariate GARCH (1, 1) model can be written as follows.

$$R_{1t} = \theta_{10} + \theta_{11} R_{1t-1} + \theta_{12} \varepsilon_{2t-1} + \upsilon_{t1} \quad (1)$$

$$R_{2t} = \theta_{20} + \theta_{21} R_{1t-1} + \theta_{22} \varepsilon_{1t-1} + \upsilon_{t2} \quad (2)$$

where the error terms are distributed as $N(0, H_t)$. The return or mean spillover parameters are θ_{12} and θ_{22}. R_{1t} is the S&P 500 returns depending on its own past values and ϵ_{2t-1}, is residuals from vector error correction model to check mean spillover from US to India. Similarly, R_{2t-1}, is BSE 30 returns depending on its own past values including residuals are derived from vector error correction model.

To capture the volatility spillover between markets, we introduce Error Correction (ECT) terms in conditional variance equations. The expansion of the matrix H_t is structured as:

$$h_{,11t} = c_{11} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11}h_{11,t-1} + \gamma_{11}\varepsilon^2_{1\ ,t-1} \quad (3)$$

$$h_{22t} = c_{22} + \alpha_{22}\varepsilon^2_{2,t-1} + \beta_{22}h_{22,t-1} + \gamma_{22}\varepsilon^2_{2\ ,t-1} \quad (4)$$

$$h_{12t} = c_{12} + \alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12}h_{12,t-1} + \gamma_{12}h_{12\ ,t-1} \quad (5)$$

The Equation (3) is conditional variance for US market which includes a function of past lagged value of residuals from VECM as well as own lagged value of residuals including past conditional variance. In this equation, γ_{11} is the coefficient spillovers from US (market 1) to India (market 2). In Equation (4) is the conditional variance equation for India, γ_{22} is the coefficient of spillovers from India (market 2) to USA (market 1)

The bivariate specification allows the conditional variances (h_{11t} and h_{22t}) and covariance (h_{12t}) of two markets returns to influence each other. The volatility spillover is measured by the parameters of γ_{11} and γ_{22}. The standard square residuals of $\varepsilon^2_{1\ ,t-1}$ and $\varepsilon^2_{2\ ,t-1}$ are obtained from Vector Error Correction (VCEM) Model.

4. Empirical Results

Table 1 presents summary of statistics for S& P 500, FTSE 100 and NIKKEI 225, BSE 30 sensex and Ordinary Share Price Index. The daily mean returns are positive, in case of S& P 500, FTSE 100 and Nikkei 225. But it is negative for BSE 30 sensex and All Ordinaries Shares. The standard deviation of S& P 500 and Nikkei 225 are higher among five stock indices. This shows that there is higher volatility in these two markets as compared to other markets. The measures for skewness and excess kurtosis indicate that the distributions of returns for all five markets are positively skewed and leptokurtic relative to non normal distribution. The Jarque Bera (denoted by JB) statistic rejects normality at 1% level of significance in all cases. The Ljung Box statistic for 16 lags applied on returns (denoted by LB (16))and squared returns (denoted by LB^2(16)) indicate that significant linear and nonlinear dependencies exist. The LM test statistic shows that there is evidence for ARCH effect and time varying volatility.

The results of correction matrix are presented in table 2. The results reveal that the five stock indices are highly correlated with each other since correlation coefficients are high. Particularly, S & P 500 index is highly correlated with European and Asian stock indices. The weekly stock returns of India (BSE 30 sensex), US (S&P 500), UK (FTSE 100), Japan (Nikkei 225) and Australia (Ordinary Share Price Index) are presented from figures 2 to 6 and their unit root statistics are reported in table 3. The results of ADF show that all series are non-stationary at level since null hypothesis is accepted in all cases. However, all stock prices are stationary at first difference, which are integrated of order one. Similar results are observed in Phillips-Perron test given in the same table.

Table 4 provides results of Johansen cointegration test. All test equations contain two lag for the endogenous variables chosen by Akaike Information Criteria (AIC), Final Prediction Error (FPE) and Schwarz Information Criteria. The Johansen results indicate that there are two cointegrating vectors in the five variables system which cannot reject null hypothesis at 5% level under trace and maximum eigen value. These results suggest there are two cointegrating vectors among five stock indices prices.

The results of vector error correction model are given in table 5. The results show that the coefficients of error correction terms are not statistically significant in case of Nikki 225 and S&P 500, but it is statistically significant for

BSE 30 sensex, FTSE 100 and All Ordinaries Shares. It indicates that whenever stock indices such as Nikki 225 and S&P 500 deviate from equilibrium level, other markets (BSE 30 sensex, FTSE 100 and All Ordinaries Shares) tend to correct back to towards long run equilibrium level during next period. These result shows that stock markets such as the US and Japan lead other markets suggesting that any external news is arrives simultaneously get affected by both stock markets and then transmitted to other Asian and European stock markets.

The results of bivariate GARCH model are reported in tables 6 to 9. The results reveal that there are positive significant volatility spillovers from the US market to Indian market (0.00979) and from the India to US stock market (0.00521). In other words, there is bidirectional volatility spillover between two markets. This is due to the fact that co-movement information flows exist between prices in the two markets. Similarly, there is positive volatility transmission from Japan to India since coefficient of γ11 is found to be significant. However, a negative volatility spillover is found from United Kingdom to India. Further results suggested that there is no reverse volatility spillover from India to Japan and United Kingdom. Finally, the results show that volatility spillovers between Australia and India are not found. The positive spillover coefficients (γ_{11} and γ_{22}) indicate that shocks to one market increase the conditional variance of another in the next period.

The spillover coefficient from the US to India (0.00979) is greater than the spillover coefficient from India to the US (0.00521). Similarly, the coefficient from Japan to India (0.00846) is larger than the coefficient from India to Japan (0.00427). Overall, these results indicate that US and Japan stock markets are exporting their volatility to India, with London exporting volatility which has a comparatively the negative influence.

5. Final Remarks

Interinkages between developed and emerging stock markets has great importance because strong linkage reduces insulation of domestic market from any global shock and creates implications, whereas weak market linkage offers potential gains from international diversifications and affects development of the emerging markets. This study investigates interdependent and volatility spillover across international stock markets using bivariate GARCH model. The weekly closing prices of the S&P500 (US), FTSE 100 (United Kingdom), Nikkei 225 (Japan), Ordinary Share Price Index (Australia) and BSE 30 sensex (India) are used from January 30th, 2000 to July 30th, 2011. Employing Johansan co-integration and vector error correction models, it is found that there is long run relationship across international stock indices prices.

Further, the results reveal that stock markets such as S&P 500 and Nikkei 225 deviate from equilibrium level, but three markets namely, BSE 30 sensex, FSTE 100 and Ordinary Share Price Index tend to make all correction to reestablish equilibrium in the long run. This implies that the US and Japan stock markets lead other markets suggesting that any external news arrival simultaneously received by both markets and then transmitted to other international stock markets. In case of volatility transmission, the study finds a bidirectional volatility spillover between the US and Indian stock markets. This may be because of the fact that these two economies are strongly interrelated through international trade, investment. Finally, the results show that a positive volatility spillover is found from Japan to India.

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Table 1. Descriptive Statistics for Selected Stock Indices Returns

	ASX	BSE 30 Sensex	FTSE 100	Nikkei 225	S&P 500
Mean	-0.0001	-0.0005	0.0001	0.00014	6.86E-05
Median	-0.0004	-0.0012	-0.0002	-7.70E-06	-0.00042
Maximum	0.0855	0.1180	0.0926	0.1211	0.0946
Minimum	-0.0536	-0.1599	-0.0938	-0.1323	-0.1095
Std. Dev.	0.0099	0.0181	0.0214	0.0193	0.0239
Skewness	0.6785	0.0944	0.0920	0.2336	0.1189
Kurtosis	10.643	8.0601	8.4553	8.7506	10.212
Jarque-Bera	7083.8	3013.8	3502.1	3912.83	6121.5
Probability	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	-0.3676	-1.4644	0.2976	0.4067	0.1936
Sum Sq. Dev.	0.2803	0.9312	0.5101	0.7496	0.5472
Results of Residuals Test					
LB-Q (16)	42.61 (0.000)	52.57 (0.000)	94.41 (0.000)	32.536 (0.000)	59.205 (0.000)
LB-Q^2 (16)	311.16 (0.000)	629.2 (0.000)	287.9 (0.000)	345.25 (0.000)	352.50 (0.000)
LM test (6)	28.387 (0.000)	37..21 (0.000)	77.54 (0.000)	16.327 (0.0183)	23.608 (0.001)

Note: LB-Q (k) and LB2-Q (k) are the portmanteau Ljung-Box Q test statistics for testing joint significance of autocorrelation of standardized residuals up to 16 lags. LM is the ARCH effect in the standardized squared residuals up to 12 lags. The figures in parentheses are the p-values.

Table 2. Correlation Matrix for Selected Stock Indices

	ASX	BSE 30 sensex	FTSE 100	NIKKE225	S&P 500
ASX	1	0.68649	0.73889	0.68063	0.68335
BSE 30 sensex	0.68649	1	0.97965	0.92467	0.95356
FTSE 100	0.73889	0.97965	1	0.91697	0.95203
NIKKE225	0.68063	0.92467	0.91697	1	0.89465
S&P 500	0.68335	0.95356	0.95203	0.89465	1

Table 3. Unit Root Statistics

Index	Augmented Dickey-Fuller Test			
	Levels	P. Value	First Differences	P. Value
All Ordinaries Shares	-0.289333	0.9240	39.9971*	0.000
BSE 30 sensex	-1.505365	0.5309	22.00650*	0.0000
FSTE 100 Index	-1.496206	0.5856	45.07651*	0.0000
NIKKEI 225	-1.669398	0.4468	-35.89363*	0.0000
S&P 500 INDEX	-0.8842	0.7893	-48.7841*	0.0000
Phillips-Perron Test				
All Ordinaries Shares	-0.276361	0.9259	40.38646*	0.0000
BSE 30 Sensex	-1.530122	0.5182	-46.92045*	
FSTE 100 Index	-1.617131	0.4736	-48.12292*	0.0000
NIKKEI 225	-1.396802	0.5853	-45.20754*	0.0000
S&P 500 INDEX	-1.728527	0.4167	49.35343*	0.0000

* indicates that unit root rejection of null hypotheses

Table 4. Johansen Cointegration Test

Null Hypothesis	Alternative hypothesis	Trace Test	Critical Value	P.value
H0	H1			
r≤0	r>0	172.5302*	69.81889	0.0000
r≤1	r>1	59.96486*	47.85613	0.0025
r≤2	r>2	27.94328	29.79707	0.0806
r≤3	r>3	12.64363	15.49471	0.1286
r≤4	r>4	1.856646	3.841466	0.1730
Maximum Eigenvalue				
Null Hypothesis	Alternative hypothesis	Eigenvalue	Critical Value	P.value
r≤0	r>0*	112.5654*	33.87687	0.0000
r≤1	r>1*	32.02158*	27.58434	0.0126
r≤2	r>2	15.29965	21.13162	0.2684
r≤3	r>3	10.78698	14.26460	0.1652
r≤4	r>4	1.856646	3.841466	0.1730

Note: * indicates 5% level of significance; lag length is chosen based on AIC and FPE and found to be 2

Table 5. Results of Vector Error Correction Model

Error Correction:	ASX	BSE 30 Sensex	FSTE 100	Nikkei 225	S&P 500
ECT	-0.52005 [-3.16071]*	-0.001794 [-10.8086]*	0.000549 [2.86304]*	0.000470 [0.86380]	0.00006 [1.25797]
ASX (-1)	0.086345 [3.74328]*	0.000685 [0.10601]	-0.019531 [-2.61251*]	0.000271 [0.01259]	-0.003209 [-1.97237]
ASX (-2)	-0.031627 [-1.37686]	-0.009606 [-1.49213]	-0.009361 [-1.25738]	0.068379 [3.19318]	0.001369 [0.84490]
BSE 30 sensex (-1)	0.018058 [0.22419]	-0.054473 [-2.41300]*	-0.045635 [-1.74812]	-0.039890 [-0.53121]	-0.005954 [-1.04796]
BSE 30 sensex (-2)	-0.110465 [-1.43863]	-0.001481 [-0.06882]	-0.016472 [-0.66191]	-0.143890 [-2.01011]	0.006489 [1.19814]
FSTE 100 (-1)	0.025677 [0.33276]	0.139133 [6.43339]*	-0.073031 [-2.92020]*	0.035797 [0.49761]	0.065245 [11.9875]*
FSTE 100 (-2)	0.082030 [1.03610]	-0.075863 [-3.41895]	-0.004330 [-0.16875]	0.051541 [0.69831]	0.027667 [4.95445]
Nikkei 225 (-1)	0.088267 [3.58843*]	-0.001995* [-3.28939]	2.82E-05 [0.00353]	-0.030766 [-1.34165]	-0.002373* [-2.36780]
Nikkei 225 (-2)	-0.021856 [-0.88573]	0.002597 [0.37548]	0.022923 [2.86627]	-0.017520 [-0.76160]	0.001463 [0.84054]
S&P 500 (-1)	0.729057 [2.18808]*	0.609714 [6.52917]*	-0.001092 [-0.01011]	0.523288 [2.68464]*	-0.210487 [-8.95627]
S&P 500 (-2)	0.091201 [0.27782]	0.121265 [1.31806]	-0.016382 [-0.15398]	-0.445557 [-1.45592]	-0.113688 [-4.91001]

Note: ECT represents the lagged error correction term; * indicates 1% level of significance; figures in parentheses are t values; lag length is chosen based on AIC and FPE and found to be 2.

Table 6. Bivariate GARCH Model between BSE 30 sensex and S&P 500 Index

	Coefficients	Z. Value	P. value
θ_{11}	0.7821	3.7891	0.0000
θ_{21}	-0.0814	-3.0174	0.0000
θ_{12}	0.0987	2.2741	0.0156
θ_{22}	-0.0008	-0.9981	0.2786
α_{11}	0.0029	8.4083	0.0000
α_{22}	0.0011	9.8224	0.0000
β_{11}	7.5E-05	1.7792	0.3489
β_{22}	-0.7955	-5.7892	0.0000
γ_{11}	0.00979	2.5891*	0.0178
γ_{22}	0.00521	2.1756*	0.0789
Residual Diagnostics	**Test Statistic**		**P. value**
LBQ (12)	8.7762		0.7791
LBQ^2 (12)	6.9981		0.8951
LM Test	4.7892		0.5786

Note: * indicates 1% level of significance. LB-Q (k) and LB^2-Q (k) are the portmanteau Ljung-Box Q test statistics for testing joint significance of autocorrelation of standardized residuals up to 12 lags. LM is the ARCH effect in the standardized squared residuals up to 6 lags. Estimates of constant and covariance terms are not reported in the table.

Table 7. Bivariate GARCH Model between BSE 30 sensex and Nikkei 225

	Coefficients	Z. Value	P. value
θ_{11}	0.7668	3. 0661	0.0000
θ_{21}	-0.0456	-1.7892	0.2871
θ_{12}	0.5894	2.8794	0.0175
θ_{22}	-0.0079	-1.9482	0.2287
α_{11}	0.0024	7.3702	0.0000
α_{22}	-0.0014	-8.7408	0.0000
β_{11}	0.4177	11.0757	0.0000
β_{22}	-0.31481	-8.0189	0.0000
γ_{11}	0.00860	2.3947*	0.0327
γ_{22}	0.00427	0.7141	0.4789
Residual Diagnostics	**Test Statistic**		**P. value**
LBQ (12)	4.5928		0.5587
LBQ^2 (12)	6.8861		0.7418
LM test	7.9975		0.8567

Note: * indicates 1% level of significance. LB-Q (k) and LB^2-Q (k) are the portmanteau Ljung-Box Q test statistics for testing joint significance of autocorrelation of standardized residuals up to 12 lags. LM is the ARCH effect in the standardized squared residuals up to 6 lags. Estimates of constant and covariance terms are not reported in the table.

Table 8. Bivariate GARCH Model between BSE 30 sensex and FTSE 100 Index

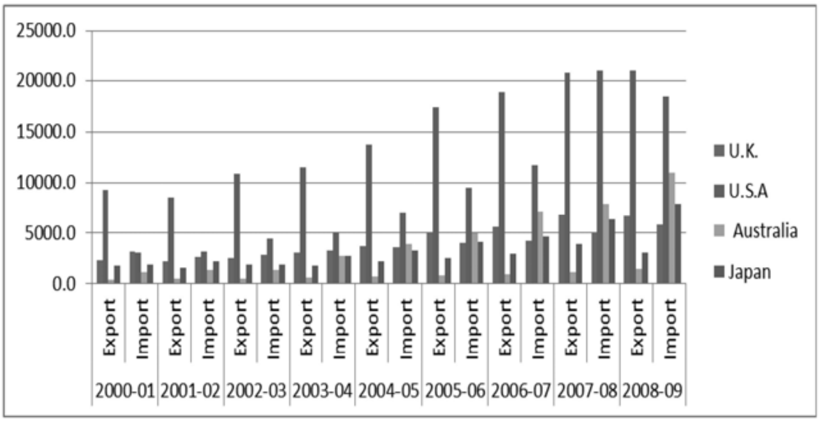
	Coefficients	Z. Value	P. value
θ_{11}	0.3870	2.7892	0.0147
θ_{21}	-0.5111	-4.8992	0.0000
θ_{12}	0.0027	1.2296	0.2339
θ_{22}	0.0489	2.7781	0.0178
α_{11}	0.0048	10.972	0.0000
α_{22}	-0.2276	-5.7790	0.0000
β_{11}	0.99258	7.0371	0.0000
β_{22}	-0.0276	-4.8923	0.0000
γ_{11}	-0.00387	-3.8912*	0.0000
γ_{22}	0.0019	0.7790	0.0122
Residual Diagnostics	**Test Statistic**		**P. value**
LBQ (12)	7.014		0.478
LBQ^2 (12)	9.878		0.571
LM test	5.721		0.479

Note: * indicates 1% level of significance. LB-Q (k) and LB^2-Q (k) are the portmanteau Ljung-Box Q test statistics for testing joint significance of autocorrelation of standardized residuals up to 12 lags. LM is the ARCH effect in the standardized squared residuals up to 6 lags. Estimates of constant and covariance terms are not reported in the table.

Table 9. Bivariate GARCH Model between BSE 30 sensex and Ordinary Share Price Index

Variable	Coefficients	Z. Value	P. value
θ_{11}	0.0234	2.456	0.000
θ_{21}	0.3267	1.562	0.014
θ_{12}	-0.0017	-0.045	0.278
θ_{22}	0.0078	0.478	0.175
α_{11}	0.00010	3.451	0.000
α_{22}	-0.89551	-5.159	0.000
β_{11}	0.69373	2.854	0.000
β_{22}	-0.78958	-4.179	0.000
γ_{11}	-0.0032	-0.018	0.378
γ_{22}	0.00072	0.425	0.744
Residual Diagnostics	**Test Statistic**		**P. value**
LBQ (12)	7.8963		0.6789
LBQ^2 (12)	8.2387		0.7892
LM test	6.7521		0.8974

Note: * indicates 1% level of significance. LB-Q (k) and LB^2-Q (k) are the portmanteau Ljung-Box Q test statistics for testing joint significance of autocorrelation of standardized residuals up to 12 lags. LM is the ARCH effect in the standardized squared residuals up to 6 lags. Estimates of constant and covariance terms are not reported in the table.



Source of Data: Reserve Bank of India website

Figure 1. India's Foreign Trade with Selected Partners Million dollars

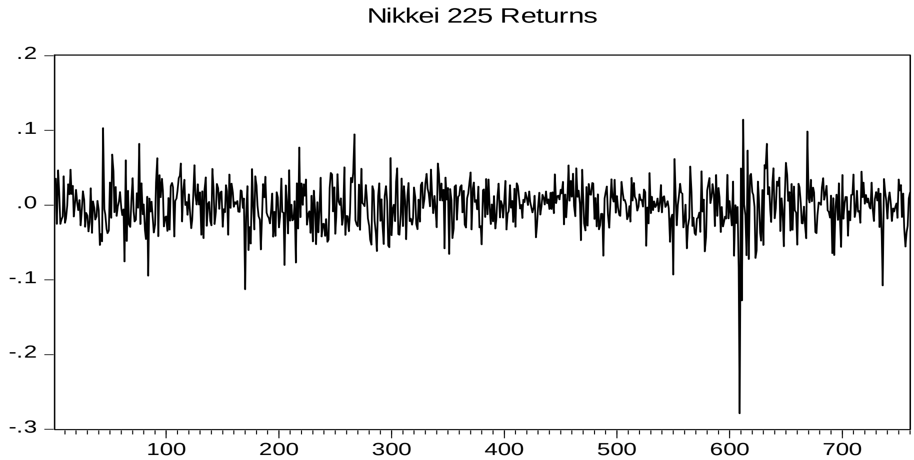


Figure 2. Nikkei 225 Returns

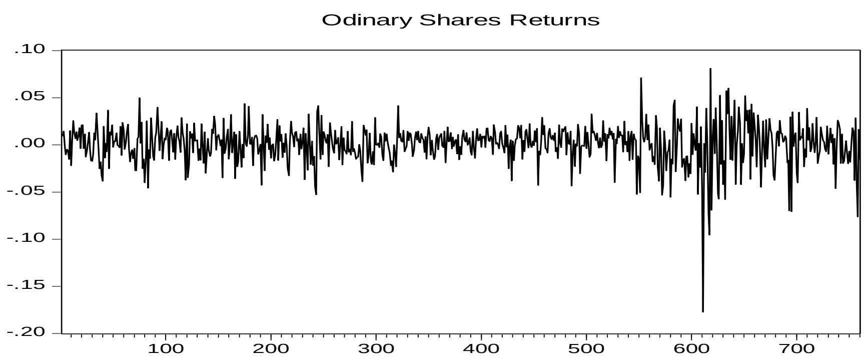


Figure 3. Odinary Shares Returns

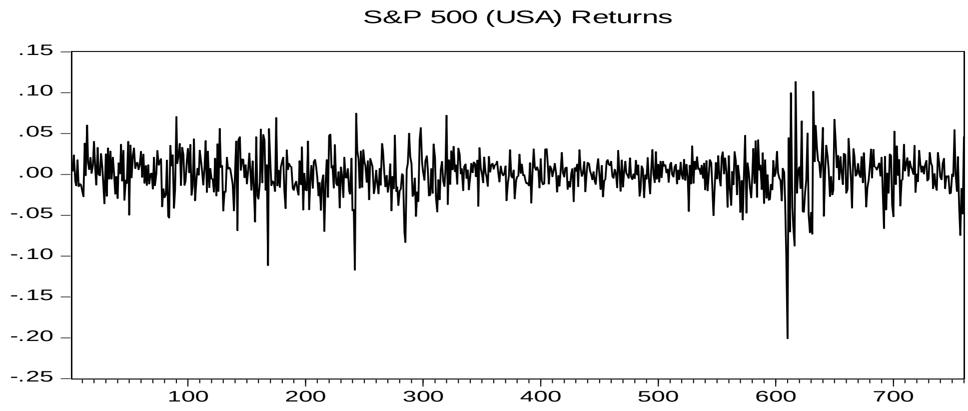


Figure 4. S&P 500 (USA) Reruns

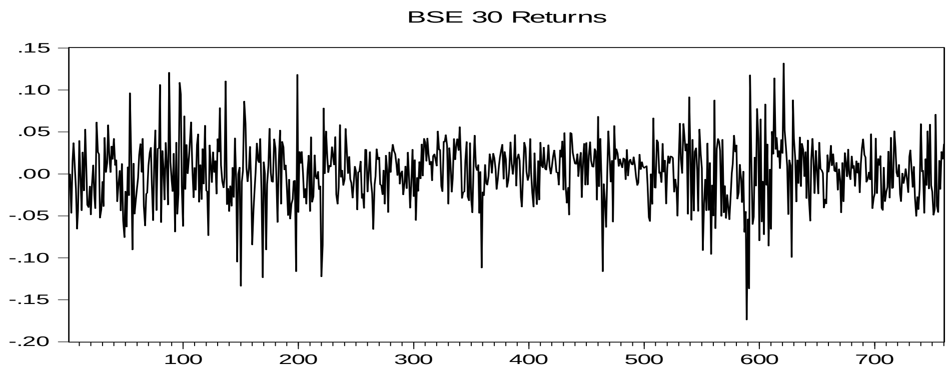


Figure 5. BSE 30 Sensex Returns

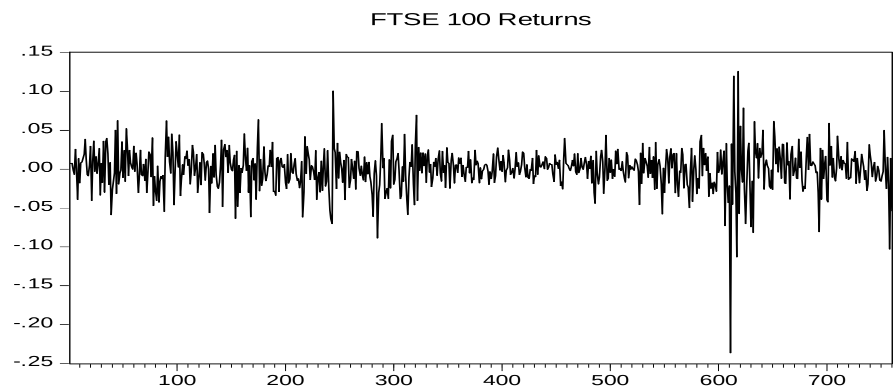


Figure 6. FTSE 100 Returns