SMART

Journal of Business Management Studies

(A Professional, Refereed, International and Indexed Journal)

Vol-17 Number-1 January - June 2021 Rs.500

ISSN 0973-1598 (Print) ISSN 2321-2012 (Online)

Professor MURUGESAN SELVAM, M.Com, MBA, Ph.D, D.Litt
Founder - Publisher and Chief Editor

SCIENTIFIC MANAGEMENT AND ADVANCED RESEARCH TRUST (SMART)

TIRUCHIRAPPALLI (INDIA)
www.smartjournalbms.org

SMART JOURNAL OF BUSINESS MANAGEMENT STUDIES
(A Professional, Refereed, International and Indexed Journal)
www.smartjournalbms.org

DOI : 10.5958/2321-2012.2021.00004.X

VOLATILITY ANALYSIS AND VOLATILITY SPILLOVER ACROSS EQUITY MARKETS BETWEEN INDIA AND EUROPE

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Abstract

This paper is a comparative study of volatility spillover effects in India and European indices.The analysis used various GARCH models, in order to measure conditional volatility (GARCH), asymmetric effect in the conditional volatility (T-GARCH), volatility persistence in conditional volatility (E-GARCH), impact of conditional volatility on conditional returns (M-GARCH) and volatility spillover (GARCH (1, 1), with exogenous variable, for the period 2005 to 2018. The major results, regarding volatility spillover, revealed that Indian stock market had exercised strong impact on selected European indices. Volatility spillover was found to be from Indian stock market to European indices and vice-versa. According to the T-GARCH model, there was significant asymmetric effect on the conditional volatility. The results of E-GARCH model established volatility persistence in conditional volatility.

Keywords: *volatility Spillover, GARCH, Co-Integration, E-GARCH and Asymmetric Volatility*

JEL Code : *C32, C58 and G15*

Paper Received : *29-08-2020* ***Revised :*** *15-09-2020* ***Accepted :*** *03-11-2020*

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1. Introduction

The stock market experiences sharp increase of uncertainty, both at developed and emerging markets. Stock market behavior analysis offers information about the future evolution of the stock market. Volatility spillover can be understood from three different standpoints - bidirectional volatility spillover among stock markets, unidirectional volatility spillover from one stock market to another stock market and vice-versa or non-persistence of volatility spillover among stock markets **(Ngo, 2019).**The co-integrated and interlinked stock markets can lead to a world-wide crash, triggered by a particular news event in one country **(Roll, 1989).** The studies of **Arshanapalli et al., (1995) and Kizys and Pierdzioch, (2011),** among others, have reported the interlinkages among developed markets of USA, Japan and Europe. The interlinkages between US, Japan and Asian markets were evidenced by **Arshanapalli et al. (1995); Anoruo et al. (2003) and (Asgharian et al., 2013),** among others. Further, these studies attributed the decline in the stock indices to the United States stock market crash of October 1987, Asian Financial Crisis of 1997 and Global Financial Crisis of 2008, resulting from co-integration and interlinkages of stock markets. These studies primarily focused on connectedness among the developed stock markets. **Hamao et al. (1990)** found volatility spillover from USA to UK to Japan. In the same line, **Koutmos** and **Booth (1995)** found that negative innovations in the USA, UK and Japan markets increased the volatility in another market to trade more, as compared to positive innovations.

2. Review of Literature

Yilmaz (2010) measured the returns and volatility spillovers in East Asia. He found significant difference in the returns and volatility spillover in the East Asian markets, during the crisis and non-crisis time periods. He concluded that volatility spillovers were more than the return spillovers.**Nath** and **Mishra (2010)** studied co-integration and volatility spillover between India and its Asian neighboring countries. Their results found co-existence of intraday volatility spillovers. These spillovers were found to be bi-directional and significant. They also concluded that there had been substantial flow of information from other Asian countries to India.**Nishimura and Men (2010)** examined volatility spillover effects in equity markets, between China and G5 countries, using the EGARCH model. **Wang and Wang (2010)** studied return and volatility spillover effects between Greater China and US and Japan, for a sample period of over two decades, using daily prices. They found statistically significant flow of volatility spillovers from China to the USA and Japanese markets. **Goudarzi & Ramanarayanan (2010)** studied the Indian market volatility, using GARCH (1, 1) models and found significant implications of the findings for the policy makers. **Gupta et al (2013)** studied various arrays of volatility and their behavior in Indian stock indices. They used GARCH models in the study and concluded that information spillover existed in Indian stock indices and dummy variable coefficient was found to be significant in the improved model. **Uyaebo et al. (2015)** studied the daily all share index of USA, Germany, China and three countries of African region, namely, South Africa, Nigeria and Kenya, by using the daily prices for the period 2000 to 2013. They used various GRACH models, to construct the best suited volatility models for each of the markets, to explain the volatility in the returns of these sample markets. These models were related to reaction of conditional volatility to market shocks **Mohammadi and Tan (2015)** examined the dynamic forces of volatility and daily returns for

USA, China and Hong Kong markets, for a period of 13 years, by using multivariate GARCH models and found that there was unidirectional volatility and returns spillover from the USA market to other markets. They also concluded that there was significant correlation between China and other markets. **Li and Giles (2015)** analyzed the relationship between stock indices across Japan, USA and six Asian countries, for a period of around two decades. They also found unidirectional volatility spillovers from the USA market to Japan and other Asian markets. **Jebran et al. (2017)** studied the volatility spillover among five emerging markets of Asia, before and after the 2007 crisis period. They used multivariate E-GARCH model for the study and found the existence of bi-directional volatility spillover, between India and Sri Lanka, for both before and after the crisis period. For the post-crisis period, unidirectional volatility spillover was found from China market to all other markets in the sample. Their study also measured asymmetric volatility spillover among the sample markets.**Xuan Vinh**and **Ellis (2018)** investigated the co-integration between the Vietnamese market and other developed markets, to study the returns relationship and volatility spillover for the time period of before and after sub-prime crisis of 2008. They used VAR-GARCH-BEKK models and the results were found to be statistically significant. **MacDonald et al. (2018)**examined volatility comparisons and spillover effects within Eurozone markets.

3. Statement of the Problem

This paper proposes to study the volatility comparison and volatility spillover effects in India and European indices.

4. Need of the Study

Volatility spillover has attained great importance in recent times, due to the increasing role of financial markets in the economy across the world. The dynamics of the progress of economy is inevitable. Nowadays the analysis of linkages among global stock markets is gaining importance. Through financial integration, native country can be linked with international capital markets. It becomes critical to understand the relationship among various stock markets for all stakeholders.

5. Objectives of the Study

Based on the previous studies, this study evaluated and compared the volatility and volatility spillovers between Indian stock index (SENSEX) and four markets of the European region.

6. Hypotheses of the Study

NH-1: There are no ARCH or GARCH errors.

NH-2: There is no asymmetric effect of negative and positive shocks on conditional volatility.

NH-3: There is no effect of volatility persistence on imminent conditional volatility.

NH-4: There is no significant impact of conditional volatility of the indices returns on the conditional returns.

NH-5 (a): There is no volatility spillover from SENSEX to European indices.

NH-5 (b): There is no volatility spillover from European indices to SENSEX.

7. Research Methodology

7.1 Sample Selection

To examine the volatility and volatility spillover, Indian index (SENSEX) and four major indices from European Region, namely, France (CAC40), Germany (DAX), Eurozone (EURO STOXX50) and United Kingdom (FTSE100), were identified as the sample.

7.2 Sources of Data

The daily closing prices of selected indices were collected from the official websites of stock exchanges. In case datawere not available for a particular index, data were collected from Bloomberg.

7.3 Period of the Study

The study used the data for the period 2005 to 2018.

7.4 Tools Used in the Study

7.4.1 GARCH (1, 1) Model

For examining the volatility clustering of the markets, ARCH LM test was applied on the residuals of ARMA (1,1) estimation model, for markets in the sample. For investigating the fauna of conditional volatility in the sample indices, GARCH (1,1) model was adopted **(Kumar, 2013).** In GARCH models, systematic variance over the time was allowed, to detect its departure from random walk. GARCH (***p, q***) model, with ***p*** lagged squared error term ***q*** lagged conditional variance term known as GARCH (1, 1) model, which proved to be useful in modelling returns of financial assets. GARCH (1, 1) test was based on following equation:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 \sigma_{t-1}^2 + \varepsilon_t \qquad (1)$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \alpha_1 \sigma_{t-1}^2 \qquad (2)$$

7.4.2 Threshold GARCH Model(T-GARCH)

TGARCH model was adopted in the study, to investigate the asymmetric effect of negative and positive shocks on conditional volatility in the sample indices. There can be asymmetric volatility in the markets because of shocks in the system or various responses of the stakeholders.

$$\sigma_t^2 = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \beta \sigma_{t-1}^2 + \gamma \mu_{t-1}^2 I_{t-1} \qquad (3)$$

7.4.3 Exponential GARCH Model (E-GARCH)

The E-GARCH model can be generalized to describe more lags in the conditional variance. The non-negativity constraints on the parameters are not there in E-GARCH model. The ARCH term was categorized into two independent variables, which indicated the sign effect of shocks on Index volatility and the size (magnitude) effect of shocks on the volatility.

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \gamma \frac{\mu_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{\mu_{t-1}}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}} \right] \qquad (4)$$

7.4.4 GARCH in Mean Model (M-GARCH)

The objective of adopting the M GARCH model was to investigate the response of price discovery process, with respect to any change in conditional volatility. The conditional volatility is found to be significant and positive if the conditional volatility is found to be associated with returns.

$$Index\ Return_t = \alpha + \beta_1 y_{t-1} + \beta_2 \varepsilon_{t-1} + \beta_3 \sigma_t^2 \qquad (5)$$

7.4.5 GARCH (1, 1) Model with Exogenous Variable

For studying the volatility spillover effects of SENSEX on European markets, GARCH (1, 1) model was adopted, including the SENSEX volatility as the exogenous variable in the GARCH equation. (Yilmaz, 2009). For studying the volatility spillover effects of European markets on SENSEX, GARCH (1, 1) model was adopted, including the European market volatility as the exogenous variable in the GARCH equation. The squared residuals of the ARMA (1, 1) model were estimated and they were considered as the volatility substitutes for the sample European markets. Such squared residuals were used as exogenous variable in the model.

$$\sigma_t^2 = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \beta \sigma_{t-1}^2 + \gamma \mu_{t-1}^2 I_{t-1} \qquad (6)$$

8. Data Analysis and Interpretation

8.1 Results of Summary Descriptive Analysis for the Sample Indices

According to the descriptive statistics, depicted in **Table-1,** mean returns of all the indices in the sample were positive. The mean daily return of SENSEX was the highest (0.06) among all the indices, followed by DAX index whereas the average daily return of STOXX50 index was the lowest (0.01) among all the indices. The fact that the emerging markets were more volatile, was evident from statistics on standard deviation of daily returns in these markets. In general, developed market returns were less volatile with standard deviation being lesser than the emerging markets. Skewness values revealed an asymmetrical distribution, with a long tail to the right. All the Kurtosis values of the stock markets, investigated in this study,were more than three, showing a leptokurtic curve, which revealed that the distribution of stock returns in these countries contained extreme values. The values of Kurtosis, recorded by Jarque-Berra statistic, clearly indicated that the returns of these markets ware not normally distributed. The ADF test was performed for each of the index in the sample.

According to **Table-1,** p-value was less than 5% for all the variables,at first difference level. In other words, all the stock indices prices were non-stationary at the original level and they were stationary at the first difference. Volatility clustering was found in each of the indices in the sample, at different levels. As the p – value of F statistics and observed R – squared were less than 1%, it indicated the existence of volatility clustering in the stock markets. The main explanation, for different levels of volatility clustering, may be because of the development of these indices and mysterious behavioral aspects of stockholders.

8.2 Results of GARCH (1.1)Analysis of conditional volatility in the sample indices

For investigating the fauna of conditional volatility in the sample indices, GARCH (1,1) model was adopted. The results of the GARCH (1,1) analysis are shown in the **Table - 2**. The results revealed that the p – value of the co-efficient of ARCH and GARCH was found to be less than 1%. In other words, there was first significant impact of residuals on the GARCH term at 1st lag. The findings also indicated that the sum total of both independent terms was less than one but the projected decaying rate of volatility in the sample indices was different. Hence, the NH-1: There are no ARCH or GARCH errors, was rejected.

8.3 Results of T-GARCH Analysis for Asymmetric Effect in Conditional Volatility

The analysis of asymmetric volatility, as displayed in **Table-3,** revealed that the p-values of slope co-efficient of ARCH term, GARCH term and the dummy variable were found to be significant. Therefore, NH-2: There is no asymmetric effect of negative and positive shocks on conditional volatility, was rejected. In other words, volatility in the sample markets did have significant persistence level and it was affected by the unpredicted shocks. Stakeholders had reported asymmetric response to negative shocks as well as positive shocks.

8.4 Analysis of E-GARCH (1, 1) Model for Persistence in Conditional Volatility

The E-GARCH model indicated the effect of volatility persistence on imminent conditional volatility in the returns of the indices **(Table – 4)**. Hence, NH-3: There is no effect of volatility persistence on imminent conditional volatility, was rejected.In other words, the conditional volatility of the sample indices had inverse relation with the sign of shock. The same relation was indicated by the coefficient of slope.

8.5 Analysis of M-GARCH (1, 1) Model for Impact of Conditional Volatility on Conditional Returns

The results of the M-GARCH model, as exhibited in **Table-5,** revealed that the slope coefficient of the M-GARCH model equation was insignificant. In other words, there was no significant impact of conditional volatility of the indices returns on the conditional returns of these indices. Therefore, NH-4 was accepted. The results revealed that in high volatile periods, selected indices did not provide high returns, as expected as per risk return tradeoff theory. No relationship was found between the conditional volatility and conditional returns of these indices.

8.6 Analysis of Volatility Spillover from Sensex to European Indices

The p-value of SENSEX volatility, as an exogenous variable, was found to be significant for all European indices used in the study. It can be inferred from**Table – 6** that there was volatility spillover, at a significant level, from SENSEX to European Indices. The p-value of European index volatility, as an exogenous variable, was found to be significant for SENSEX. It can be inferred from these results, displayed in **Table-7** that there was volatility spillover, at a significant level, from European Indices to SENSEX.

9. Findings of the Study

This paper investigated volatility and volatility spillover between India and four European indices, using various GARCH models. The results reported volatility clustering in all the indices, used in the study, which were indicated by the residuals of the ARMA (1, 1) estimation model. GARCH (1, 1) model was applied to the sample indices and the slope coefficients of ARCH term and GARCH term were found to be statistically significant, which established the existence of conditional volatility. For comparison of various constituents of conditional volatility in the sample, various GARCH family models were applied on the residuals of ARMA (1, 1) model. The results of T-GARCH model revealed the existence of significant asymmetric effect on the conditional volatility. In other words, the impact of negative shocks was much higher than positive shocks. The results of E-GARCH model proved the existence of volatility persistence in conditional volatility. The slope coefficient of size effect was found to be positive and coefficient of sign effect was found to be negative for all indices. This indicated the inverse relationship of conditional volatility with the sign of the index. The results of M-GARCH model indicated that there was no significant impact of conditional volatility on conditional returns of the indices in the sample.

10. Suggestions

The knowledge of basics and driving forces of volatility and cross correlation among various markets is crucial for stakeholders, policy makers and investors. Previous studies found a very high positive linkage between returns related to shocks and the co-integration among stock markets. This paper observed the development of a new feature of time-varying shock spillover concentrations as the co-integration exercised a vital impact on the cost of equity capital as well as it was considered a significant factor in various macroeconomic models. The results of the study could provide valuable inputs to policy makers, with respect to Indian stock market and the European countries. Market traders, hedgers and portfolio managers will be capable of understanding the interrelation of volatility association among the stock indices. According to **Xuan Vinh and Ellis (2018)**, "globalization and financial integration is the outgoing trend to promote further international connectedness."

11. Conclusion

The results regarding volatility spillover revealed that Indian stock market had exercised strong impact on selected European indices. Volatility spillover was found to be flow from Indian stock market to European indices and vice-versa. The coefficients were found to be positive, which indicated the positive impact of volatility of one market on the other.

12. Limitation of the Study

This study was based on the daily closing price data and seasonal anomalies were ignored. This study was not able to generalize the findings as it had used SENSEX and European indices only.

13. Scope for Further Research

This study can be extended to other indices such as BRIC countries. This study could consider individual stocks or other significant indices (e.g. Nifty-50) as the sample.

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Table 1: Results of Summary Statistics of Sample Indices

	SENSEX	CAC40	DAX	STOXX50	FTSE100
Mean	0.06	0.02	0.04	0.01	0.02
Median	0.09	0.04	0.1	0.02	0.01
Max.	17.34	11.18	11.4	11	9.84
Min.	-10.96	-9.04	-7.16	-7.88	-8.85
Standard Deviation	1.52	1.45	1.4	1.45	1.19
Skewness	0.32	0.2	0.17	0.17	0.03
Kurtosis	12.53	9.48	9.46	9.19	11.33
JB Statistic	10688.63	5121.59	5077.95	4462.43	8548.11
p – value	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	170.96	46.04	115.76	39.37	46.72
Sum. Sq. Deviations	6511.39	6098.94	5713.37	5852.77	4181.57
ADF Test	-49.23^{**}	-56.55^{**}	-54.08^{**}	-26.21^{**}	-26.07^{**}
ARCH Test	76.163^{**}	105.623^{**}	77.307^{**}	127.049^{**}	57.397^{**}

Source: Author's Calculation, ** *Significant at 1% level*

Table 2: Results of GARCH (1, 1) Analysis for Conditional Volatility

Index	Intercept	GARCH (-1)	RESID (-1)^2	Decaying Rate
SENSEX	1.89E-06 (0.0000)**	0.912 (0.0000)**	0.086 (0.0000)**	2.1%
CAC40	4.02E-06 (0.0000)**	0.933 (0.0000)**	0.126 (0.0000)**	1.9%
DAX	3.02E-06 (0.0000)**	0.906 (0.0000)**	0.113 (0.0000)**	1.7%
STOXX50	3.66E-06 (0.0000)**	0.910 (0.0000)**	0.132 (0.0000)**	2.9%
FTSE100	5.14E-06 (0.0000)**	0.932 (0.0000)**	0.087 (0.0000)**	2.1%

*Source: Author's Calculation, ** Significant at 1% level*

Table 3: Results of T-GARCH Analysis for Asymmetric Effect in Conditional Volatility

Index	Intercept	RESID(-1)^2	GARCH (-1)	RESID(-1)^2* RESID(-1)<0
SENSEX	2.05E-06 (0.0000)**	0.048 (0.0000)**	0.912 (0.0000)**	0.111 (0.0000)**
CAC40	4.57E-06 (0.0000)**	-0.005 (0.0000)**	0.891 (0.0000)**	0.212 (0.0000)**
DAX	3.51E-06 (0.0000)**	0.003 (0.0000)**	0.903 (0.0000)**	0.171 (0.0000)**
STOXX50	3.49E-06 (0.0000)**	-0.003 (0.0000)**	0.881 (0.0000)**	0.213 (0.0000)**
FTSE100	5.24E-06 (0.0000)**	-0.009 (0.0000)**	0.921 (0.0000)**	0.136 (0.0000)**

*Source: Author's Calculation, ** Significant at 1% level*

Table 4: Results of E-GARCH Analysis for Persistence in Conditional Volatility

Index	Intercept	GARCH Term	Sign Effect of ARCH Term	Size Effect of ARCH Term
SENSEX	-0.291 (0.0000)**	0.190 (0.0000)**	-0.082 (0.0000)**	0.986 (0.0000)**
CAC40	-0.351 (0.0000)**	0.135 (0.0000)**	-0.153 (0.0000)**	0.975 (0.0000)**
DAX	-0.349 (0.0000)**	0.156 (0.0000)**	-0.126 (0.0000)**	0.974 (0.0000)**
STOXX50	-0.311 (0.0000)**	0.132 (0.0000)**	-0.167 (0.0000)**	0.981 (0.0000)**
FTSE100	-0.240 (0.0000)**	0.101 (0.0000)**	-0.130 (0.0000)**	0.140 (0.0000)**

*Source: Author's Calculation, ** Significant at 1% level*

Table 5: Results of M-GARCH Analysis for Impact of Conditional Volatility on Conditional Returns

Index	Intercept	GARCH Term
SENSEX	0.002 (0.0018)**	0.875 (0.659)
CAC40	0.000 (0.5011)	1.712 (0.391)
DAX	0.000 (0.1812)	2.012 (0.3891)
STOXX50	0.000 (0.3217)	2.612 (0.1715)
FTSE100	-0.002 (0.3801)	3.012 (0.1786)

Source: Author's Calculation

Table 6: Results of Volatility Spillover from SENSEX to European Indices

Index	Intercept	RESID(-1)^2	GARCH (-1)	Volatility Spillover
CAC40	4.62E-06 (0.0000)**	0.131 (0.0000)**	0.833 (0.0000)**	0.033 (0.0000)**
DAX	3.27E-06 (0.0000)**	0.112 (0.0000)**	0.861 (0.0000)**	0.032 (0.0000)**
STOXX50	3.17E-06 (0.0000)**	0.136 (0.0000)**	0.829 (0.0000)**	0.036 (0.0000)**
FTSE100	4.78E-06 (0.0000)**	0.091 (0.0000)**	0.903 (0.0000)**	0.014 (0.0000)**

*Source: Author's Calculation, ** Significant at 1% level*

Table 7: Results of Volatility Spillover from European Indices to SENSEX

Index	Intercept	RESID(-1)^2	GARCH (-1)	Volatility Spillover
CAC40	1.13E-06 (0.0000)**	0.091 (0.0000)**	0.912 (0.0000)**	0.014 (0.0000)**
DAX	1.27E-06 (0.0000)**	0.086 (0.0000)**	0.901 (0.0000)**	0.015 (0.0000)**
STOXX50	1.31E-06 (0.0000)**	0.090 (0.0000)**	0.899 (0.0000)**	0.012 (0.0000)**
FTSE100	1.29E-06 (0.0000)**	0.077 (0.0000)**	0.925 (0.0000)**	0.003 (0.0000)**

*Source: Author's Calculation, ** Significant at 1% level*