Association Between Indian and U.S. Stock Markets : Volatility Spillover Effect Using GARCH Models

** Pushpa M. Savadatti*

Abstract

This paper explored the possibilities of volatility spillover between the Indian stock market and the U.S. stock market. For this purpose, BSE Sensex (India) and Dow Jones (USA) stock market indices were selected, and the analysis was based on the weekly stock returns for a period of 1997 to 2018 using generalized auto regressive conditional heteroscedasticity (GARCH) technique along with Granger - causality test, Augmented Dicky Fuller test, and Phillips - Peron test. The Granger - causality test indicated the existence of unidirectional causation flowing from the American stock market to the Indian stock market. The GARCH (1,1) model was estimated to study the volatility spillover effect between the two markets and the results displayed the existence of volatility spillover from the American stock market (DOW) to the Indian stock market (BSE Sensex) as the spillover coefficient was positive and statistically significant. It was further observed that the volatility in the BSE stock market was highly persistent. The analysis is of great importance to domestic investors, policy makers, companies, and regulatory authorities for effective decision making in the competitive world.

Keywords : **DJIA, BSE, GARCH, Granger-causality test, volatility spillover**

JEL Classification : C22, C32, C53

Paper Submission Date : March 12, 2018 ; Paper sent back for Revision : March 27, 2018 ; Paper Acceptance Date : March 30, 2018

The globalization and liberalization processes have resulted into speedy movement of international capital among countries of the world. Developments in information technology, liberalization of capital markets in developing and developed economies, and surge in financial instrument varieties have added further to the development process and enhancing the importance of financial markets in economies around the world. Stock markets are reflected as economic barometers as they are the direct source of capita for the industry, trade, and commerce of the economy. The stock markets are ,therefore, considered as the engine of economic growth of a country. Stock market fluctuations not only reveal the macroeconomic scenario of an economy, but also the confidence level that domestic and international investors have in an economy. The internationalization of stock markets enhances the association between different stock markets resulting into greater and diverse implications to the domestic economy of a country. 'Securities' pricing in a stock market is highly influenced by the inter - market volatility ; hence, understanding the volatility spillover effects between stock markets becomes important and helps in formulating the regulatory policies of the domestic stock markets. The present study investigates the association between the Indian and U.S. stock markets with the specific objective of measuring the volatility relationship between Indian and the American stock market returns. Due to globalization, capital flows, mutual investments, and trade volumes between India and USA have increased manifold. Therefore, the present paper aims at studying the empirical lead-lag relation between U.S. and Indian stock markets. The results are of great importance to domestic investors, policy makers, companies, and regulatory authorities for effective decision making in the competitive world.

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Literature Review

The importance of the stock markets in the changed world scenario has motivated the researchers to study the relationship between different stock markets with advanced econometric techniques like generalized auto regressive conditional heteroscedasticity (GARCH). The relationship between South Africa and China stock markets was studied with the help of GARCH model and the results revealed the persistence of high volatility in both the markets and similar movements in the returns (Cheteni, 2016). Another study by Patel (2017) made an attempt to explore the association between 14 countries' stock markets based on the daily indices using correlation technique, Granger - causality test, and Johansen cointegration test. The results showed the existence of a long run relationship between the selected markets. Market integration among BRIC countries (Brazil, Russia, India, and China) was investigated using Johansen cointegration test and vector error correction model. The results showed nonexistence of long run causality among the four stock markets, though there existed short run causality flowing from Russia, China, and Brazil's stock markets to the Indian stock market (Aggarwal & Khurana, 2018).

Univariate GARCH models were used to model the stock market volatility from Sudan and Egypt based on daily closing prices, and results provided ample evidence of presence of a positive risk premium in both markets and also significant evidence for asymmetry in stock returns in the two markets (Zakaria, Abdalla, & Winker, 2012). The study was conducted to test the volatility spillover effect between the Indian stock market and foreign exchange market return, and the analysis showed that a long run relationship existed between the two markets and there was information flow between the markets (Mitra, 2017). There are a number of studies which have used the GARCH technique to study the volatility of single stock markets of different countries (Ahmed & Suliman, 2011; Adesina, 2013; Al-Najjar, 2016; Das & Megaravalli, 2017 ; Karthikeyan & Karthika, 2016 ; Maqsood, Safdar, Shafi, & Lelit, 2017 ; Savadatti, 2018). The review of related works provided the required analytical background for the present study.

Research Methodology

(1) Database : The main objective of the study is to examine the association between the Bombay Stock Exchange Sensitive Index, also known as BSE Sensex, which is regarded as the pulse of the domestic stock markets of India and the Dow Jones Industrial Average (DIJA) or simply Dow Jones Stock Market Index of America. For this purpose, the secondary data related to the weekly closing prices of S&P BSE Sensex (India) and Dow Jones Industrial Average (DJIA) or just DOW Stock Market (USA) were collected from the source : finance.yahoo.com website. The data were collected for the period 10 years and 6 months dating from 29-6-1997 to 11-02-2018. The total number of observations available for the study are 1078 excluding public holidays. To create homogeneity in the data series pertaining to BSE and Dow Jones stock market, appropriate adjustments have been made. For the present analysis, weekly returns of the closing prices have been used and are calculated as follows (Savadatti, 2018) :

$$R_t = \log\left(\frac{P_t}{P_{t-1}}\right) \text{---------- (1)}$$

where, R_t is the weekly returns of the BSE and Dow Stock Markets, P_t and P_{t-1} are weekly closing prices at time t and t-1 of BSE and Dow Markets, respectively. The data analysis is carried out with E-views software.

(2) Methodology

(i) Summary Statistics : The various descriptive statistics like mean, variance, skewness, kurtosis, Quantile - Quantile (Q-Q) plot, etc., have been considered to study the properties of the weekly return series.

(ii) Unit Root Tests : Next return series pertaining to BSE and DOW stock markets are to be tested for stationarity using Augmented Dicky Fuller (ADF, 1988), Phillips-Perron (P-P, 1987) tests, and correlogram of the squared residuals of the series.

(iii) Test for ARCH Effects : Further analysis requires the testing for presence of auto regressive conditional heteroscedasticity (ARCH effect) in residuals of the returns series for two markets which has been done with the help of Lagrange multiplier (LM) test. The residuals were calculated from running the conditional mean equation.

(iv) GARCH (1,1) Model : The objective of the paper is to test for volatility transmission between the BSE (India) and DOW (U.S.) stock markets. There is a possibility that volatility in one stock market may induce volatility in another stock market through lead-lag or lag-lead relationship due to the existence of causal association between markets. For this purpose, weekly return series of both the markets are tested for causal association with the help of Granger causality test. Then squared residuals of the return series are generated from the specific volatility procedures and these are used as proxy for the shocks in the other market (Mitra, 2017). GARCH (1,1) model (Bollerslev,1986) is used for the analysis of spillover effect between BSE and DOW stock markets of India and U.S. (Savadatti, 2018).

$$R_t = \mu + \varepsilon_t \text{ ; Mean Equation} \quad \text{---------- (2)}$$

here, R_t is weekly return of both stock indices at time t, μ is intercept, and ε_t is white noise error term.

$$\sigma^2_t = \gamma + \propto \varepsilon^2_{t-1} + \beta\sigma^2_{t-1} + \varphi \in^2_t \text{ ; Variance Equation} \quad \text{---------- (3)}$$

Here, $\gamma > 0, \alpha \geq 0, \beta \geq 0$. σ^2_t is the conditional variance for the BSE weekly return series. ε^2_{t-1} is the lagged ARCH term and σ^2_{t-1} is lagged GARCH term for BSE return series. φ indicates the coefficient of the squared residuals of the DOW stock indices used as proxy for the shocks in the DOW (U.S.) stock market (Mitra, 2017). In the above equation, α is the ARCH parameter and β is the GARCH parameter.

Analysis and Results

This section presents the results of the data analysis for the BSE and DOW stock market weekly return series. The Figure 1 shows the movements in the weekly closing prices of the BSE and DOW stock markets. It is very clear from the Figure 1 that the weekly closing prices of BSE and DOW stock markets had a tendency to move together during the study period. Both the stock prices showed increasing trend with lot of volatility. It may be observed that there was a sharp decline in weekly closing prices in both the markets during 2009. The weekly return series for both the markets are presented in the Figure 2.

Both the return series show a lot of volatility during the study period (Figure 2) and appear to be stationary. The periods of high volatility continued for a longer period followed by the periods of sustained low volatility. This type of fluctuations resulted into volatility clustering as evident from the Figure 2. The return series are fluctuating around mean returns in both the markets, though variances are oscillating.

(1) Descriptive Statistics of BSE & DOW Return Series : In order to understand the properties of the return series in both Indian (BSE) and U.S. (DOW) stock markets, the summary statistics have been calculated and presented in the Table 1. The average returns for BSE index is higher (0.001925) compared to mean returns of the DOW index (0.001079). The values for skewness and kurtosis indicate that the return series for both the markets are not normally distributed. Since the skewness has negative values and the kurtosis is greater than 3 in both the markets,

Figure 1. BSE Sensex (India) and Dow Jones (U.S.) Stock Market Closing Prices

Figure 2. BSE and DJ Weekly Return Series

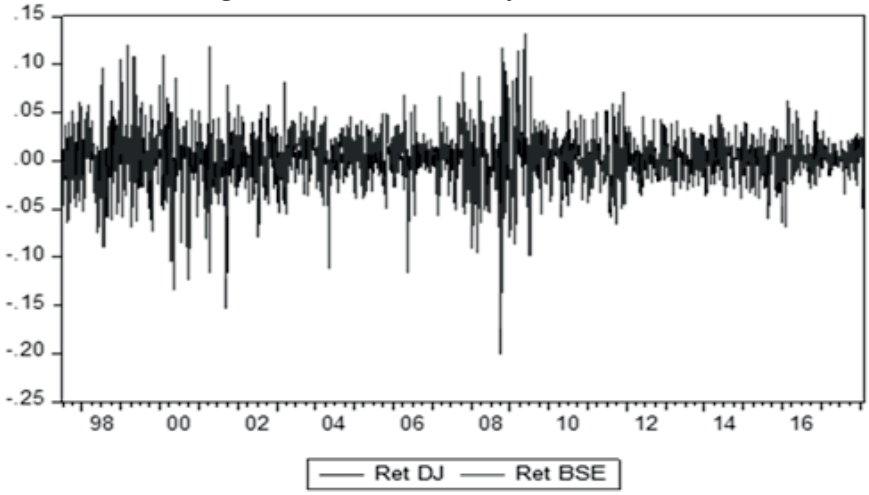
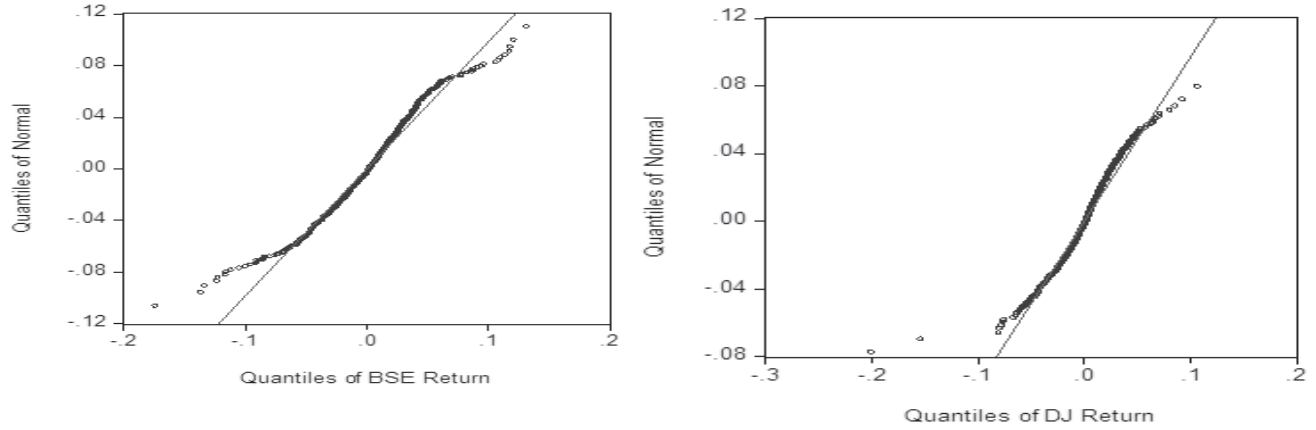


Table 1. Descriptive Statistics for Weekly Returns

BSE Returns		DJ Returns	
Mean	0.001925	Mean	0.001079
Median	0.003886	Median	0.002877
Maximum	0.131709	Maximum	0.106977
Minimum	-0.173808	Minimum	-0.200298
Std. Dev.	0.032680	Std. Dev.	0.023679
Skewness	-0.359297	Skewness	-0.894120
Kurtosis	5.603713	Kurtosis	10.30761
Jarque-Bera	327.0904	Jarque-Bera	2537.522
Probability	0.000000	Probability	0.000000
Observations	1076	Observations	1076

DJ = Dow Jones

Figure 3. Quantile - Quantile Plot for BSE & DJ Return Series



DJ = Dow Jones **BSE Return** **DJ Return**

it signals that both the series show distributions with long left tail and leptokurtic. The Jarque - Bera test has a very high value resulting into very low probability, validating the fact that both BSE and DOW weekly return series are not normally distributed. The Quantile - Quantile plot depicted in Figure 3 also substantiates our understanding that both return series are not normally distributed as the plot of the thick black lines is not along the straight line (Figure 3) but represents 'S' shape (Adesina, 2013).

(2) Unit Root Test Results : The results of unit root test for BSE and DOW weekly return series are presented in the Table 2. The ADF and P-P test results reveal that both the return series are stationary as their probability is < 0.05. Hence, it is concluded that the return series are stationary at levels - *I*(0) at 1% level of significance.

Table 2. Stationary Test Results

BSE Return Series		***t* - Statistic**	**Prob.***
	Augmented Dickey-Fuller test statistic	-31.84354	0.0000
		Adj. *t* - Stat	**Prob.***
	Phillips - Perron test statistic	-31.88117	0.0000
DJ Return Series		***t*-Statistic**	**Prob.***
	Augmented Dickey-Fuller test statistic	-35.45456	0.0000
		Adj. *t*-Stat	**Prob.***
	Phillips - Perron test statistic	-35.42715	0.0000

*MacKinnon (1996) one-sided *p* - values ; DJ = Dow Jones

(3) ARCH Effects - Test Results : The study is interested in analysing the volatility of the return series in the markets which necessitates for testing the presence of heteroscedasticity in the residuals of both the return series. The residuals for both the return series were obtained by running the regression of the conditional mean equation. The Lagrange Multiplier (LM) test results for the residuals are presented in the Table 3. The results provide evidence for the presence of the ARCH effects by rejecting the null hypothesis of no ARCH effects as the probability of the test statistics is < 0.05 for both BSE and DOW weekly return series.

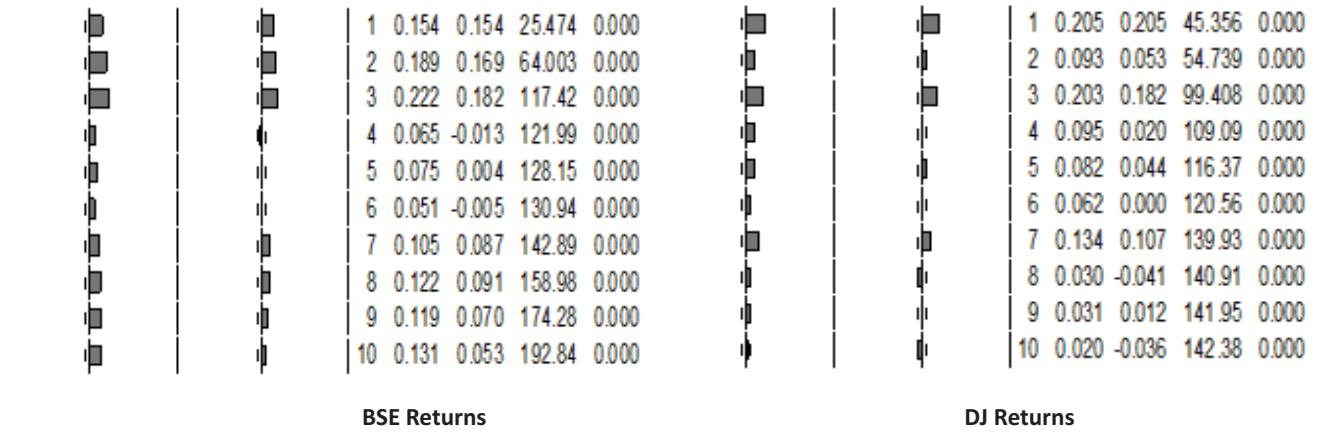
The correlogram of the squared residual series for BSE and DOW weekly return series are shown in the Figure 4. All the auto correlations and partial auto correlations for both the return series are significant as the

Table 3. Heteroscedasticity Test - ARCH-LM (Weekly Returns)

BSE Returns	*F*-statistic	19.32736	Prob. *F*(5, 1065)	0.0000
	Obs**R*-squared	89.09671	Prob. Chi-Square(5)	0.0000
DJ Returns	*F*-statistic	18.22505	Prob. *F*(5, 1065)	0.0000
	Obs**R*-squared	84.41572	Prob. Chi-Square(5)	0.0000

DJ = Dow Jones

Figure 4. Correlogram of Squared Residuals for Weekly Returns



DJ = Dow Jones

probability of Q statistics is less than 0.05, strengthening the fact that there exists ARCH effects in both the weekly return series.

(4) Granger - Causality Test : The main objective of the present analysis is to analyze the volatility spillover between BSE stock market of India and DOW stock market of USA. In order to do this, it is necessary to check whether there exists any causal relationship between BSE stock market and DOW stock market. For this, the Granger-causality test is employed and the results are reported in the Table 4.

It is evident from the Table 4 that DOW weekly returns series Granger causes BSE weekly return series as the probability is < 0.05, but the reverse is not true as the probability is > 0.05. It is concluded that there exists lead-lag relationship between DOW and BSE stock markets. However, BSE return series does not Granger cause Dow return series. This information helps for further analysis of understanding the volatility spillover effect from DOW weekly return series to BSE weekly return series.

The squared residuals of the DOW indices were obtained by fitting the GARCH (1,1) for the DOW weekly return series. These residual squares have been used as an explanatory variable in the volatility equation of BSE

Table 4. Pairwise Granger Causality Test : BSE and DJ Return Series

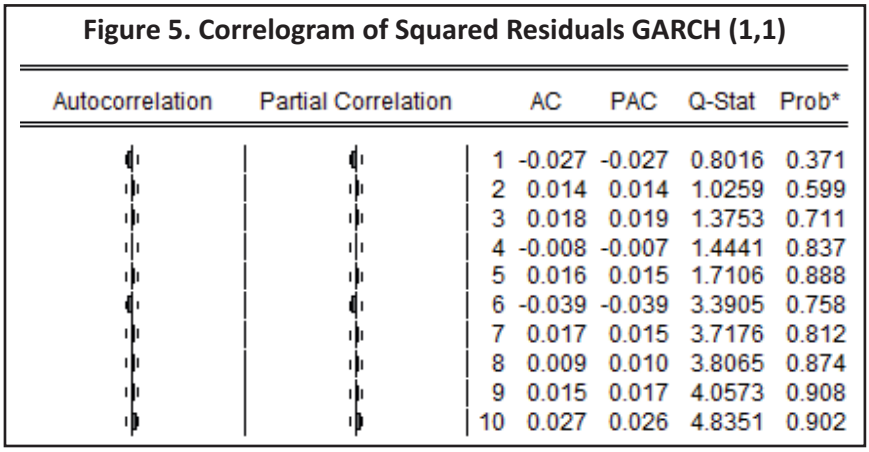
Null Hypothesis	Observations	*F*-Statistic	Probability
DJ Ret does not Granger cause BSE Ret	1074	16.5549	8.E-08
BSE Ret does not Granger cause DJ Ret		0.70659	0.4936

Table 5. GARCH (1,1) Results for Weekly Returns

Mean Equation				
Variable	**Coefficient**	**Std. Error**	***z* -Statistic**	**Prob.**
μ	0.002967***	0.000809	3.666850	0.0002
Variance Equation				
γ	1.24E-05**	5.44E-06	2.285726	0.0223
α (ARCH Effect)	0.093927***	0.016874	5.566431	0.0000
β (GARCH Effect)	0.839506***	0.020731	40.49469	0.0000
α + β	0.933433			
φ (Spill over effect)	0.117298***	0.026667	4.398639	0.0000
R - squared	-0.001019	Mean dependent var	0.001925	
Adjusted *R* - squared	-0.001019	S.D. dependent var	0.032680	
S.E. of regression	0.032697	Akaike info criterion	-4.228494	
Sum squared resid	1.149257	Schwarz criterion	-4.205348	
Log likelihood	2279.930	Hannan-Quinn criter.	-4.219728	
Durbin-Watson stat	1.941485			

***,** indicate significance at 1% and 5% levels, respectively.

Figure 5. Correlogram of Squared Residuals GARCH (1,1)



stock market as proxy for the volatility in the DOW stock market. To test the volatility spillover effect from the DOW (U.S.) stock market weekly return to BSE (India) stock market return, the GARCH (1,1) model is estimated, and the results are presented in the Table 5.

The results show that all the coefficients are significant at the 1% level except 'γ,' which is significant at the 5% level. The value of the GARCH coefficient is larger than estimated ARCH coefficient (Table 5), signalling that the volatility in BSE stock returns is influenced greatly by the previous periods' volatilities than the information about the volatility from the previous periods. The sum of the GARCH and ARCH coefficients, though less than one but close to one, specifies that shocks may decay over a period of time, but slowly. The coefficient of the squared residuals of DOW weekly return series has a positive sign and is significant at the 1% level, indicating that there is volatility spillover from the DOW stock weekly return series to the volatility of BSE stock weekly return series. Hence, the volatility in American stock market (Dow Jones) influences positively and significantly the volatility in the BSE stock market but vice versa, this statement is not true. There exists unidirectional volatility between DOW stock market and BSE stock market volatility.

Table 6. GARCH (1,1) Model Adequacy Tests

ARCH-LM test for Heteroscedasticity - (Residuals)			
F - statistic	0.318737	Prob. *F*(5,1065)	0.9019
Obs**R* - squared	1.600270	Prob. Chi-Square(5)	0.9012
Wald Test for Coefficient Diagnostics			
Test Statistic	**Value**	**Degrees of Freedom**	**Probability**
F-statistic	4528.093	(3, 1071)	0.0000
Chi-square	13584.28	3	0.0000

Null Hypothesis for Wald test : ARCH Coefficient = 0, GARCH Coefficient = 0, Spillover coefficient = 0

The estimated GARCH model is tested for its adequacy by testing for the presence of ARCH effects in the residuals with the help of correlogram of the squared residuals presented in the Figure 5. It may be seen from the Figure 5 that all the auto correlations and partial auto correlations are insignificant as the probability is > 0.05, revealing the absence of ARCH effects in the residuals. The LM test is also used to test for the presence of ARCH effects along with the Wald test to test the collective significance of the coefficients estimated, and the results of the same are presented in the Table 6.

The LM test clearly shows the absence of ARCH effect (conditional heteroscedasticity) in the residuals as the probability is quite high. The Wald test reveals that all the estimated coefficients have significant impact on the volatility of the BSE weekly return series as the probability values are < 0.01. Thus, it may be concluded that the estimated GARCH (1,1) model is adequately specified.

Conclusion and Implications

The present analysis examines the volatility spillover between Indian BSE stock market and American Dow Jones stock market during 1999 to 2018. The purpose of the paper is to test if volatility in weekly returns of the Dow Jones stock market influences the volatility of returns in the Indian BSE stock market. The GARCH (1,1) model is used for the analysis, and results amply support the conclusion that volatility in BSE stock weekly returns are significantly influenced by the volatility in the weekly stock returns of the Dow Jones of U.S. Further results show that the BSE stock returns volatility is also influenced heavily by the previous periods' volatility and news about the volatility from previous periods in the market. Volatility in the BSE stock market is highly persistent. It is also confirmed that there exists volatility spillover from Dow Jones stock market to BSE stock market, and vice versa is not revealed by the results. The analysis is of great importance to domestic investors in managing their investment portfolio and for policy makers, companies, and regulatory authorities for effective decision making in a competitive world.

Limitations of the Study and Scope for Further Research

The present analysis used univariate GARCH model to model the volatility spillover effect between BSE stock returns and DJ stock returns. However, different types of GARCH models are available to capture the other aspects of stock markets : GARCH - M model to find the risk - return relationship, E-GARCH model to capture the asymmetric effects, T-GARCH model to detect the association between asymmetric volatility and returns, and multivariate GARCH models are also useful when more than one variable is involved in the analysis. Further research may be carried out using these techniques to capture other aspects of stock markets around the world.

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INDIAN JOURNAL OF RESEARCH IN CAPITAL MARKETS

Statement about ownership and other particulars about the newspaper "INDIAN JOURNAL OF RESEARCH IN CAPITAL MARKETS" to be published in the 1st issue every year after the last day of February.

FORM 1V
(see Rule 18)

1.	Place of Publication	:	NEW DELHI
2.	Periodicity of Publication	:	QUARTERLY
3.	4,5 Printer, Publisher and Editor's Name	:	S. GILANI
4.	Nationality	:	INDIAN
5.	Address	:	Y-21,HAUZ KHAS, NEW DELHI - 16
6.	Newspaper and Address of individual	:	ASSOCIATED MANAGEMENT
	Who owns the newspaper and partner of	:	CONSULTANTS PRIVATE LIMITED
	Shareholder holding more than one percent.	:	Y-21, HAUZ KHAS, NEW DELHI-16

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DATED : March 1, 2018

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