An Empirical Study on Volatility of International Stock Indices

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Abstract: *Volatility is the measure of uncertainty or the risk present in the value of a particular security. Presence of high volatility in a security means that the value of the security or the stock can change rapidly with the change in the patterns of the market. After globalization, investors have started investing beyond the national boundaries by taking advantages of the global market integration. With respect to this, the given study aims at measuring the volatility and presence of volatility clustering in the international stock market indices. For this purpose, 15 stock market indices have been selected on the basis of market capitalization. The study has considered daily market returns for a period of 5 years (January 2013 to January 2018). PGARCH model has been applied to determine the volatility of the indices. The results of ADF showed that the data is stationary at 1st level difference and significant at 5 percent level. The results of PGARCH showed that the data is heteroscedastic in nature and there is significant volatility. The data is significant at 5 percent level and the data exhibits significant volatility clustering in the selected indices.*

Keywords*: PGARCH, volatility, volatility clustering, ADF Test, International Indices*

1. INTRODUCTION:

With the innovation of new technology and networking system, the new age investors aspire to invest beyond their national boundaries. Markets have started integrating globally and such expansion has also led to the increase in the volatility of these markets. New age innovations have helped companies raise finance beyond the boundaries of their home country. Such increase in the number of trading's and investors have made the markets more volatile. Such increase in volatility has attracted researchers to determine the possible effects of such changes in the market and therefore a lot of studies have been conducted in this field. With this background, the current study aims to focus on the level of volatility of fifteen stock indices and determining the level of volatility clustering using GARCH models.

2. REVIEW OF LITERATURE:

Joshi. P (2011) in this study aims to analyse the comovement of USA, Mexico, Brazil, Chinese and Indian markets. The period of the study was 10 years, i.e., January 1996 to July 2007. It also tries to examine the efficiency of the markets as a result of regulatory measures taken by the regulatory authority (SEBI). The tool used for the study is Johansen and Juselius multivariate cointegration test and vector error correction model for examining the short run dynamics. It was analysed that the markets show a common trend movement. It was also observed that the Indian market showed faster adjustments when compared to the other markets taken into consideration for the purpose of study. It was observed the speed of adjustments in the markets was faster in the years 2002-2007. These results depicted that the regulatory decisions taken by SEBI and made the market more efficient. [1]

Srikanth P, Dr. Aparna. K (2012) try to examine the integration of the stock markets. For the purpose of this study, BSE, NYSE, NASDAQ, S&P 500, Hang Sang, Nikkei225, SSE composite and FTSE100 have been selected. The author examines the level of integration by using correlation t-test. The results of the study showed that there was high level of cointegration among the selected indices. BSE showed the highest coefficient of variation when compared to the other indices taken for the purpose of the study. The conclusion of the study was that there was high level of integration of the Indian markets with the US markets. [2]

Tennant D.F, Tracey M.R (2014) in this paper aim to investigate the volatility of the stock market in developing countries which are denominated by banks and the capital markets are not highly integrated. The tool used for the purpose of the study is Generalized Autoregression. The results of the study show that the improper regulations or unsystematic working culture of the banks may affect stock market volatility. It was also observed that such ineffectiveness of the banks impact industries which depend on external financing and therefore impacting stock market volatility. [3]

Srivastava A (2014) has tried to determine the volatility of the Indian Stock markets. The author has compared the closing prices of National Stock Exchange and Bombay stock Exchange for the purpose of comparison. The period of the study was 6 years i.e., 2008 to 2013. The author has 3 methods to examine volatility i.e., close to close volatility, open to open volatility and Intra- day volatility. The author has collected data from secondary sources. It was concluded that the returns were high in 2008-09 under all the methods but gradually started decreasing because of the stock market crash in the year 2008. The results showed that the market was highly volatile during the recession period and the markets remained volatile even during and after the recession period. [4]

Banumathy K, Azhagaiah R (2015) examines the volatility of the Indian stock market. The period of the study was from January 2003 to December 2012. The author has used models like GARCH, TGARCH, Akaike information Criterion and Schwaz Information Criterion for estimating the results. The results showed that the coefficients were insignificant and the increase in the risk did not increase the returns. The market showed high volatility during the selected period. [5]

3. METHODOLOGY:

The objectives of the study are:

1) To study the volatility of the selected international stock indices.
2) To study the volatility clustering effect of the selected international stock indices.

The study is entirely based on secondary sources. The indices are selected on the basis of market capitalization as per the data provided on the World Federation of Exchanges database and the closing prices are taken from yahoo finance and the respective websites of the selected indices. The data is collected for the period of 5 years i.e., January 2013 to January 2018. Daily closing prices are taken into consideration for the calculations of log returns. The following table shows the selected stock indices and their respective market capitalization (as given in the world federation of exchanges database)

Table: List of Stock Indices on the basis of Market Capitalization

SL NO.	STOCK INDEX	MARKET CAPITALIZATION (IN TRILLIONS)	SL NO.	STOCK INDEX	MARKET CAPITALIZATION (IN TRILLIONS)
1	NYSE Group	19.22	9	TMX Group	1.94
2	NASDAQ	6.83	10	Deutsche Borsé	1.76
3	London Stock Exchange	6.19	11	Bombay Stock Exchange	1.68
4	Japan Stock Exchange	4.48	12	National Stock Exchange	1.64
5	Shanghai Composite	3.99	13	Six Swiss Exchange	1.52
6	Hong Kong Stock Exchange	3.32	14	Australian Securities Exchange	1.27
7	Euronext	3.22	15	Korea Exchange	1.25
8	Shenzhen Stock Exchange	2.28			

Source: World Federation of Exchanges database

The returns of the stock indices were calculated on the logged differences using the following formula:

$$\mathbf{R_t = \ln (P_t) - \ln (P_{t-1})}$$

Where, R_t is the daily return of the closing prices of the indices, P_t indicates the closing price of the index at time t and Pt-1 indicates the price of the index at time t-1. EViews 9.5 student version was used for the purpose of analysis of the data.

3.1 TOOLS USED FOR THE STUDY:

The tools used for the study were descriptive statistics, Augmented Dicky-Fuller test, PGARCH and ARCH LM test.

Generalized ARCH Model

Bollerslev (1986) generalized ARCH model developed by Engle (1982). He defined conditional variance as an Autoregressive Moving Average (ARMA) process. GARCH process introduces the lagged conditional variance as a regressor (Bollerslev, 1986). The GARCH model allows the conditional variance to be dependent up on previous own lags (Source: Econometrics in Finance, Chris Books). The general equation of GARCH Model is given below:

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

Source: Banumathy K, Azhagaiah R (2015) [5]

Using the GARCH model it is possible to interpret the current fitted variance, σ_t^2; as a weighted function of a long-term average value (dependent on ω), information about volatility during the previous period ($\alpha\varepsilon_{t-1}^2$) and the fitted variance from the model during the previous period ($\beta\sigma_{t-1}^2$). (Source: Econometrics in Finance, Chris Books) [7]

Power ARCH Model

Ding, Granger and Engle (1993) defined a new model called the Power ARCH Model. In the model, the coefficients of the variables can be either positive or negative and the power term (δ) can be estimated rather than using the squared values as in the GARCH model. The Power GARCH model is represented in the equation below:

$$\sigma_t^{\delta} = \alpha_0 + \sum_{i=1}^{p} \propto_i (|\varepsilon_{t-1}| + \gamma_i \varepsilon_{t-i})^{\delta} + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^{\delta}$$

Source: N N, G R Ram, Angadi S H (2017) [6]

Where, σ_t^{δ} is the variance for the time period t, α_0 is the unconditional variance or the constant, ε_{t-1} is the lagged residuals from the mean equation and σ_{t-j}^{δ} is the lagged forecasted variance. In the PGARCH model, if $\gamma \neq 0$, this captures asymmetric effects. The PGARCH model reduces to the GARCH model when $\delta = 2$ and $\gamma_i = 0$ for all i. (Source: Wiphatthanananthakul, C., & Sriboonchitta, S (2010)).

4. LIMITATIONS OF THE STUDY:

- The period of the study is only 5 years.
- The composition of the selected indices is ignored
- The methodology of calculating index is ignored.

5. ANALYSIS:

Descriptive Statistics

The descriptive statistics for the selected indices have been presented in the table below.

Table: Descriptive Statistics

Index	Mean	Median	Max	Min	Std. Dev	Skewness	Kurtosis	Jarque-Bera
NYSE	0.000523	0.00055	0.038291	-0.04021	0.007448	-0.44436	5.901228	489.7475(0.0000)
NASDAQ	0.000708	0.001084	0.041520	-0.04202	0.008802	-0.50923	5.364078	352.8406(0.0000)
LSE	0.001003	0.000513	0.128438	-0.08984	0.015411	0.342418	10.77229	3251.869(0.0000)
JAPAN	0.000627	0.000779	0.074262	-0.08252	0.013929	-0.34454	7.381368	1018.806(0.0000)
SSE INDEX	0.000362	0.000785	0.056036	-0.08873	0.015813	-1.26539	10.48028	3206.318(0.0000)
HANG SANG	0.000568	0.00001	0.076780	-0.08097	0.013565	-0.28988	7.950511	1297.047(0.0000)
EURONEXT	0.000326	0.000586	0.040105	-0.06958	0.001016	-0.41419	6.67699	767.7457(0.0000)
SZSE COMPOSITE	0.000345	0.000784	0.056036	-0.08873	0.014808	-1.26147	10.47069	3199.495(0.0000)
TMX	0.000323	0.000496	0.073920	-0.10850	0.013766	-0.64579	9.245444	2155.709(0.0000)
DEUTSCHE	0.000743	0.000729	0.056529	-0.09716	0.013802	-0.19239	5.848027	442.9062(0.0000)
BSE	0.000486	0.000613	0.037034	-0.06119	0.008984	-0.40389	6.000837	505.0099(0.0000)
NSE	0.000495	0.000588	0.037380	-0.06097	0.009141	-0.41241	5.901228	502.1661(0.0000)
SIX SWISS	0.000232	0.000586	0.033658	-0.09070	0.009325	-1.09543	12.47230	5009.791(0.0000)
ASE	0.000454	0.000568	0.034897	-0.06240	0.010241	-0.51721	5.799830	476.6356(0.0000)
KOREA	0.000198	0.000308	0.029124	-0.03143	0.007192	-0.19282	4.591115	138.9322(0.0000)

Source: Author's calculation

The above table shows the summary of descriptive statistics of the selected indices. It can be observed that Korea Stock Exchange has the lowest mean among all the selected indices and London Stock Exchange has the highest mean. It is also observed that the standard deviation value of Shanghai Stock Exchange is the highest and

Euronext has the lowest standard deviation. The skewness is negative for all the indices except for London Stock Exchange. The kurtosis values are the highest for Six Swiss group and lowest for Korea Stock Exchange. The Jarque-Bera test for all the indices is significant at 5% level indicating that the closing prices are not distributed normally.

Results of the Augmented Dicky-Fuller Test

Unit root tests are conducted to check if the data is stationary or not. For this purpose, ADF test is conducted to check the stationarity of the data collected for the purpose of the study. The results are represented below:

Table: ADF Test Results

SL NO.	INDEX	ADF t-STATISTIC	PROBABILITY
1	NEWYORK STOCK EXCHANGE	-15.39661	0.0000
2	NASDAQ	-15.38900	0.0000
3	LONDON STOCK EXCHANGE	-17.56172	0.0000
4	JAPAN STOCK EXCHANGE	-20.68089	0.0000
5	SHANGHAI STOCK EXCHANGE	-14.85561	0.0000
6	HONG KONG STOCK EXCHANGE	-17.17449	0.0000
7	EURONEXT	-15.84215	0.0000
8	SHENZHEN STOCK EXCHANGE	-14.81772	0.0000
9	TMX GROUP	-20.10205	0.0000
10	DEUTSCHE BORSE STOCK EXCHANGE	-19.22869	0.0000
11	BOMBAY STOCK EXCHANGE	-19.22869	0.0000
12	NATIONAL STOCK EXCHANGE	-17.24583	0.0000
13	SIX SWISS EXCHANGE	-15.43874	0.0000
14	AUSTRALIAN SECURITIES EXCHANGE	-19.22869	0.0000
15	KOREA STOCK EXCHANGE	-15.75050	0.0000

Source: Author's calculation

ADF test uses the null hypothesis which states that the data is non stationary or has unit root. For the null hypothesis to be rejected, the probability values should be less than 0.05. From the above table, it can be observed that the probability values for all the indices are less than 0.05 which implies that the data is stationary and hence therefore, the null hypothesis is rejected. It can be inferred that the probability values of all the indices are stationary at 5 percent level. The data is stationary at this level and therefore the null hypothesis is rejected.

Results of PGARCH Volatility

Table: PGARCH ESTIMATES

INDEX	ARCH TERM (α_i)	ASYMMETRIC TERM (γ_i)	GARCH TERM (β_j)	POWER TERM (δ)
NEWYORK STOCK EXCHANGE	0.108553 (0.0000)	1.000000 (0.0000)	0.872787 (0.0000)	0.489553 (0.0000)
NASDAQ	0.095609 (0.0000)	1.000000 (0.0000)	0.863472 (0.0000)	0.491312 (0.0000)
LONDON STOCK EXCHANGE	0.127423 (0.0000)	0.614072 (0.0000)	0.850855 (0.0000)	0.521804 (0.0000)
JAPAN STOCK EXCHANGE	0.122409 (0.0000)	0.5883575 (0.0000)	0.867854 (0.0000)	0.792159 (0.0000)
SHANGHAI STOCK EXCHANGE	0.065116 (0.0000)	-0.044657 (0.3471)	0.948717 (0.0000)	1.329523 (0.0000)
HONG KONG STOCK EXCHANGE	0.016184 (0.0118)	0.224105 (0.0054)	0.931391 (0.0000)	3.009984 (0.0000)
EURONEXT	0.078673 (0.0000)	0.999947 (0.0000)	0.897194 (0.0000)	1.294278 (0.0000)

SHENZHEN STOCK EXCHANGE	0.065214 (0.0000)	-0.050567 (0.2902)	0.948868 (0.0000)	1.310643 (0.0000)
TMX GROUP	0.110427 (0.0000)	0.514130 (0.0000)	0.785138 (0.0000)	0.813438 (0.0000)
DEUTSCHE BORSE STOCK EXCHANGE	0.100294 (0.0000)	0.490616 (0.0000)	0.838302 (0.0000)	0.522966 (0.0074)
BOMBAY STOCK EXCHANGE	0.050283 (0.0000)	0.999982 (0.0000)	0.944349 (0.0000)	0.849342 (0.0000)
NATIONAL STOCK EXCHANGE	0.052884 (0.0000)	0.997992 (0.0000)	0.945678 (0.0000)	0.751822 (0.0001)
SIX SWISS EXCHANGE	0.130243 (0.0000)	0.641565 (0.0000)	0.850576 (0.0000)	0.873931 (0.0000)
AUSTRALIAN SECURITIES EXCHANGE	0.042114 (0.0000)	-0.029123 (0.7036)	0.959039 (0.0000)	1.308918 (0.0027)
KOREA STOCK EXCHANGE	0.038184 (0.0000)	1.00000 (0.0000)	0.940403 (0.0000)	0.610855 (0.0003)

Source: Author's calculation

For the purpose of the study, PGARCH model was used to determine the conditional variance. The results of the test are represented in the above table. To determine the level of volatility, the ARCH term is estimated. The ARCH ($\propto_i$) term determines the level of volatility for the indices selected for the study. The ARCH term is significant at 5 percent level for all the selected indices. Most of the markets showed high volatility in the 2016 possibly because of Brexit and Greek crisis which occurred during this period.

The asymmetric term (γ_i) represents the impact of negative news of the previous day as a positive effect on the prices for the next day. This is known as leverage effect. The asymmetric term was significant for all the indices except Shanghai Stock Exchange, Shenzhen stock Exchange and Australia Securities Exchange. This means that all the stock indices show leverage effect in price volatility except for Shanghai Stock Exchange, Shenzhen Stock Exchange and the Australia Securities Exchange.

The volatility clustering effect is explained by the GARCH (β_j) term from the table above. It can be observed that the GARCH term for all the indices is significant at 5 percent level. From this, it can be inferred that there is significant volatility clustering among the prices of the selected stock indices. The estimated power transmission coefficient (δ) ranges from 0.49 to 3; which is differentiated from the generalized squared power.

Results of ARCH LM Test

Table: Results of ARCH LM test

Index	Obs* R Squared Values	Probability
NEWYORK STOCK EXCHANGE	2.0909326	0.1482
NASDAQ	0.103891	0.7472
LONDON STOCK EXCHANGE	1.288650	0.2563
JAPAN STOCK EXCHANGE	0.292785	0.5884
SHANGHAI STOCK EXCHANGE	0.716394	0.3973
HONG KONG STOCK EXCHANGE	0.339406	0.5602
EURONEXT	0.009404	0.9227
SHENZHEN STOCK EXCHANGE	0.742134	0.3890
TMX GROUP	0.002193	0.9627
DEUTSCHE BORSE STOCK EXCHANGE	0.254946	0.6136
BOMBAY STOCK EXCHANGE	2.010699	0.1562
NATIONAL STOCK EXCHANGE	1.887437	0.1695
SIX SWISS EXCHANGE	1.045936	0.3064
AUSTRALIAN SECURITIES EXCHANGE	8.888901	0.0639
KOREA STOCK EXCHANGE	0.089067	0.7654

Source: Author's calculations

ARCH LM (Lagrange multiplier test) is the test used to determine the significance of ARCH effects. The results of the test are represented in the table above. The null hypothesis for such test would be that the PGARCH residuals do not have ARCH type of heteroscedasticity. If the residual do not have ARCH type of heteroscedasticity then it can be inferred that the PGARCH model is fitted well on the selected data. From the above table it can be observed that the probability values of all the indices are above 0.05 and hence null hypothesis can be accepted. Therefore, it can be inferred that the PGARCH model fits the study well and the residual are free from ARCH type of heteroscedasticity.

6. FINDINGS:

The analysis of the study show that the data collected is stationary and therefore further models can be applied to run the objectives. The PGARCH results exhibit that the markets are volatile during the study period among which London Stock Exchange exhibited the highest level of volatility. All the indices assumed the leverage effect except for Shanghai Stock Exchange, Shenzhen Stock Exchange and the Australia Securities Exchange. The analysis also showed that there is significant volatility clustering in the indices selected for the study. ARCH-LM test was conducted to examine the significance of the ARCH effects and the results concluded that the PGARCH model fits the study well and the residuals are heteroscedastic in nature.

7. CONCLUSION:

The study focused on analysing the level of stock market volatility of 15 international stock indices. The closing prices were considered for a period of 5 years i.e., (January 2013 to January 2018). The results showed there markets were highly volatile and had volatility clustering effect during the selected period. The results of PGARCH model proved the presence of volatility clustering effect in the selected indices. The presence of leverage effect showed that the asymmetric model perform better than the symmetric models like GARCH. During the study, it was also observed that the markets were highly volatile during the year 2016, which was a result of Brexit and Greek Crisis. Both the economic factors impacted the global markets causing high fluctuations in the movement of the prices. London stock exchange showed the highest volatility during the entire period of study. With this it can be concluded that the selected markets have high volatility and volatility clustering effect and the model used fits the data well.

8. RECOMMONDATIONS:

- Further studies can use the volume traded information and check the impact of the same on the volatility of the indices.
- New algorithms like R and python can be used to study volatility.
- An event study can be conducted to check the recent fall in the global market indices.

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