Analyzing spillovers in International Stock Markets: A Multivariate GARCH Approach

Taufeeque Ahmad Siddiqui[1*] & Mazia Fatima Khan[2]

[1]*Assistant Professor, Centre for Management Studies, Jamia Millia Islamia, New Delhi
[2]Research Scholar, Centre for Management Studies, Jamia Millia Islamia, New Delhi

Abstract

Equity markets provide scope for diversification and risk reduction for investors and aid policy makers in developing appropriate strategies, therefore it is imperative to learn about the co movements and transmissions of volatility prevailing within these markets . Spillovers expedite comprehension of cross market effects in a financial downturn. The study attempts to examine the spillovers among advanced nations (U.S, Japan) and developing markets (India and China) in a Multivariate framework, to comprehend a holistic picture of linkages. For this purpose daily returns are taken from January1 2008 to December 31 2018. Along with Descriptive statistics, Augmented Dickey fuller test is used to check the stationarity of the series. Multivariate model namely BEKK GARCH is applied to capture the spillovers among the selected equity markets. The results suggest the presence of spillovers among the indices of sample countries.

Keywords: Spillovers, BEKK GARCH, Stationarity, Volatility

Introduction

According to Ezzati (2012) when there is a price change of an asset with time, it is termed as 'financial volatility'. International equity markets facilitate advantageous opportunities for investors by understanding patterns of volatility and making it possible to reap the benefits of growth within other markets. Several studies have examined the interaction and behavior of markets, some have scrutinized long run integration among the variables (Wuthisatian. 2015, Assidenou.2011, Dimpfl. 2014, Guidi. 2014) but the subject of spillovers transmission is evolving. Spillovers can be described as changes in the fundamentals of one economy that could affect other economies as well. The effect of spillovers is different during volatile periods than stable periods and this may reduce the return and may result in Financial Contagion (Ng. 2000). "Spillovers need to be closely attended to especially in the light of interconnectedness of global financial markets" Frank et al (2009).

For exploring the co movements of markets Univariate as well as Multivariate analysis have been adopted in the literature. Many researchers have given preference to the univariate modeling such as the GARCH model of Bollerslev (1986) and its extensions and others like Wang and Wu (2012) who state that the performance of Multivariate models is better. After the introduction of VEC GARCH model by Bollerslev, Engle and Wooldridge (1988), several other modeling techniques have been analyzed. Vardar et al,.(2018) suggest that BEKK model describes well the volatility of a market as well as the spillovers from other markets that affect the dynamics of returns.

Ng (2000) worked on volatility spillovers present in the selected markets of pacific basin region from the advanced nations like U.S and Japan and found that these markets contribute to the level of existing volatility. Present research is directed to observe the equity markets of developed nations such as U.S and Japan, the two most dominant markets. To represent emerging markets India and China are explored. Purpose is to determine the

***Corresponding Author:**
Taufeeque Ahmad Siddiqui, Assistant Professor, Centre for Management Studies, Jamia Millia Islamia, New Delhi
Email : taufeeque@gmail.com, Tel.: +91 9719667004

existence of spillovers among them so that policy makers and investors make appropriate strategic decisions.

Literature Review

Baele (2005) finds the presence of financial contagion among thirteen countries of Europe from equity markets of U.S using regime switching models. Possible contributors of spillovers are cited as low inflation, advancement of stock markets and increase in linkages of trade., **Caceres (2003)** also examined the exchange rate dynamics among the two nations, Guatemala and El Salvador. Framework of study is based on a mechanism of spillovers. The study deploys GARCH model to recognize the impact of one currency on another and also Probit model and Granger causality to provide insight about the nature of cross-market transmissions. It was concluded that El Salvador is impacted by its counterpart nation.

There are Other studies based on spillovers among commodity markets. **Barunik et al (2015)** carried forward the works of Diebold and Yilmaz (2009) and Barndorff et al (2010) to demonstrate the short run interdependence. To discover the impact of crude oil, gasoline and heating oil on each other the sample period is taken from the year 1987 to 2014. It is pointed out that after the financial crisis of 2008 the influence of negative effect is more like the impact of positive effect on the variables under consideration. **In same direction Guesmi and Boubaker (2016)** suggest that corrected dynamic conditional correlation fractionally integrated asymmetric power ARCH (C-DCC-FIAPARCH) model is competent to model spillovers between the Brent crude oil and equity markets of USA and France. It was empirically found that the dynamic correlations are higher than usual levels during downturns and reach normal levels during tranquil periods. **Likewise, Sinha et al (2017)** explored the futures and spot price of Black pepper using Johansen Co-integration test, VEC BEKK and DCC model. The paper concludes an increase in the short run interdependence only in one period.

In another study transmissions from U.S to other markets have been assessed. **Grosvernor and Greenidge (2010)** study the linkages among three markets of the Caribbean region namely Jamaica, Trinidad and Barbados and one Developed market namely U.S. The time period of study is from 2005 to 2008. Both univariate and multivariate models are used to suggest that indeed there are transmissions from U.S to these markets. **Likewise, Karolyi (1995) has** also explored the connections of U.S equity index with the stock market of Canada and show that the influence of former on latter is of lesser degree. The econometric tools employed are Bivariate M-GARCH, VAR,MGARCH CC, Univariate GARCH. **Also , Hamao et al (1990) pointed** that there exists transmission of volatility from U.S and U.K to Japan using GARCH –M model. **One more study finds** transfer of volatility from US to other countries. **Li and Giles (2013)** made an overview of Asian financial crisis of 1997 and global financial crisis of 2007-2008 by using MGARCH model for a 20 year period on two developed markets namely US and Japan to six emerging markets and revealed that there was unidirectional transfer of volatility from US to other sample countries.

There are studies which are based on analyzing spillover within a region, such as, **Hammoudeh et al (2009). The** study is focused to seek the characteristics of Gulf nations by comprehensive analysis of spillover among Service, Banking and Insurance sectors of each country in the sample. Results of VAR (1) GARCH model suggests optimal portfolios for investment. **In the same sense Kenourgios (2010)** worked on the BRIC stock market as well as U.S and U.K to observe the presence of asymmetry in financial returns by applying regime switching copula and AG-DCC model. Data was taken from the year 1995 to 2006.Contagion was documented in all the crises period.

Another study based on a region is by **Joshi (2011). The author** works on the spillovers experienced by the markets in Asian region by applying Asymmetric Multivariate BEKK-GARCH model, the markets for the study comprised of India, Hong Kong, Japan, China, Jakarta and Korea from February 2 ,2007 to February 28, 2010. It is found that there is volatility spillover among majority of the indices.

There is one more study based on different sectors but of a same country is by **Wu and Li (2013). They** consider crude oil, corn and fuel ethanol that reflects the commodity market of China. co movements among them have been assessed. The span of study is September 5, 2003 to August 31, 2012. Using weekly data and univariate GARCH and BEKK MVGARCH study suggest an increase in spillovers aftermath of 2008.

Several studies have considered India also, such as, **Joshi (2011), Siddiqui and Khan (2017) and Li and Giles (2013). Siddiqui and Khan (2017)** use univariate GARCH model to identify the volatility of India and China's equity markets. **Similarly, Dey and Sampath (2017)** suggest that gold can be used against the risk the equity stocks of two sectors namely, financial services and information technology companies. The analysis put to use BEKK GARCH, CCC GARCH, DCC GARCH and Diagonal GARCH with VAR framework.

Several studies have tried to find the best model to forecast volatility. **Caporin and Aleer (2010)** explored the Multivariate GARCH models that are able to predict the forecast the volatility present in stock markets. The analysis included wide range of models from CCC model to DCC model, Scalar BEKK and Weighted moving average approach. Researchers couldn't conclude a single best model as a preferred one.

Research Gap

Evaluation of literature suggest that various characteristics of financial market volatility have been worked on including the spillover effects which play a major role at the time of financial instability therefore modeling of short run interdependence is crucial for global financial architecture. Multivariate analysis has an advantage over univariate analysis as Joint distribution of returns covers all the available information about the stock markets. This study proposes a robust model for determining spillover effects among the advanced economies of U.S, Japan and developing markets of India and China.

Objectives

To ascertain own market volatility spillovers among the stock markets of four major Developed and Emerging economies(USA, Japan, China and India).

To determine cross market volatility spillovers among the stock markets of four major Developed and Emerging economies(USA, Japan, China and India).

Hypothesis

Ho: There is no spillover among the indices of USA, Japan, India and China

Research Methodology

The Data for the purpose of analysis is from Jan 1 2008 to Dec 31 2018. The Indices selected for the study are S&P 500 of USA, Nikkei 225 of Japan, Nifty of India and Shanghai composite of China.

The daily returns are calculated with the help of closing prices using following equation:-

$Rt = \ln(Pt/Pt\text{-}1)*100$

To check the stationarity of the series Augmented Dickey fuller test is carried out. The model used for the analysis of spillovers is Multivariate BEKK GARCH (1,1).

BEKK model

$$y_t = \mu_t(\Theta) + \varepsilon_t$$

$$H_t = C'C + A_i'\varepsilon_{t-1}'\varepsilon_{t-1}A_i + B'_i H_{t-1} B$$

Here C represents the upper triangular matrix and A and B are diagonal variance- covariance matrices. Diagonal elements provide with own market shocks and volatility, whereas off diagonal suggest the impact of shocks of one country on another. This model is an extension of Univariate GARCH model and assures the semi definiteness of the variance covariance matrix. This is what that makes it robust in computation and an edge over previous models such VECH .

"The coefficients of matrices A and B indicate the innovations in each specific market and the persistence or the rate of the decay of news in each specific market respectively" Antonakakis (2008)

Empirical Analysis-

Table-1: **Descriptive Statistics**

	S&P 500	NIFTY	Nikkei 225	SSE Composite
Mean	0.000271	0.000415	0.000116	8.43E-05
Median	0.000733	0.000563	0.000647	0.000731
Std Dev	0.013722	0.016024	0016996	0.018769
Skewness	-0.516976	-0.282216	-0.658289	-0.542946
Jarque Bera	18236.87	1817.33	7033.492	2057,713
Prob	0.000000	0.000000	0.000000	0.000000

Table -1 demonstrates that the US market is the least volatile as it has the lowest standard deviation whereas the return series of all markets are negatively skewed. The results of Jarque-bera statistics reject the normality of returns hypothesis.

UNIT ROOT TEST OF STATIONARITY–

Table-2: **Augmented Dickey fuller test**

	At level		At first difference	
	t stat	Prob	t stat	Prob
S&P 500	0.668766	0.9915	-51.96337	0.0001
NIFTY	-0.127436	0.9447	-47.37766	0.0001
Nikkei 225	-0.504478	0.8879	-49.75683	0.0001
SSE	-1.876713	0.3436	-48.47789	0.0001

Table -2 indicates that the return series are non stationary at level with probability values of 99%(S&P 500), 94%(Nifty), 88%(Nikkei 225)and 34 %(SSE composite). The series became stationary after taking the First difference with 0 probability values for all the markets.

Table-3: **BEKK GARCH**

Variable	Coeff	Std Error	T-Stat	Signif
Mean(1)	0.000410290	0.000125697	3.26411	0.00109809
Mean(2)	0.000568084	0.000236530	2.40174	0.01631708
Mean(3)	0.000445576	0.000155581	2.86395	0.00418392
Mean(4)	0.000141311	0.000353231	0.40005	0.68911773
C(1,1)	0.002256610	0.000207005	10.90121	0.00000000
C(2,1)	0.005126896	0.000688536	7.44608	0.00000000
C(2,2)	0.005033257	0.000571430	8.8018	0.0000000

C(3,1)	0.001396970	0.000263832	5.29492	0.00000012
C(3,2)	0.00182336	0.000198298	9.19491	0.00000000
C(3,3)	-0.00000007	0.000196430	-3.55702e	0.99997162
C(4,1)	0.001354906	0.00032210	3.84687	0.00011964
C(4,2)	0.001977544	0.0002997754	6.64154	0.00000000
C(4,3)	-0.00000014	0.0003445626	-3.99141e	0.99996815
C(4,4)	0.00000002	0.000259195	5.99764e	0.99999521
A(1,1)	0.104812476	0.030510925	3.43524	0.00059202
A(1,2)	-0.736874212	0.048893533	-15.07100	0.00000000
A(1,3)	-0.388236078	0.023645037	-16.41935	0.00000000
A(1,4)	-0.412139902	-0.035790609	-11.51531	0.00000000
A(2,1)	0.037705626	0.012850727	2.93412	0.00334490
A(2,2)	0.369282288	0.021027497	17.56188	0.00000000
A(2,3)	0.026292733	0.013212392	-1.9901	0.04659033
A(2,4)	-0.034311330	0.021086759	-1.62715	0.0000000
A(3,1)	0.0759888674	0.023628076	3.21603	0.00129976
A(3,2)	-0.243898471	0.028492640	-8.56005	0.00000000
A(3,3)	0.35509699	0.016142328	21.99768	0.00000000
A(3,4)	0.241958966	0.031121203	7.77473	0.00000000
A(4,1)	-0.003302813	0.000939999	-3.51363	0.00044202
A(4,2)	-0.000229299	0.001987918	-0.11535	0.90817082
A(4,3)	-0.017359638	0.001298045	-13.37368	0.00000000
A(4,4)	0.111053746	0.008592004	12.92524	0.00000000
B(1,1)	0.968902074	0.008222388	117.83706	0.00000000
B(1,2)	0.222273073	0.018488306	12.92524	0.00000000
B(1,3)	0.103492317	0.011519114	8.98440	0.00000000
B(1,4)	0.114105468	0.017640230	6.46848	0.00000000
B(2,1)	-0.143331822	0.018115871	-7.91195	0.00000000
B(2,2)	0.613026525	0.033667933	18.20802	0.00000000
B(2,3)	-0.156530910	0.013922885	-11.24271	0.00000000
B(2,4)	-0.065952620	0.022454302	-2.93719	0.00331198
B(3,1)	-0.048537339	0.011141902	-4.35661	0.00001321
B(3,2)	0.006022974	0.018387642	0.32756	0.74324774
B(3,3)	0.881065955	0.007642290	115.28821	0.0000000

B(3,4)	-0.414608065	0.016056746	-25.82142	0.00000000
B(4,1)	0.009200877	0.003100870	2.96719	0.00300533
B(4,2)	0.008307079	0.004707922	1.76449	0.07764961
B(4,3)	0.076831885	0.002861534	26.84989	0.00000000
B(4,4)	0.988608782	0.003717398	265.94109	0.00000000

Table-3 shows the values of diagonal coefficients representing own market effects. Elements of matrix that constitute the Arch terms are namely A(1,1) A (2,2) A(3,3) A(4,4). The coefficients that constitute the GARCH term are B (1, 1) B (2, 2) B (3, 3) B (4, 4).

All the Arch and GARCH terms have probability values less than 5% implying that previous period innovations of a particular market significantly affect its future volatility.

In case of off diagonal coefficients which examine the cross market spillovers, all values of t statistic have a significant probability suggesting that in the short run all markets affect each other's volatility.

In the long run cross market spillovers are significant for all except B (3, 2) and B (4,2). It shows that India doesn't have a cross market effect on Japan. Similarly China doesn't affect the Japanese stock market. In remaining all the cases there is significant impact.

Conclusion and Implications

The study facilitates the understanding of risk in a multivariate framework among four developed and developing economies to offer an insight as to how these markets move together and their effect on each other. This also assist the policy makers in understanding the possible ways a crisis could outbreak and formulating guidelines to overcome such severe situations. BEKK GARCH is employed on returns from January 1 2008 to December 31 2018. The results suggest that there are own market volatility spillovers in all the cases whereas cross market spillover is also present except two cases namely spillovers from India and China towards Japan. The results are useful for investors in formulating portfolios and forecasting patterns.

References

Assidenou, K.E., (2011), ' Cointegration of Major Stock Market Indices during the 2008 Global Financial Distress' Retrieved from https://www.DOI:10.5539/ijef.v3n2p212

Baele, L.,(2005), ' Volatility Spillover Effects In European Equity Markets', *Journal Of Financial And Quantitative Analysis*, 40(2), 373-401

Barunik , J., Kocenda ,E.,Vacha ,L., (2015), 'Volatility Spillovers Across Petroleum Markets', *The Energy Journal*,36(3), 309-329

Bollerslev,T., (1986), 'Generalized Autoregressive Conditional Heteroskedasticity', *Journal of Econometrics*, 31, 307-327

Bollerslev, T., Engle,R.F., J.M. Wooldridge.,(1988), ' A Capital Asset Pricing Model With Time- Varying Covariances', *Journal of Political Economy*, 96(1), 146-31

Caceres,L.R.,(2003), 'Volatility Spillover Across Exchange Rate Markets', *Savings And Development*, 27 (1) , 23-38

Caporin , M., Aleer , M,M.,(2010), ' Ranking Multivariate GARCH Models By Problem Dimension . Retrieved from https:// at SSRN-id 1314231.pdf

Dimpfl, T., (2014), ' A note on Cointegration of International Stock Market Indices', *International Review of Financial Analysis*, 33, 10-16

Dey, S., Sampath,A., (2017), 'Dynamic linkages between Gold and Equity Prices: Evidence from Indian Financial Services and Information Technology Companies', Retrieved from

https://www.IIMK/WPS/251/EA/2017/35

Engle, R.F., Kroner,K., (1995), ' Multivariate Simultaneous Generalized ARCH' , *Econometric Theory*,11, 122-150

Ezzati, P., (2012), 'Analysis of Volatility Spillover Effects: Two Stage Procedure Based on a Modified GARCH-M', Retrieved from https://www. business.uwa.edu.au

Frank, N., Hesse,H.,(2009) , 'Financial Spillovers to

Emerging Markets during the Global Financial Crises', *IMF Working Paper, WP/09/104*, Retrieved from http://www.econ.tu.ac.th

Growenor,T., Greenidge, K.,(2010), ' Stock Market Volatility Spillovers From Developed Markets To Regional Markets', Retrieved from https://www.ccmfuwi.org/files/publication/conference/2010

Guesmi, k., Boubaker,H.,Lai,V.S., (2016), 'From Oil to Stock Markets', *Journal Of Economic Integration*, 31 (1), 103-133

Guidi, F., (2010), ' Cointegration Relationship and Time Varying Co Movements Among Indian and Asian Developed Stock Markets' , Retrieved from http..//mpra.ub.uni-muenchen.de/19853

Hamao, Y.,Masulis , R.W.,Ng ,V., (1990) , 'Correlations in Price Changes and Volatility across International Stock Markets' *The Review Of Financial Studies,3*(2), 281-307

Hammoudeh ,S.M., Yuan ,Y., Aleer ,M.M.,(2009), 'Stock And Volatility among Equity Sectors Of The Gulf Arab Stock Markets', *The Quarterly Review Of Economics And Finance*, 49(3)

Jebran, K., Iqbal,A., (2016), ' Examining Volatility Spillover between Asian Countries Stock Markets', China Finance and Economic Review, 4, 6

Joshi, P.,(2011), 'Return And Volatility Spillovers Among Asian stock Markets'. Retrieved from https://www.journals sagepub.com/doi/pdf/10.1177/2158244011-413474

Karolyi ,G.A., (1995), 'A Multivariate GARCH Model of International Transmissions Of Stock Returns and Volatility : The Case Of USA and Canada, *Journal Of Business and Economic Statistics*, 13(1), 11-25

Kenourgios , D., Samitas , A., Paltalidid,N.,(2010), 'Fianancial Crises and Stock Market Contagion in a Multivariate Time Varying Asymmetric Framework' *International Financial Markets, Institutions and Money'*, 21, 92-106

Li,Y., Giles ,D.E.,(2013), 'Modelling Volatility Spillover Effects Between Developed Stock Markets And Asian Emerging Stock Markets', Retrieved from https://www. editorial express.com/cgi-bin/conference download.cgi

Ng, A.,(2000), ' Volatility Spillover effects from Japan and the US to the Pacific Basin', *Journal Of International Money And Finance,19, 207-233*

Siddiqui, T.A., Khan, M. (2017) " Volatility Estimation in Emerging Markets: A Study of India's and China's Stock Market" Presented at the International Conference on Strategies in Volatile and Uncertain Environment for Emerging Markets, July 14-15 2017, IIT-D

Sinha , k.,Gurung,B.,Paul, R.K.,GV,A.K.,(2017) 'Volatility Spillover using Multivariate GARCH Model : An Application in Futures and Spot Market : Price Of Black Pepper' , Retrieved from https://www.researchgate.net/publication/316429909

Vardar, G., Coskun, Y.,Yelkenci ,T., (2018), 'Shock Transmission And Volatility Spillover In Stock And Commodity Markets: Evidence From Advanced And Emerging Markets'. Retrieved from http://doi.org/10/1007/s 40822-018-0095-3

Wang ,Y., Wu, C.,(2012), ' Forecasting Energy Market Volatility Using GARCH Model : Can Multivariate Models Beat Univariate Models?', *Energy Economics*, 34(6), 2167-2181

Wu, H., Li, S.,(2013), ' Volatility spillovers In China's Crude Oil, Corn and Fuel Ethanol Markets', *Energy Policy*, 62, 878-886

Wuthisatian, R., (2015), 'Cointegration of Stock Markets : The Case of Thailand' Retrieved from https://doi.org/10.1177/0974929215582244

Taufeeque Ahmad Siddiqui is associated with Centre for Management Studies, Jamia Millia Islamia (Central University), New Delhi. His current areas of research interest are Stock Markets, financial inclusion, behavioural finance, Islamic Finance and financial econometrics/modeling etc. Dr. Siddiqui has completed several research projects. He has to his credit four books. He has also written more than 30 research articles published in reputed Indian and foreign journals and books. He has presented more than 50 research papers in various national and international conferences.

Mazia Fatima Khan is a Research scholar in Jamia Millia Islamia, New Delhi. Her professional interests include financial crisis , systematic risk and corporate finance. She has presented papers in several national and international conferences.