Volatility Modelling and Dynamic Linkages between Pakistani and Leading Foreign Stock Markets: A Multivariate GARCH Analysis

GHULAM GHOUSE, SAUD AHMED KHAN, and MUHAMMAD ARSHAD

It is essential for financial institutions and academicians to understand volatility spillover and financial market returns. However, previous studies examined the effects of direct spillover only and ignored those of the newly emerging stock markets. Therefore, this study attempts to estimate the time-varying volatility of Pakistani and leading foreign stock markets. It also tries to explore the direct and indirect volatility spillover effect between Pakistani and eight leading foreign stock markets. Daily data were used from nine international equity markets (KSE 100, NIKKEI 225, HIS, S&P 500, NASDAQ 100, DOW JONES, GADXI, FTSE 350 and DFMGI) for the period between 2005 and 2016. The univariate GARCH and GJR models were employed for analysing volatility, and the multivariate GARCH Diagonal BEKK model was used to explore direct and indirect volatility spillover effects. In order to analyse the volatility spillover effect during and after the global financial crisis period, the data were categorised into two periods: between 2005 and 2009 and between 2010 and 2016. The Chow break-point test was also employed to identify structural breaks in return series due to global financial crises. Direct and indirect spillover effects were found between KSE100, S&P 500, NASDAQ 100, DOW JONES and DFMGI.

Keywords: Volatility, Spillover, Equity Market, Financial Crisis and GARCH

1. INTRODUCTION

Globalisation has lead to great changes in the global business including easy capital flow, the growth of technology, financial associations among the economies, and markets integration. However, the integration of markets extends the effects of financial crises, which means a crisis in one market affects other markets around the world. Therefore, financial institutes, portfolio managers, and market players should understand the volatility modelling and make an analysis of linkages among different financial markets. The global financial crisis stands as a perfect opportunity to quantify the magnitude of interdependence among the global financial markets. The objective of this study is to conduct an investigation to describe the direct and indirect spillover effects among the Pakistani and leading foreign financial markets.

Ghulam Ghouse <Ghouserazaa786@gmail.com> is PhD Scholar, Pakistan Institute of Development Economics, Islamabad. Saud Ahmed Khan <saudak2k3@yahoo.com> is Assistant Professor, Pakistan Institute of Development Economics, Islamabad. Muhammad Arshad <Wakeupnation786@gmail.com> is Lecturer, Government Commerce College, Faisalabad.

The severe financial crisis took place in the US in 2008 not only caused imbalances in the US economy but also affected the global economy. The main reasons for this crisis were imperfections in the international financial planning, an exceptionally relaxed monetary policy, accumulation of imbalances in the global balance of payment, and regulatory breakdowns at micro-prudential and macro-prudential levels [Kawai, *et al.* (2012)]. Generally, global financial crises begin in the US, and owing to the strong linkages between the US economy and global economies, the effects of these crises reach all integrated economies.

The effects of the 2008 global financial crisis directly transferred to the Pakistani economy through capital flow, exports, equity values and remittances [Amjad and Din (2010)]. The Pakistani economy at that time was also suffering from some domestic social and economic problems, such as energy shortage, political instability, the deficit in the current account, growing unemployment, bad governance and inefficient macroeconomic policies [Ghouse and Khan (2017)]. Accordingly, the Pakistani economy encountered a shortfall in balance of payment, a reduction in exports volume and stagflation. Nazir, *et al.* (2012) stated that financial institutions in Pakistan, especially the commercial banks, were directly affected by the 2008 financial crisis, which also significantly compressed their market policies, working strategies, and financial arrangements. However, the Islamic banking system was less affected than the conventional baking system [Phulpoto, *et al.* (2012)].

Pakistan stock exchange (KSE 100 index) closed at its highest points 14,814.85 on 26 Dec. 2007 with accumulated market assets of Rs 457 trillion. The accumulated stock market capitalisation was only Rs.1.85 trillion ($23 billion) with points 5,865.01 on 31 Dec. 2008. A more critical situation arose on 23 Jan. 2009, when the stock market index had only pointed 4,929.54 with a total market capitalisation of Rs 1.58 trillion [Amjad and Din (2010)]. It indicates the loss of approximately 65 percent from the highest point of 26 Dec. 2007. In 2006-07, the foreign direct investment in PSX listed companies was $500 million, which was reduced due to the global financial crisis (for further detail see SBP, 2006-07 and 2008-09).

Dubai economy also suffered from the effects of the US mortgage crisis 2008 (hereafter global financial crisis) due to its investment linkages with the US economy and the international financial system [Onour (2010)]. The real estate was one of the most prominent sectors of Dubai in 2007-08. The real estate sector contributed more than 23 percent to the GDP of Dubai economy in 2007-08, which was badly affected by the global financial crisis. Dubai property sharply slumped due to the global recession; home prices were declined 50 percent from their peak in 2008. In the real estate sector, the government of Dubai hampered $59 billion liabilities, and the total debt became $80 billion in a few weeks [Gabbatt (2009)]. Dubai banking sector was stuck in this vicious circle of financial crisis, limited capital reserves and the regulation imposed on bank lending. The investment in the real estate sector was reduced due to the shortage of loaning from the banks.

The financial sector of Dubai contributed 11 percent to the GDP in 2008, while exports and other trade contributed 31 percent to the GDP. Because of the global financial crisis, the oil prices dropped significantly from $140 to $50 from June 2008 to March 2009 in the international market, which curtailed the volume of trade [Ellaboudy (2010)]. Dubai

financial market also impressively affected Dubai economic growth. Dubai financial market was also crashed by the global financial crisis as the portfolio investment declined from 42 percent to 18 percent in the crisis period, which resulted in a debt crisis (known as Dubai financial crisis 2009). In June 2008, the Dubai stock market fell down; 57 companies were listed on the Dubai financial market (DFM) with an accumulated market capitalisation of about \$360 billion in 2007 [Gabbatt (2009)]. Dubai financial market index (DFMGI) closing price was found \$5489.37 on Nov. 13, 2007, while on 31 Jan. 2008, Dubai financial market index (DFMGI) closing price was recorded \$5615.95. Also, on 21 Dec. 2008, (DFMGI) closing price was found only \$1793.26.

Pakistan has a significant economic relationship with Dubai. Dubai is one of the emerging markets in the United Arab Emirates (UAE) where over 1.2 million Pakistani emigrants are providing their services. Their remittances significantly contribute to Pakistan's foreign reserve, which makes the UAE the second prominent source of remittances to Pakistan. For example, Pakistan expatriates provided \$2.52 billion remittances in 2013-14 with a share of 19.57 percent in total remittances. Similarly, the UAE has a major share in Pakistan exports and imports [PES (2010)].

In 2006-08, a lot of money moved from Pakistan and many other countries to Dubai where property and capital markets were flourishing. At that time, credit was available at low cost, and traders were operating the market to gain large dividends. These people did not know what would be the result of this easy money. During the UAE cityscape "7th annual property and real estate exhibition 2008" in Dubai, more than 100 Pakistani, out of 40,000 visitors from all over the world, invested over \$100 million in the booking of construction projects. Within the 10 to 11 months after Nov. 3, 2007, the outflow of capital from Pakistan economy to Dubai was estimated to be between \$30 billion and \$45 billion [Aziz (2008)]. A huge amount of new money arrived in Dubai and a large ratio of it wiped out when Dubai capital and the property market crashed.

The above discussion elaborates the financial linkages between Pakistan, US, and Dubai economies. In this study, the stock markets of those countries are considered, which are interlinked with the Pakistan economy and the global economic and financial system. Although Pakistan economy is not very much linked with the international financial system, it could be affected through indirect channels which have not been explored in any previous study especially in context of Pakistan, US, and Dubai stock markets.

The main objective of this study is to measure the degree of direct and indirect volatility spillover effects of other leading foreign stock markets on Pakistan stock exchange. To explore the spillover effects among leading stock markets in crisis and after the crisis period, data from the period between 2005 and 2016 is used. To see the magnitude of volatility spillover effect during and after the crisis, data was split into two parts, from 2005 to 2009 and post-crisis period ranging between 2010 and 2016. The findings of the study are helpful in device short run and long economic policies during and after crises.

2. LITERATURE REVIEW

This section briefly discusses previous studies. Kawai, *et al.* (2012) found that global markets experienced a huge wave of financial crisis due to the United State sub-

prime mortgage crisis. This crisis affected not only the US domestic economy but also other economies of the world, which were integrated directly or indirectly with the US economy. Mishkin (2011) indicated that this crisis started from a small segment of the financial system, but in 2008-2009, it became a reason for the global financial crisis.

Jawed (2015) investigated co-movements between S&P 500 and KSE 100 and found a significant spillover effect from the S&P 500 to KSE 100. Ahmed, *et al.* (2018) explored the mean and volatility spillover effect between stock indices of five developed and seven developing stock markets and concluded that there is a spillover effect from NIKKIE 225 to KSE 100. Jebran, *et al.* (2017) explored the spillover effect amongst emerging markets of Asia. They found that there is a bi-directional volatility spillover effect among Pakistan, India, and Sri Lanka stock markets. Zia-ur-Rehman, *et al.* (2011) found that the global financial crisis's negative effect was transmitted to the Pakistan stock market. Aziz and Iqbal (2017) explored the spillover effect among the USA, India, Japan, and Pakistan stock markets. He found a volatility spillover effect between Pakistani, USA, and Japan stock markets. Jan and Jebran (2015) investigated the volatility spillover effect from USA, Germany, France, and UK stock markets to Pakistan stock market. They found a significant volatility spillover effect from G5 stock markets to KSE 100 in the global financial crisis. The volatility spillover effect was transmitted to Pakistan from international stock markets due to the regional connectivity [Wahid and Mumtaz (2018)]. Draz (2011) examined that Pakistan economy faced five financial crises (1958, 1974, 1979, 1997 and 2008); four out of them significantly affected the Pakistan economy. Li and Giles (2015) measured the spillover effect from US stock markets to Japan and other six Asian developing countries stock markets. They found a unidirectional return and volatility spillover from the US to other markets.

Iqbal and Sattar (2010) found that the global crisis was also a cause for dipping remittances, fewer exports, stock markets decay, the flight of capital, and local currencies depreciation. They also concluded that the global crisis critically affected foreign direct investment, exports, and portfolio investment. During the financial crisis, Pakistan needed financial inflows in different shapes from other countries to improve economic growth. Financial inflow to the developing countries decreased by approximately US$300 billion. Investors shifted Portfolio investment and foreign direct investment to those countries that were not affected by the global financial crisis [Cali, *et al.* (2008)].

Kharchenko and Tzvetkov (2013) examined the volatility spillover effect between developing and developed market economies and found that there is a spillover effect between the USA and European stock markets. Angkinand, *et al.* (2009) investigated how the financial crisis in US markets impacted 17 developed economies, and they found that spillover effects from the US to other industrial countries were highest after the collapse of the U.S subprime mortgage market in 2007. Fraser and Oyefeso (2001) explained the significant dynamic links of United State stock markets with the UK and European stock markets.

Ghouse and Khan (2017) examined the spillover effect between Dubai financial market and S&P 500, DOW JONES, and NASDAQ indices. They found a significant bidirectional spillover effect between Dubai financial market and USA stock markets. Alsukker (2010) explored that the US mortgage crisis 2008 affected Dubai financial market, the banking system, economy, and Dubai's companies credit ratings. Onour

(2017) stated that the spillover effect of the US Mortgage crisis 2008 badly affected oil-producing countries including Dubai. The portfolio investment in the financial market of Dubai decreased by 42 percent. Due to this spillover effect, Dubai also faced an internal debt crisis in 2009. Hasan (2010) found that the financial crisis crushed the major sector of the economy. The Global financial crisis barely affected Dubai among all the other oil-producing countries leading to reducing the oil prices in the developed countries. Ellaboudy (2010) indicated that from mid-2008 to March 2009, oil prices dropped down from \$140 to \$50 at the international market.

All the studies reviewed in this section examined direct channels of the volatility of spillover effect from leading foreign stock markets. There is no single study exploring the indirect channel of volatility spillover effect between Pakistani and foreign leading stock markets. Also, the relation between Pakistan and Dubai stock markets has not been significantly explored. To fill these gaps at first, the magnitude of direct volatility spillover effect between Pakistani and foreign stock markets was re-estimated. Secondly, the indirect volatility spillover effect between Pakistani and foreign stock markets was estimated. Lastly, the volatility spillover effect between Pakistani and Dubai financial market was estimated.

3. ECONOMETRIC METHODOLOGY AND MODEL SPECIFICATION

To capture the time-varying conditional variance phenomenon, Engle (1982) proposed the Autoregressive Conditional Heteroscedastic (ARCH) model. Although the ARCH model is a considerable contribution to the econometric literature, it has some problems including long lag length and non-negativity restriction on parameters. To solve the first problem, Bollerslev (1986) introduced generalised autoregressive conditional heteroscedastic (GARCH) model, which improves the unique specification with the addition of the lag value of conditional variance, which acts as a smoothing term. The GARCH model cannot analyse asymmetric and leverage effects. For this, Glosten, Jagannathan, and Runkle (1993) proposed a GJR model. GJR model is a significant extension of the standard GARCH model. It contains an asymmetric term in conditional variance equation. To avoid any non-convergence problem in this study, an appropriate univariate GARCH type model such as GARCH (p, q) and GJR (p, q) is employed to estimate volatility models, and the multivariate DGARCH-BEKK is employed to explore volatility spillover effect.

The financial series at a level are trendy in nature [Ghouse and Khan (2017)]. It is impossible to estimate a robust model if the series is trendy. To deal with the trend, the log return is used.

$$R_t = log_e(l_t/l_{t-1})$$

l_t= Financial time series at level i.e. stock indices and exchange rates at the end of time *t*.

l_{t-1}= First lag of financial time series.

3.1. Modelling for Volatility

3.1.1. *GARCH (p, q) Model*

Bollerslev (1986) proposed a generalised extension of ARCH (q) model Generalised autoregressive conditional heteroscedastic (GARCH) model.

The general description of the GARCH model is

Conditional Mean Equation

$$R_t = \alpha_0 + \beta X_t + \varepsilon_t \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \quad (3.1)$$

Where $\varepsilon_t = z_t \sigma_t, \quad z_t \sim N(0,1)$

Conditional Variance Equation

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon_{t-1}^2 + \sum_{i=1}^{p} \varphi_j \sigma_{t-1}^2 \qquad \dots \qquad \dots \qquad \dots \qquad \dots \quad (3.2)$$

Where $\theta_0 > 0, \theta_i \geq 0, \varphi_j \geq 0$

In the GARCH (p, q) model, the conditional variance depends upon the square of past values of process ε_t and lag of conditional variance σ_{t-1}^2. The condition of non-negativity of parameter also applied in this model.

3.1.2. *GJR (p, q) Model*

Glosten, *et al.* (1993) introduced (GJR) model in 1993. GJR model is a significant extension in a simple GARCH model. This model also captures the asymmetries in ARCH process. GJR model also accounts for the leverage effect in a financial series.

The general representation of the GJR model is:

Conditional Mean Equation

$$R_t = \alpha_0 + \beta X_t + \varepsilon_t \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \quad (3.3)$$

Where $\varepsilon_t = z_t \sigma_t, \quad z_t \sim N(0,1)$

Conditional Variance Equation

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \delta_i \varepsilon_{t-i}^2 G_t + \sum_{i=1}^{p} \varphi_j 6_{t-j}^2 \qquad \dots \qquad \dots \quad (3.4)$$

Where $\theta_0 > 0, \theta_i \geq 0, \varphi_i \geq 0, 0 \leq \delta_i \geq 1$ Range of parameter of leverage effect. Gt = 1 when $\varepsilon_{t-1} < 0$ and $G_t = 0$ when $\varepsilon_{t-1} \geq 0$.

3.2. Modelling for Volatility Spillover

The multivariate GARCH diagonal BEKK has been used to measure the spillover effect between the markets. The Chow break-point test is used to test the breaks in return series, especially due to the financial crisis.

3.2.1. *Chow Break-Point Test*

The Chow break-point test is proposed by Chow (1960). Chow test is employed to identify the structural breaks due to the financial crisis, whether the coefficient of linear regressions are equal in different data sets. The Chow test is used to identify the structural breaks in return series due to the global financial crisis.

$$F = \frac{(RSS_{UR} - (RSS_{Res1} + Rss_{Res2}))/K}{(Rss_{Res1} + RSS_{Res2})/(N - 2K)} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \quad (3.5)$$

RSS_{URes} is the residual sum of square of whole data sets. RSS_{Res1} is the residual sum of square of the first part of data. Rss_{Res2} is the residual sum of square of second part of data N is the number of observations and K is the number of parameters.

3.2.2. *Multivariate GARCH Diagonal BEKK*

Baba, Engle, Kraft, and Kroner (1990) proposed the BEKK model to guarantee the positive definiteness of the variance-covariance matrix Ht. the BEKK model is also known as a restricted version of the VEC model. When A and G matrices become diagonal then the BEKK model is converted into Diagonal BEKK which is introduced by Bollerslev, Engle, and Wooldridge (1988).

$$R_t = \sum_{i=1}^{k} \vartheta_i R_{t-i} + \varepsilon_t \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \quad (3.6)$$

Where $R_t' = [r_1 \quad r_2 \quad , \dots\dots\dots \quad , \quad r_n]$ and $\varepsilon_t' = [\varepsilon_1 \quad \varepsilon_2 \quad , \dots\dots\dots \quad , \quad \varepsilon_n]$

The Diagonal BEKK (p,q,k) Model

$$H_t = \delta\delta' + \sum_{i=1}^{q} \sum_{k=1}^{k} A_{ki}' \, \varepsilon_{t-i}\varepsilon_{t-i}' A_{ki} + \sum_{i=1}^{p} \sum_{k=1}^{k} G_{ki}' \, H_{t-i} G_{ki} \quad \dots \qquad \dots \quad (3.7)$$

Where $H_t = \begin{bmatrix} h_{11,t} & \cdots & h_{k1,t} \\ \vdots & \ddots & \vdots \\ h_{k1,t} & \cdots & h_{kk,t} \end{bmatrix}$ and $\delta = \begin{bmatrix} \delta_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ \delta_{k1} & \cdots & \delta_{kk} \end{bmatrix}$

$Diagonal\ A = [a_{k1}, \dots\dots, \quad a_{kk}]$, and $Diagonal\ G = [g_{k1}, \dots\dots, \quad g_{kk}]$

Where H, A, δ and G are parameter matrices. δ is a lower triangular matrix. The constant term decomposition of into a multiplication of two triangular matrices, is to ensure the variance covariance matrix Htpositive definiteness. The GARCH Diagonal BEKK model is used here instead of GARCH-BEKK because of the large parameter, the GARCH-BEKK, has a convergence problem.[1]

3.3. Description of Data and Sources

The daily data of stock market indices have been used for the period between 2005 and 2016. The leading stock markets are taken from Asia, Europe, America, and Gulf regions. The American markets are S&P 500, DOW JONES (DJI), and NASDAQ 100. Leading markets from Europe are London (FTSE 350) and German (GDAXI) stock exchange. The prominent markets from Asia are Pakistan (PSX 100), Japan (NIKKEI 225) and Hong Kong (HIS) stock markets. The Dubai financial market (DFM) is taken from Gulf countries.

4. ESTIMATIONS AND ANALYSIS

This section describes results and discussion of results.

4.1. Graphical Analysis

Figure 1 indicates that all the series have an upward trend and a sharp decline around 2008 due to the global financial crisis. Then again, there is a continuous upward trend with some fluctuations. It shows that the series is trendy and seems non-stationary at level.

[1]Khan, S.A (2012). https://asadzaman.net/my-students/

Fig. 1. Graph of Series at Level
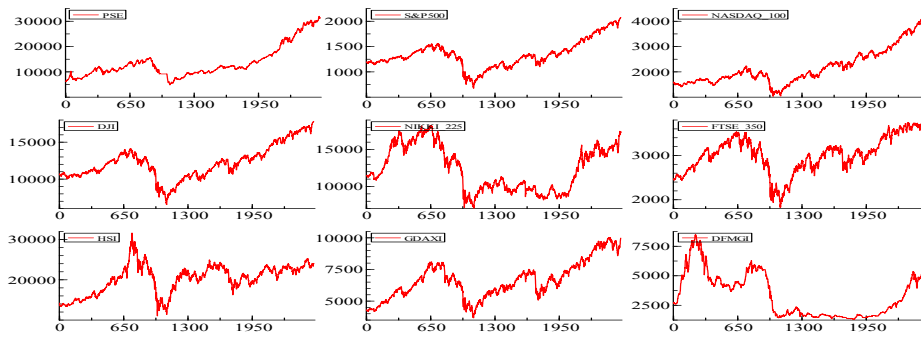
A single return series (PSX 100) is used for further data visualisation, and other return series could be visualised in the same manner. Figure 2 given below is representing a return series of PSX 100 index. In financial econometrics, the spread is characterised as volatility. Figure two shows that the spread does not remain the same throughout the series, which is known as Heteroscedasticity. The circles in Figure 2 are indicating low and high volatility. According to The Efficient Market Hypothesis (EMH), returns are unpredictable and show mean reversion behaviour." We can easily distinguish between low volatility clustering and high volatility clustering period. The greater depreciation from a constant level (mean of return series) indicates high volatility clustering, and less depreciation illustrates low volatility clustering. If all effects are combined, they indicate the ARCH (Auto-Regressive Conditional Heteroscedasticity) effect.

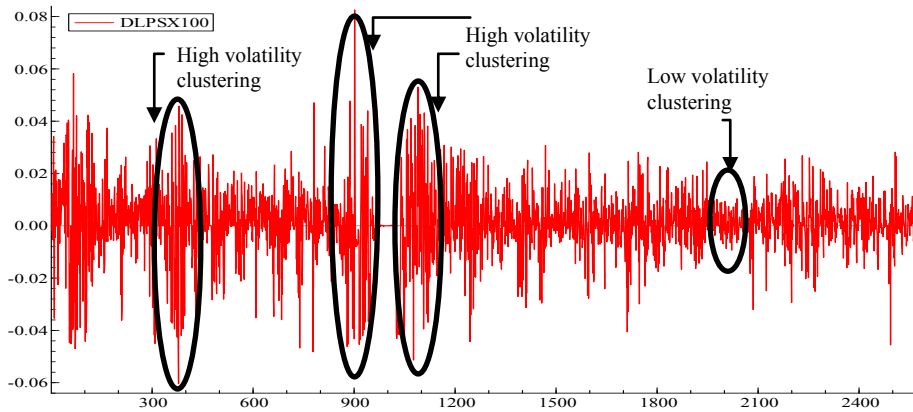**Fig. 2. Graph of Given Return Series**

Figure 3, illustrates the distribution of the return series of PSX 100 index. In this graph, the blue line shows the normal reference distribution of return series. The red line indicates the actual distribution of the return series. Histograms describe the outliers (extreme values) in return series.
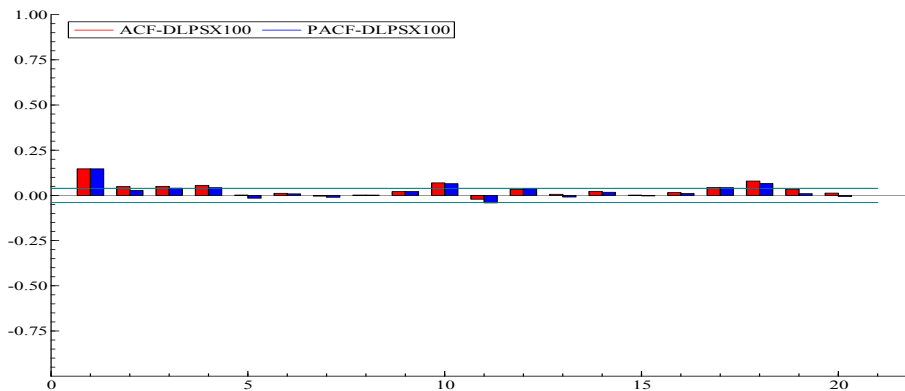
Fig. 3. Graphs Distribution of the Return Series
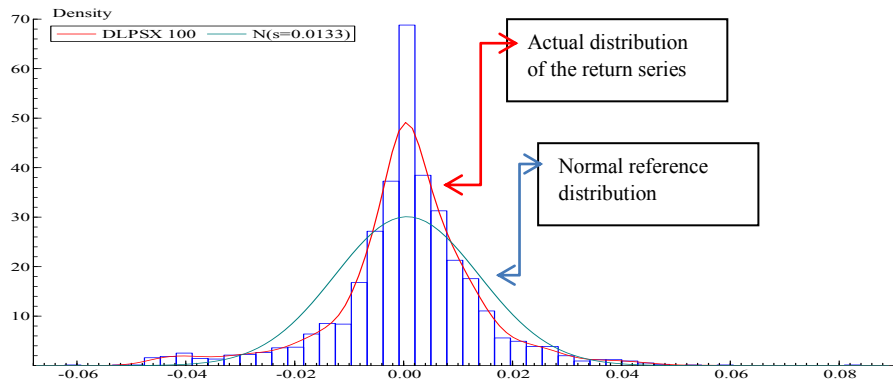
The distribution of return series has heavy tails and is leptokurtic, which shows that the distribution of return series is non-normal. This is due to the different response of market players who have the same information from the same market.

Figure 4, given below, presents ACF (Auto-correlation function) and PACF (Partial Auto-correlation function) of return series of PSX 100 index. The green straight lines in this graph show a 95 percent confidence interval. If any bar of ACF and PACF is outside these lines, it means at that lag the values are autocorrelated. It significantly varies from zero. The ARMA (p, q) process specifies through the significant lags of ACF and PACF. The ACF specifies the MA (q) process. PACF specifies the AR (p) process. In order to identify the ARMA process, prominent lags of ACF and PACF are focused upon. In this graph 1st lags of ACF is significantly prominent and 1st lag of PACF is also significant and prominent.

Fig. 4. Graphs of ACF and PACF of Return Series

4.2. Summary Statistics

The results in Table 1 show the initial statistics of return series of stock markets indices. The statistics unveil some indications about the behaviour of stock markets. The distributions of return are non-normal, heavy tails and leptokurtic. The mean of all

returning series is about zero, which implies that return series have a mean reversion behaviour. The standard deviation of return series describes the dispersion from the mean value, which shows that if the return series has a greater standard deviation, it has more deviations from the mean value. The skewness deals with the asymmetry of the distribution. The distributions of PSX 100, S&P 500, NASDAQ 100, DJI, NIKKEI 225, FTSE 350 and DFMGI return series are negatively skewed, which means that the return of these stock markets is less than average return. The distributions of HIS and GDAXI are positively skewed, which implies that the returns of these markets are more than average returns. The Jarque-Bera (J.B) test with a null hypothesis of a normal distribution is employed. Jarque-Bera statistics of all returning series are significant, which means the distribution of all returning series is non-normal.

Table 1

Summary of Statistics

Series	Mean	Standard deviation	Skewness	Jarque Bera	Excess Kurtosis	Q-stat (5)	Q2-stat (5)	ARCH 1-2	KPSS
KSE 100	0.0006	0.0133	–0.3054	1096.1	3.1075	76.12	1167.51	266.88	0.2073
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
S&P 500	0.0002	0.0427	–0.0409	17088	11.448	45.484	1131.31	266.72	0.1965
				(0.000)	(0.000)	(0.000)	(0.000)	(0.010)	
NASDAQ 100	0.0003	0.0736	–0.0587	7685.9	8.6282	24.928	765.777	156.96	0.2005
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
DJI	0.0001	0.0716	–0.0851	3168	11.499	45.037	1123.85	283.89	0.1548
				(0.000)	(0.000)	(0.000)	(0.000)	(0.006)	
NIKKEI 225	0.0001	0.0653	–0.0737	9597.9	8.885	10.564	1396.71	489.45	0.1994
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
HIS	0.0002	0.0856	0.1459	18971	10.12	8.387	1361.38	361.66	0.0525
				(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	
FTSE 350	0.0001	0.0018	–0.2879	7088.8	8.2401	39.367	1130	147.29	0.0569
				(0.000)	(0.000)	(0.000)	(0.000)	(0.009)	
GDXI	0.0003	0.0637	0.5297	5010.5	7.1719	16.783	686.71	111.39	0.07411
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
DFMGI	0.0001	0.0883	–0.7778	19612	11.135	32.381	166.23	44.647	0.4874
				(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	

Null Hypotheses (All Null Hypotheses are for nth order).
KPSS H0: Return series is level stationary, Asymptotic significant values 1 percent (0.739), 5 percent (0.463), 10 percent (0.347). Q-stat (return series) there is no serial autocorrelation. Q2-stat (square return series) H0: there is no serial autocorrelation. Jarque-Bera H0: distribution of series is normal. LM-ARCH H0: there is no ARCH effect. Use these Asymptotic Significance values of t-stat 1 percent (0.01), 5 percent (0.05), 10 percent (0.1) and compare these critical values with P-values (Probability values). P-values are in the parenthesis.

The Excess kurtosis in Table 1 of all returns series is significant, which means that return series distributions are leptokurtic and indicates that the probability of large values is more than normal return values. Q-stat of return series is significant, which shows that there is serial autocorrelation in return series. Q-stat of squared return series is significant, which shows that there is serial autocorrelation in square return series. LM-

ARCH test validates that there is ARCH effect in return series. KPSS is a unit root test with a null hypothesis of stationary series. KPSS test results of all variable show that the return series is level stationery.

4.3. Volatility Modelling

A lot of empirical work on volatility modelling exists in financial literature. However, the predictability and modelling of volatility are still challenging for researchers. Many researchers in their studies employed GARCH family models for volatility modelling and forecasting. Akhtar and Khan (2016) used GARCH models for volatility modelling of KSE 100 index. Lim and Sek (2013) employed a symmetric and asymmetric GARCH model for volatility modelling of Malaysia. Ghouse and Khan (2017) used GARCH models to capture the dynamic symmetric and asymmetric effects in return series of leading financial markets.

The results in Table 2 describe the volatility modelling statistics of return series, and Table 3 contains the results of the residual analysis. the equation structure of one series (PSX 100) is provided for convenience in reading table results.

The GJR model is employed for PSX 100 volatility modelling. The estimated conditional mean Equation (4.3) is derived from Equation (3.9) and the estimated conditional dispersion Equation (4.4) is derived from Equation (3.10). The P-values are in parenthesis.

$$R_t = 0.0008 + 0.8900R_{t-1} - 0.9000\varepsilon_{t-1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4.1)$$
$$\quad (0.0000) \quad (0.0000) \quad \quad (0.0000)$$

$$\sigma_t^2 = 0.0056 + 0.1460\varepsilon_{t-2}^2 + 0.3234\varepsilon_{t-1}^2 G_t + 0.8031\sigma_{t-1}^2 \quad \ldots \quad \ldots \quad (4.2)$$
$$\quad (0.9010) \quad (0.0000) \quad \quad (0.0000) \quad \quad (0.0000)$$

In the first equation, AR (1) term R_{t-1} is statistically significant which means that the current return depends upon 1st lag. The MA (1) term ε_{t-1} is also different from zero, which shows the relationship between past and current variations, while the constant term is also significant. The second equation describes that the PSX 100 series has an asymmetric effect, because the GJR term $\varepsilon_{t-1}^2 G_t$ is significant which indicates the existence of a leverage effect. The leverage effect directs that the current return is negatively correlated with future volatility, while the ARCH ε_{t-2}^2 and GARCH terms σ_{t-1}^2 are also significant at 1 percent level of significance.

Similarly, the returns series of NIKKEI 225 also have asymmetric effects. All other series S&P 500, DOW JONES (DJI), NASDAQ 100, FTSE 350, GDAXI, HIS and DFMGI are having symmetric effects. Most of the parameters are statistically significant at 5 percent level of significance. ARCH and GARCH terms are also significant in the models, meaning that the return series are subject to ARCH effect.

The persistence of shock in return series is very important factor for forecasting different effects persisting in return series and their decay time. If it becomes close to 1, it means the persistence of ARCH and GARCH effect takes a long time to decay. If it is not close to 1 or less than 1, it shows that the persistence of ARCH and GARCH effect takes a short time to decay. As shown in Table 2, the persistence of shock estimators value is close to 1, which means that the persistence of ARCH and GARCH effects takes a long time to decay from all the series.

Table 2

Volatility Modeling of Stock Markets

	PSX-100 ARMA(1,1) GJR (1,1)	NIKKEI-225 ARMA(0,0) GJR (1,1)	HIS ARMA(0,0) GARCH (3,2)	S&P 500 ARMA(1,1) GARCH (1,2)	NASDAQ 100 ARMA(0,0) GARCH (1,1)	DOW JONES ARMA(2,1) GARCH (1,1)	FTSE 350 ARMA(0,0) GARCH (1,1)	GDAXI ARMA(1,1) GARCH (1,1)	DFMGI ARMA(1,1) GARCH (1,1)
Conditional Mean Equation									
Constant α_0	0.0009 (0.7538)	0.0006 (0.0093)	0.0006 (0.0013)	0.0008 (0.0000)	0.0011 (0.0000)	0.0008 (0.0000)	0.0006 (0.0000)	0.0010 (0.0000)	0.0005 (0.2032)
AR(1) ϑ_1	1.0000 (0.0000)	—	—	0.7395 (0.0000)	—	−0.9511 (0.0000)	—	0.9396 (0.0000)	0.8848 (0.0000)
AR(2) ϑ_2					—	-0.0560 (0.0039)	—	—	—
MA(1) $\varnothing_1$	−0.9000 (0.0000)	—	—	-0.7992 (0.0000)	—	0.8958 (0.0000)	—	-0.9551 (0.0000)	−0.8330 (0.0000)
Conditional Variance Equation									
Constant θ_0	0.0000 (1.0000)	0.0475 (0.0007)	0.0070 (0.0830)	0.0219 (0.0000)	0.0232 (0.0000)	0.0130 (0.0005)	0.0139 (0.0025)	0.0218 (0.0025)	0.0313 (0.0633)
ARCH(1) θ_1	0.1460 (0.0003)	0.0273 (0.0240)	—	—	0.0890 (0.0000)	0.1112 (0.0000)	0.1145 (0.0000)	0.0988 (0.0000)	0.0630 (0.0000)
ARCH(2) θ_2	—	—	0.0523 (0.0000)	0.1433 (0.0000)	—	—	—	—	—
GARCH(1) φ_1	0.8032 (0.0000)	0.8839 (0.0000)	2.0078 (0.0000)	0.8481 (0.0000)	0.8991 (0.0000)	0.8841 (0.0000)	0.8790 (0.0000)	0.8943 (0.0000)	0.9311 (0.0000)
GARCH(2) φ_2	—	—	1.7205 (0.0000)	—	—	—	—	—	—
GARCH(3) φ_3	—	—	0.6600 (0.0000)	—	—	—	—	—	—
GJR(1) δ_1	0.3234 (0.0000)	0.1287 (0.0000)	—	—	—	—	—	—	—
Persistence of shock	0.9109	0.9755	0.9996	0.9915	0.9883	0.9954	0.9935	0.9932	0.9941

Null Hypotheses (All Null Hypotheses are for n^{th} order).

AR (p) H0: $\vartheta_i = 0$ No AR Process, MA (q) H0: $\varnothing_i = 0$ No MA Process, ARCH H0: $\theta_i = 0$ No ARCH effect, GARCH H0: $\varphi_i = 0$ No GARCH effect, Leverage effect H0: $\delta_i = 0$ No leverage effect. P-values are in the parenthesis.

Table 3

Residual Analysis

Parameter Series	Jarque Bera	Q-Stat (5)	Q-Stat (10)	Q^2-Stat (5)	Q^2-Stat (10)	LM –ARCH (1-2)	LM-ARCH (1-5)
PSX-100	7.0272	0.0019	0.0024	0.0020	0.0039	0.0004	0.0004
ARMA(1,1) GJR (1,1)	(0.0000)	(0.9999)	(1.0000)	(0.9999)	(1.0000)	(0.9999)	(1.0000)
NIKKEI-225	509.46	2.0605	6.0220	0.6678	5.1253	0.2047	0.1380
ARMA(0,0) GJR (1,1)	(0.0000)	(0.8407)	(0.8134)	(0.8807)	(0.7440)	(0.8149)	(0.9835)
HIS	128.04	1.7793	5.1972	5.2051	13.983	0.3964	0.5536
ARMA(0,0) GARCH (3,2)	(0.0000)	(0.8787)	(0.8776)	(0.3913)	(0.5267)	(0.6727)	(0.7356)
S&P 500	524.96	4.5842	7.4715	1.2465	9.7895	0.2319	0.2597
ARMA(1,1) GARCH (1,2)	(0.0000)	(0.2049)	(0.4867)	(0.5361)	(0.2008)	(0.7930)	(0.9350)
NASDAQ 100	213.74	2.8643	5.1957	5.8315	14.408	2.7272	1.1573
ARMA(0,0) GARCH (1,1)	(0.0000)	(0.2387)	(0.6360)	(0.1201)	(0.0717)	(0.0656)	(0.3279)
DOW JONES	438.61	5.2781	8.9697	8.5410	17.475	3.8500	1.6483
ARMA(2,1) GARCH (1,1)	(0.0000)	(0.0714)	(0.2548)	(0.0360)	(0.0255)	(0.0214)	(0.1438)
FTSE 350	134.01	3.5698	5.2425	3.7790	5.0251	0.6032	0.7742
ARMA(0,0) GARCH (1,1)	(0.0000)	(0.6128)	(0.8743)	(0.2863)	(0.7548)	(0.5471)	(0.5682)
GDAXI	309.27	4.5445	7.4357	6.9227	8.9998	0.8606	1.4246
ARMA(1,1) GARCH (1,1)	(0.0000)	(0.2083)	(0.4904)	(0.0744)	(0.3423)	(0.4230)	(0.2121)
DFMGI	12835	6.7335	12.502	3.4343	8.3277	0.2255	0.6888
ARMA(1,1) GARCH (1,1)	(0.0000)	(0.0808)	(0.1301)	(0.3293)	(0.4021)	(0.7981)	(0.6319)

Null Hypotheses (All Null Hypotheses are for n^{th} order).

Q-stat (return series) there is no serial autocorrelation. Q^2-stat (square return series) H0: there is no serial autocorrelation. Jarque-Bera H0: distribution of series is normal. LM-ARCH H_0: there is no ARCH effect. P-values are in the parenthesis.

Tables 3, illustrates the post-estimation results (Residual analysis). The Jarque-Bera test (Normality test) results show nonnormal distributions of residuals. The Q-stat are insignificant up to 10th lags, accept the null hypothesis that there is no serial autocorrelation in the standardised residuals. If the Q-stat on squared standardised residuals is insignificant up to 10th lags accept the null hypothesis of no serial autocorrelation in squared standardised residuals. LM-ARCH test is also insignificant up to 5th lags accept the null hypothesis of no ARCH effect remains in series residuals.

4.4. Identification of Structural Break

The Chow break-point test was employed to identify the structural break in the return series due to the global financial crisis. As shown below, all the breaks are significant which indicates that the global financial crisis affected all the series to some extent.

Table 4

Chow Test Statistics

Series	Chow Statistic	Probability value
KSE 100	67.021	0.0013
S&P 500	45.044	0.0123
NASDAQ 100	25.918	0.0356
DJI	41.371	0.0292
NIKKEI 225	18.564	0.0474
HIS	29.873	0.0291
FTSE 350	30.367	0.0108
GDXI	61.831	0.0075
DFMGI	34.3072	0.0258

Ho: there is no structural break.
H1: there is a structural break.

4.5. Volatility Spillover Effect

The multivariate GARCH Diagonal BEKK model was employed to trace out the dynamic linkages between Pakistani and leading foreign stock markets. A simple multivariate equation is shown. There are heavy complicated calculations behind these results [for further details see Khan (2012)].[2] The whole data set for these estimations from 2005 to 2016 are used.

[2]Khan, S. A .(2012). https://asadzaman.net/my-students/

$$H_{t,PSX} = 0.4557 + 0.461S\&P + 0.1061NAS + 0.6745DJ + 0.0834NIKK + 0.0310HIS$$
$$(0.0010) \quad (0.0051) \quad\quad (0.0076) \quad\quad (0.00342) \quad\quad (0.0914) \quad\quad (0.0875)$$
$$+0.1546FTSE + 0.2107GDXI + 0.6745DFM + 0.8131H_{t-1} \quad \ldots \quad\quad \ldots \quad (4.3)$$
$$(0.9010) \quad\quad\quad (0.0001) \quad\quad (0.0000) \quad\quad (0.0516)$$

It is clear that the coefficients of the S&P 500, NASDAQ 100, DOW JONES and DFMGI are statistically significant at 1 percent level of significance. The coefficients of HIS, NIKKEI 225 and FTSE 350 are statistically significant at 10 percent level of significance. It shows that there is a huge volatility spillover effect from S&P 500, NASDAQ 100, DOW JONES and DFMGI to PSX 100. It also indicates that there is a very weak volatility spillover effect from HIS, NIKKEI 225 and FTSE 350 to PSX 100; thus, they can be neglected to some extent. The coefficients of GDXI are statistically insignificant.

The data are divided into two parts; the first part contains the crisis period, and the second part consists of the post-crisis period. The MGARCH model has been employed on both data sets. The results are indicating that there is a strong linkage among these markets in both periods. Equation (4.4) shows the results of the first part of the data set. The results show a significant volatility spillover effect from S&P 500, NASDAQ 100, DOW JONES and DFMGI to PSX 100 in the crisis period. Equation (4.5) illustrates the results of the second part of the data set. The results indicate a significant volatility spillover effect from S&P 500, NASDAQ 100, DOW JONES and DFMGI to PSX 100 in the post-crisis period.

$$H_{t,PSX} = 0.0081 + 0.2806S\&P + 0.1427NAS + 0.0156DJ + 0.6410DFM + 0.52331H_{t-1}(4.4)$$
$$(0.0000) \quad (0.0061) \quad\quad (0.0078) \quad (0.0410) \quad\quad (0.0001) \quad\quad (0.0000)$$

$$H_{t,PSX} = 0.010 + 0.3401S\&P + 0.5497NAS + 0.4301DJ + 0.3494DFM + 0.7652H_{t-1} \quad (4.5)$$
$$(0.0050) \quad (0.0081) \quad\quad (0.0009) \quad\quad (0.0001) \quad\quad (0.0000) \quad\quad (0.0000)$$

Likewise, the MGARCH DBEKK model was employed for DFMGI for both periods. Volatility spillover effects were found from S&P 500, NASDAQ 100 and DOW JONES to DFMGI. Equation (4.6) shows the results of the first part of the data set. The results show a significant volatility spillover effect from the S&P 500, NASDAQ 100 and DOW JONES to DFMGI in the crisis period. Equation (4.7) illustrates the results of the second part of data set. The results indicate a significant volatility spillover effect from S&P 500, NASDAQ 100 and DOW JONES to DFMGI in post-crisis period.

$$H_{t,DFM} = 0.0093 + 0.2622S\&P + 0.1570NAS + 0.1134DJ + 0.0410PSX + 0.98671H_{t-1} \ (4.6)$$
$$(0.0059) \quad (0.0101) \quad\quad (0.0280) \quad\quad (0.0019) \quad\quad (0.09001) \quad\quad (0.0008)$$

$$H_{t,DFM} = 0.0597 + 0.5681S\&P + 0.1034NAS + 0.1289DJ + 0.6745PSX + 0.5734H_{t-1} \quad (4.7)$$
$$(0.9010) \quad (0.0001) \quad\quad (0.0000) \quad\quad (0.0001) \quad\quad (0.8003) \quad\quad (0.0000)$$

While PSX 100 remains insignificant in both equations, which shows that there is no volatility spillover effect from PSX 100 to DFMGI. In the first equation, PSX 100 is significant at 10 percent level of significance. The results are explaining direct and indirect volatility spillover effects from S&P 500, NASDAQ 100, DOW JONES and DFMGI to PSX 100. Figure 5 explains the direct and indirect paths.

Fig. 5. Direct and Indirect Paths of Volatility Spillover Effects
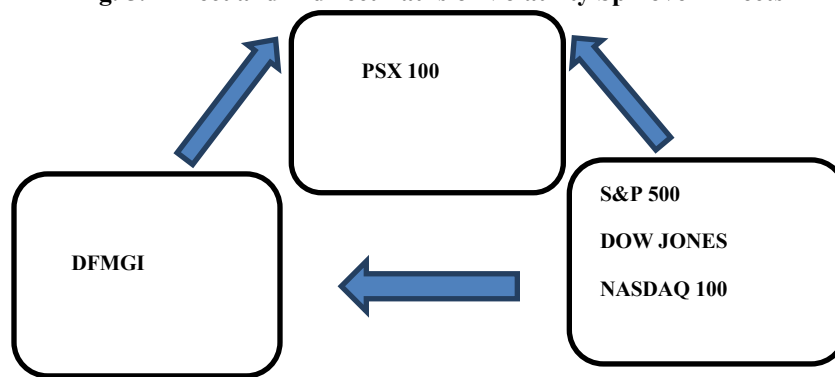
5. CONCLUSION

This study discusses the time-varying volatility and explores the spillover effects among equity markets. Since the past decade, the Dubai market has become very attractive for Pakistani investors, especially in the real estate sector. Pakistani are amongst top investors in the real estate sector considering Dubai as a safe haven for investment. This phenomenon is examined in the present study. This study provides important conclusions for financial institutions, market players, and portfolio managers enabling them to detect the nature of markets and level of linkages among the financial markets. Dubai is the nearest top market for Pakistani market players to be utilised as hedging and portfolio management. Based on the findings of this study, investors may minimise their risk. The portfolio managers can use these results in their diversified portfolios investment, which is badly affected by stock market prices. The stability of stock market prices is very important for foreign direct investment and domestic investment, which improves macroeconomic stability and positively affects economic growth. This study may have a significant impact on the trading behaviour of the PSX 100 that is beneficial for the retail investors, institutional investors (both local and foreigner) and mutual funds managers. The explored integration between Pakistani and Dubai markets may also be utilised by foreign investors who are interested in the Pakistani energy sector.

REFERENCES

Ahmed, R. R., J. Veinhardt, D. Štreimikienė, S. P. Ghauri, and M. Ashraf (2018) Stock Returns, Volatility and Mean Reversion in Emerging and Developed Financial Markets. *Technological and Economic Development of Economy* 24:3, 1149–1177.

Akhtar, S. and Naimat U. Khan (2016) Modelling Volatility on the Karachi Stock Exchange, Pakistan. *Journal of Asia Business Studies* 10: 3, 253–275.

Alsukker, A. (2010) Dubai Crisis. SSRN Paper No, 1663548. It can be viewed at: https://ssrn.com/abstract=1663548

Amjad, R. and M. Din (2010) Economic and Social Impact of Global Financial Crisis: Implications for Macroeconomic and Development Policies in South Asia. (PIDE Monograph Series, 1).

Angkinand, A. P., J. R. Barth, H. Kim, and B. Gup (2009) Spillover Effects from the US Financial Crisis: Some Time-Series Evidence from National Stock Returns. *The Financial and Economic Crises: An International Perspective* 24–52.

Aziz, K. (2008) Investors from Pakistan Buying Property Worth Millions of Dollars at UAE. It can be viewed at: www.chowrangi.pk.

Aziz, Z. and Iqbal (2017) Testing the Dynamic Linkages of the Pakistani Stock Market with Regional and Global Markets. *Lahore Journal of Economics* 22:2, 89–116.

Baba, Y., R. F. Engle, D. F. Kraft, and K. F. Kroner (1990) Multivariate Simultaneous Generalised ARCH, Department of Economics. University of California at San Diego. (Working Paper).

Bollerslev, T. (1986) Generalised Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics* 31:3, 307–327.

Bollerslev, T., R. F. Engle, and J. M. Wooldridge (1988) A Capital Asset Pricing Model with Time-Varying Covariances. *Journal of Political Economy* 96:1, 116–131.

Cali, M., I. Massa, and D. W. te Velde (2008) The Global Financial Crisis: Financial Flows to Developing Countries Set to Fall by One Quarter. London. ODI blog 13.

Chow, G. C. (1960) Tests of Equality between Sets of Coefficients in Two Linear Regressions. Econometrica. *Journal of the Econometric Society* 591—605.

Draz, M. U. (2011) Impact of Financial Crises on Pakistan and China: A Comparative Study of Six Decades. *Journal of Global Business and Economics* 3:1, 174–186.

Ellaboudy, S. (2010) The Global Financial Crisis: Economic Impact on GCC Countries and Policy Implications. *International Research Journal of Finance and Economics* 41, 180–193.

Engle, R. F. (1982) Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica* 50:4, 987–1007.

Fraser, P. and O. Oyefeso (2001) The UK Stock Market's Relationship with us and European Stock Markets: Is the UK Stock Market Snuggling-up to the US -or to Europe? In *University of Otago Department of Finance Seminar Series.*

Gabbatt, A. (2009) Dubai on the Brink—Latest Developments. *The Guardian*. It can be viewed at: https://www.theguardian.com/world/2009/nov/27/dubai-financial-crisis-debt

Ghouse, G. and S. A. Khan (2017) Tracing Dynamic Linkages and Spillover Effect between Pakistani and Leading Foreign Stock Markets. *Review of Financial Economics* 35, 29–42.

Glosten, L. R., R. Jagannathan, and D. E. Runkle (1993) On the Relation between the Expected Value and the Volatility of the Nominal Excess Return on Stocks. *The Journal of Finance* 48:5, 1779–1801.

Hasan, Z. (2010) Dubai Financial Crisis: Causes, Bailout and After— A Case Study. *Journal of Islamic Banking and Finance* 47–55.

Iqbal, Z. and A. Sattar (2005) The Contribution of Workers' Remittances to Economic Growth in Pakistan. Pakistan Institute of Development Economics. (Working Paper No. 2005: 187).

Jan, W. and K. Jebran (2015) Empirical Analyses of Volatility Spillover from G5 Stock Markets to Karachi Stock Exchange. *Pakistan Journal of Commerce and Social Sciences* 9:3.

Jawed, S. M. (2015) An Analysis of Coincidence between KSE-100 and S&P 500 Index Using Spectral Approach. *Pakistan Journal of Engineering, Technology and Science* 4:2.

Jebran, K., S. Chen, I. Ullah, and S. S. Mirza (2017) Does Volatility Spillover among Stock Markets Varies from Normal to Turbulent Periods? Evidence from Emerging Markets of Asia. *The Journal of Finance and Data Science* 3:(1-4), 20–30.

Kawai, M., D. G. Mayes, and P. Morgan (Eds.) (2012) *Implications of the Global Financial Crisis for Financial Reform and Regulation in Asia*. Edward Elgar Publishing.

Kharchenko, I. and P. Tzvetkov (2013) Estimation of Volatilities and Spillover Effects between Developed and Emerging Market Economies. Department of Economics, Lunds Universitet. Retrieved from http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=3801343&fileOId=3813321

Li, Y. and D. E. Giles (2015) Modelling Volatility Spillover Effects between Developed Stock Markets and Asian Emerging Stock Markets. *International Journal of Finance and Economics* 20:2, 155–177.

Lim, C. M. and S. K. Sek (2013) Comparing the Performances of GARCH-type Models in Capturing the Stock Market Volatility in Malaysia. *Procedia Economics and Finance* 5, 478-487.

Mishkin, F. S. (2011) Over the cliff: From the subprime to the global financial crisis. *Journal Economic Perspectives* 25:1, 49–70.

Nazir, M. S., R. Safdar, and M. I. Akram (2012) Impact of Global Financial Crisis on Banks' Financial Performance in Pakistan. *American Journal of Scientific Research* 78, 101–110.

Onour, I. (2010) The Global Financial Crisis and Equity Markets in Middle East Oil Exporting Countries. University Library of Munich, No. 23332.

PES (2010) *Economic Survey of Pakistan*. Ministry of Finance Pakistan. It can be viewed at: http://www.finance.gov.pk/survey_1617.html

Phulpoto, L. A., A. B. Shah, and F. M. Shaikh (2012) Global Financial Crises and Its Impact on Banking Sector in Pakistan. *Journal of Asian Business Strategy* 2:6.

SBP (2007) Annual Report. Karachi: State Bank of Pakistan. It can be viewed at: http://www.sbp.org.pk/reports/annual/

SBP (2008) Annual Report. Karachi: State Bank of Pakistan. It can be viewed at: http://www.sbp.org.pk/reports/annual/

Wahid, A. and M. Mumtaz (2018) The Paradigm Shift in the Pakistan Stock Exchange's Financial Integration Post-FTA and CPEC. *Lahore Journal of Economics* 23:1, 21–50.

Zia-ur-Rehman, M., Z. A. Shah, and R. Mushtaq (2011) Sources of Return and Volatility Spillover for Pakistan: An Analysis of Exogenous Factors by Using EGARCH Model. *International Conference on Business and Economics Research* 16, 151–157.