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Mechanism of Volatility Spillover Between Stock, Currency, and Commodity Markets of Pakistan

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This research aims to examine the mechanism of volatility transmission between stock, currency, and commodity markets of Pakistan. For this purpose, daily data covering the period August 4, 1997 to August 31, 2016 is analysed. Empirical investigation is conducted by using EGARCH model. The strength of the study is analysis of the commodity market together with stock and currency markets of Pakistan. Results of the EGARCH model suggests that bidirectional volatility spillover exists between all the bivariate cases of the three markets except in the case of volatility spillover from the currency market to the commodity market.

JEL Classifications: Q43, G10, C13, F31, F36
Keywords: Stock, Currency and Commodity Markets, Volatility Spillover, EGARCH Model

1. INTRODUCTION

Over the last few decades, financial market volatility has been the subject of study for many researchers globally. Increasing integration among major financial markets has focused the attention of academics, researchers, and policy-makers in volatility modelling and analysing the volatility transmission mechanism among major international financial markets. Volatility, in the literature is defined as *instability*, *fickleness*, or *uncertainty*, whether appearing in asset pricing, risk management, or portfolio optimisation (Jamil, 2011). Due to financial liberalisation and globalisation of the world markets, volatility of a certain market may lead to instability or uncertainty in other related markets called volatility spillover (Mishra et al. 2010). True facts and figures of volatility and volatility spillover among financial markets provide huge help for making economic and financial decisions.

In the 1990s, after financial sector reforms, the financial markets of Pakistan have become interdependent. Zapatero (1995) argued that in perfectly integrated and interdependent financial markets, explicit linkages always exist between the volatility of markets. Due to these explicit inter-market linkages, the exchange rate has become more responsive to innovations in the stock market and uncertainty in commodity markets

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(Yang & Doong, 2004). Economists and investors consider gold a safe haven industrial commodity and investment asset (Shahzadi & Chohan, 2011). Likewise, as oil and gold are international commodities and their prices are determined in international markets, volatility of oil and gold prices due to any national or international shock directly affect the exchange rate and its volatility. This may have an indirect impact on stock market volatility as well. Because of uncertainty in financial markets and frequent portfolio switching by investors, volatility in one market can travel to other related markets very easily. Keeping in mind the implications of inter-market linkages, the present study intends to analyse the research hypothesis that bidirectional volatility spillover exists between stock, currency and commodity markets.

Information available through this study can be of great importance for policy makers, investors, market players, and managers. Policy-makers can benefit from this study by understanding the behaviour of the three markets in order to efficiently formulate and implement policies for economic and financial stability. Investors and other market players can use the information available through this study to manage their local and international portfolio risk policies. By managing their exposure to foreign contracts and the exchange rate risk, results of this study can help managers to stabilise their earnings. The intended study is a unique work in the context of Pakistan, jointly analysing the mechanism of volatility transmission between three major markets. In this aspect the presented study is a novel contribution in literature with reference to Pakistan. The next four sections are as follows: Section 2 provides literature review. Section 3 comprises methodology and data. Results, and their detailed discussion are in Section 4 and Section 5 provides the conclusion.

2. LITERATURE REVIEW

Theoretical links between stock prices and the exchange rate can be explained through *Flow Oriented model* and *Stock Oriented model*. The Flow Oriented model provided by Dornbusch and Fischer (1980) suggests that causality runs from exchange rate to stock prices and the exchange rate has a positive impact on stock prices. In the Stock Oriented model provided by Branson (1983), causality runs from stock prices to the exchange rate. This model also suggests a positive relationship between stock prices and exchange rates. According to Dornbusch and Fischer (1980), appreciation (depreciation) of a local currency will decrease (increase) indebtedness of a particular country in terms of foreign currency denominated debts. In other words, the outstanding debts of local companies will be worth less (more) and thus they will have to pay less (more) in terms of the domestic currency. It results in increasing (decrease) a company's net worth and hence stock prices. Stock prices rise when the net worth of a company increases and demand for the company's shares goes up. This in turn pushes up stock prices.[1]

On the other hand, Branson (1983) proposed that a booming stock market of a country attracts domestic as well as foreign investors. Consequently, demand for local currency rises resulting in appreciation of the currency.

[1]Local currency appreciates when foreign investors seeking high returns sell foreign currency for local currency, to buy local stock, which pushes up capital inflows. Thus capital inflow will lead to an appreciation of the local currency.

According to the flow and stock oriented models, a positive relationship exists between stock prices and the exchange rate, which shows that the stock market and currency markets are interlinked. Due to interlinkage of both markets, if the returns volatility of stock (currency) market increases due to any external or internal shock, it will induce volatility in currency (stock) market returns as well.

Gold serves as a safe haven against inflation. Investors become reluctant to invest in the stock market because in periods of uncertainty, returns[2] on stocks fall. When there is instability and uncertainty in an economy, investors withdraw their investments from the stock market and prefer to park their funds in more stable commodities like gold. This pushes demand for gold giving rise to high prices of gold and ultimately high gold returns. High prices of gold will add to inflation in the economy. To reduce inflation, the central bank will set a relatively high interest rate. As interest rates and stock prices have a negative relationship, stock prices and stock returns fall. Negative linkage between gold price returns and stock price returns indicate that the rising volatility in the stock market will lead to volatility of gold price returns to some extent. However, being a safe haven, gold price returns show relatively less volatility.

An increase in oil prices due to any internal or external shock will lead to an increase in oil price returns, making room for the volatility of oil price returns to rise. Demand for other stocks will increase and hence, it will positively affect the volatility of stock returns (Park & Ratti, 2008). Prices of international commodities are determined in international currencies, most usually in US dollars. Therefore, any change in the dollar rate will most likely be transmitted to the prices of international commodities. Therefore, if appreciation in foreign exchange rates takes place, it will result in a rise in prices of imported commodities, including gold and oil in the domestic market. This suggests that a positive relationship exists between the exchange rate and commodity prices for countries importing commodities (Sjaastad & Scacciallani, 1996). The existence of strong positive linkages between currency and commodity markets signals that volatility of exchange rate returns can travel to the commodity market, making commodity price returns also volatile.

Volatility transmission has been examined in different perspectives by researchers in literature. Kanas (2000) examined the long run relationship and volatility spillover among stock returns and exchange rate in six developed countries. Analysis of the study based on Exponential Generalised Autoregressive Conditional Heteroskedasticity (EGARCH) model suggests that a significant long run relationship and volatility spillover exists among stock returns and exchange rate for all the countries. Kalu (2014) reported the bidirectional volatility spillover among stock and currency markets of selected Asian countries using the multivariate Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model. Similar results are postulated by Jebran and Iqbal (2016) for selected Asian countries by using EGARCH model.

In Pakistan, Qayyum and Kemal (2006) conducted the very first study on volatility transmission between stock market and foreign exchange market. The focus of the study was stock and flow oriented models. The Engle-Granger 2-step procedure and bivariate EGARCH model was employed for the analysis of the issue. The same results are postulated by this study; however, no long run relationship among stock market and currency market is reported. Yang and Doong (2004) postulate the same results for developed countries.

[2]Return on prices of a stock can be defined as logarithmic difference between two period prices (Fama, 1965).

However, Khan et al. (2016) have investigated the same subject matter for gold prices and the Karachi stock exchange by using the same data analysis techniques. The conclusion is that gold prices have no relationship with the KSE 100 index. Chen and Rogoff (2003) examine the impact of commodity prices on the exchange rate for Australia, New Zealand and Canada. Results of the OLS technique suggest that the exchange rate is driven by commodity prices. In Pakistan’s context, the impact of crude oil prices and gold prices on the exchange rate are also analysed by Jan et al. (2014). Results of OLS and Vector Autoregressive (VAR) models suggest that oil prices affect the exchange rate positively and significantly, whereas the impact of gold prices is negative and significant. Moreover, Park and Ratti (2008) determine the issue of financial contagion and volatility spillover in India. The Dynamic Conditional Correlation (DCC)-GARCH model has been employed to analyse the daily data. It reports volatility spillover from gold, stock and foreign exchange market to the Indian commodity market.

Using Generalise Impulse Response Function (IRF), Generalised Forecast Error Variance Decompositions (FEVD) and VAR models, Masih et al. (2011) suggested that the stock market is significantly affected by oil price volatility in emerging economies. However, Aktham (2004) suggested that there is no significant relationship between oil price shocks and stock market indices of emerging economies. For Gulf Cooperation Council (GCC) countries, volatility spillover across equity markets and the two dominant commodities, gold and oil prices, has been studied by Thuraisamy et al. (2013) using multivariate GARCH model. Results of the study suggested volatility spillover from stock markets to commodity markets in mature markets, whereas in immature markets volatility is transmitted from commodity markets to stock markets. In addition, bidirectional volatility transmission increases during a period of financial crisis. Arouri et al. (2011) report the same results for Asian and GCC countries.

Another study for Pakistan determined the relationship between stock market volatility and macroeconomic variables (Hussain et al. 2015). The macroeconomic variables of inflation, exchange rate, money supply, industrial sector output, and oil prices have been studied in relation to stock market volatility. Monthly time series data has been estimated by employing EGARCH and Autoregressive Distributed Lag (ARDL) models. Analysis of the study revealed that the exchange rate has a positive and significant impact on stock returns volatility (Aliyu, 2012). However, the impact of oil prices is positive but insignificant on the stock returns volatility. Najaf and Najaf (2016) have studied the relationship between gold and oil prices and the Karachi stock exchange. Results of the study suggest that oil prices have an insignificant negative impact on stock returns, whereas gold prices have a positive but insignificant relationship with stock returns. Analysis of the study is carried out by developing a correlation matrix. Opposite results are suggested by Basher and Sadorsky (2006) for emerging economies. International multi-factor is used for data analysis.

This type of analysis, comprising of local market interlinkages can be very interesting and informative through many perspectives. Therefore, deep understanding and a strong analysis of volatility and volatility spillover between local markets is the need of the day for asset price determination, portfolio optimisation, effective policy formulation, and portfolio management in developing countries like Pakistan.

3. METHODOLOGY

In past studies, for the sake of measuring volatility of financial variables, simple measures of volatility i.e. rolling variance of the series have been used. Engle (1982) provided a family of models based on the concept that the time variant nature of a variance follows an autoregressive process. Engle (1982) and Bollerslev (1986) suggested that it would be better to simultaneously model the mean and variance of a series. Bollerslev (1986) argues that the conditional variance of an error term not only depends on past squared values of the error term but also on the variance of the error term. In pure econometric terms, if the ARCH (p, q) model follows the ARMA (p, q) process then it is called a GARCH (p, q) model. The GARCH (p, q) model allows both autoregressive and moving average components in the conditional variance of error term. Autoregressive Conditional Heteroskedasticity Models (ARCH) developed by Engle (1982) are based on the assumption that positive and negative error terms (shocks) have a symmetric effect on volatility because error terms have been taken in square form in the model. However, generally, this assumption is frequently violated in practice and it is often observed as well as reported in literature, that bad news has more impact on volatility relative to good news. In literature this phenomenon has been introduced as the leverage effect by Black (1976). In GARCH type models, it is necessary to show that all estimated coefficients should be non-negative. This means the effect of positive and negative news will be the same on the volatility series of a variable. As a solution, Nelson (1991) has introduced an extension of the GARCH model called EGARCH model. It captures the leverage effect while calculating volatility. A GARCH family model that does not require non-negativity constraints and accounts for the asymmetric effect of news is called EGARCH model. Hamilton (1989) reported that, for quantifying volatility, the EGARCH model is more advantageous than other members of ARCH/GARCH family models are.

Formally, *AR(k)-EGARCH(p, q)* model for calculating returns' volatility of KSE-100 index ($RKSE$), bilateral nominal exchange rate returns' volatility ($REXR$), oil prices returns' volatility (ROP) and gold prices returns' volatility (RGP) variables' data series can be expressed as follows:

$$R_t^x = \alpha_0 + \alpha_1 \sum_{i=1}^{n} R_{t-i}^x + e_t \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (1)$$

$$log(h_t^x) = \omega + \sum_{i=1}^{p} \gamma_j \, logh_{t-j}^x + \sum_{j=1}^{q} \rho_j \left| \frac{\mu_{t-j}}{\sqrt{h_{t-j}}} \right| + \sum_{m=1}^{r} \theta_m \frac{\mu_{t-m}}{\sqrt{h_{t-m}}} \qquad \dots \qquad (2)$$

The above two equations represents the *AR(k)-EGARCH(p, q)* model. In equation (1) R_t^x represent returns of variable x at time t and $t = 1,2,\dots,T$. R_{t-i}^x is the previous period returns of variable x where, $i = 1,2,\dots,n$. Variable x represents the data series of $RKSE$, $REXR$, ROP and RGP. In Equation (2) $log(h_t^x)$ is the log of variance of variable x which automatically restricts the volatility to be positive. ω is the constant level of volatility. Logarithm of the conditional variance (h_{t-j}^x) on the right hand side imply that the leverage effect is exponential, rather than quadratic, and that forecasts of the conditional variance are guaranteed to be nonnegative without imposing any restriction on the coefficients. The coefficient ρ_j measures reaction of volatility to change in news. We take the residual modulus that measures the relation with respect to positive news.

The coefficient θ_m explains the relationship of volatility to both positive and negative news, because we are not taking modulus. In this paper we employ Schwarz Bayesian Information Criteria (SBIC) for the selection of the orders k, n, p and q in Equation (1) and Equation (2) respectively.

After calculating the volatility of returns, the phenomenon of volatility spillover between stock, currency and commodity markets is captured by using bivariate *AR(k)-EGARCH(p, q)* model. Following Enders (2006), corresponding mean and variance equations used for estimating the volatility spillover are as follows:

$$R_t^x = \alpha_0 + \alpha_1 R_{t-1}^x + \beta_1 R_{t-1}^y + e_t \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

$$log(h_t^x) = \omega + \sum_{i=1}^{p} \gamma_j \, log h_{t-j}^x + \sum_{j=1}^{q} \rho_j \left| \frac{\mu_{t-j}}{\sqrt{h_{t-j}}} \right| + \sum_{m=1}^{r} \theta_m \frac{\mu_{t-m}}{\sqrt{h_{t-m}}} + \pi_y log\left(h_t^y\right) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$$

Equation (3) is mean equation. In mean equation R_{t-1}^y is representing autoregressive term of returns of variable y, where y is the second variable from $RKSE$, $REXR$, ROP and RGP variables, for bivariate analysis. For example in mean equation, if x is representing returns on oil prices (ROP) then y will be KSE-100 index returns ($RKSE$). Equation (4) is representing variance equation. $\pi_y log\left(h_t^y\right)$ is the returns' volatility of variable y and π_y is volatility spillover parameter for volatility spillover from variable y to variable x i.e. from KSE-100 index returns' volatility ($RKSE$) to oil prices returns' volatility (ROP). Explanations of the remaining parameters of the Equations (3) and (4) are same as discussed for the Equations (1) and (2).

4. DATA

In order to investigate the mechanism of volatility transmission across the stock, currency, and commodity markets of Pakistan, daily data comprising five trading days has been analysed. KSE-100 index (KSE) representing the Karachi Stock Exchange market and bilateral nominal exchange rate PKR in terms of USD (EXR) representing the currency market has been analysed. Whereas, gold prices (GP) and oil prices (OP) as a representative of commodity market are being selected.[3] The Time series data sample from August 4, 1997 to August 31, 2016 is used. The reason behind the selection of daily data set is to capture more information than we would be able to with the weekly and monthly data set. A brief summary of all variables is presented in the Table 1.

Returns on stock prices, bilateral nominal exchange rate, oil prices and gold prices is calculated as the first difference of logarithmic values of $LKSE$, $LEXR$, LOP and LGP, respectively. Calculation of returns is being done according to following formula;

$$R_t^x = log(x_t) - log(x_{t-1}) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (5)$$

Where, R_t^x is returns at time period t of variable x, where x represent the data series of variables $LKSE$, $LEXR$, LOP and LGP. x_t is the value of variable x at time period t

[3]As gold and oil, as a commodity, represent a major portion of commodity market, therefore both are selected as a representative of commodity market (Shahzadi & Chohan, 2011).

Table 1

List and Description of the Variables

Indicator	Notations	Data Source	Description
KSE-100 Index	KSE	www.brecorder.com	KSE-100 index is a capital weighted index, composed of 100 representative companies in terms of market capitalisation. Daily closing stock prices in term of Pak-rupees are taken to represent KSE-100 index.
Exchange Rate	EXR	www.sbp.gov.pk	EXR is a bilateral nominal exchange rate between USD and PKR. It is taken in PKR.
Oil prices	OP	www.eia.gov	OP is Crushing Oklahoma Crude Oil prices per barrel taken in PKR.
Gold prices	GP	www.forex.pk	GP is 24 Karat gold prices taken in Troy Ounce in term of PKR.

Source: Author's own work.

(current time period) and x_{t-1} is value of variable x at time period $t-1$ (previous time period). After computing the returns for all variables data series, volatility of all variables is being calculated by using the *AR(k)-EGARCH(p, q)* methodology.[4]

5. RESULTS

Descriptive statistics of all the variables are presented in Table 2. Panel A of table shows descriptive statistics of logarithmic values of KSE-100 index ($LKSE$), bilateral nominal exchange rate ($LEXR$), oil prices (LOP) and gold prices (LGP). The mean of logarithmic values of all the variables is positive and is significantly different from zero. Panel B shows descriptive statistics of growth rate of KSE-100 index ($RKSE$), bilateral nominal exchange rate ($REXR$), oil prices (ROP) and gold prices (RGP). Mean of growth rate of all variables is positive and is not significantly different from zero. Median, range and standard deviation in both panels reveals that there is no outlier in the data.

Table 2

Descriptive Statistics

	Variable							
	Panel A				Panel B			
Statistics	LKSE	LEXR	LOP	LGP	RKSE	REXR	ROP	RGP
Mean	11197.89	72.35	4491.26	65413.26	0.0006	0.0002	0.0004	0.0005
Median	9429.37	60.81	3831.67	39556.32	0.0010	0.0000	0.0008	0.0004
Max.	40057.52	108.57	11580.65	170950.2	0.128	0.083	0.172	0.965
Min.	765.73	40.47	519.65	12265.97	-0.099	-0.083	-0.171	-0.989
S.D.	10235.47	19.40	3059.22	51863.47	0.014	0.004	0.024	0.023
Skew.	1.137	0.418	0.516	0.523	-0.389	1.004	-0.089	-1.099
Kurt.	3.320	1.727	1.985	1.646	8.632	169.258	7.768	1233.443
J.B.	1026	481	434	607	6702	5733069	4720	31300000

Source: Author's own work.

[4]To support the use of EGARCH model for volatility calculation, significant evidences provided by a number of researchers have been summarised by Hamilton and Susmel (1994).

J.B. test of normality is a test of the joint hypothesis that implies skewness and kurtosis are zero and 3 respectively. Therefore, J.B. statistics are expected to be zero for variable to be normally distributed. To test whether, series of variables are normally distributed or not, null hypothesis is formulated as; H_0: Variable x is normally distributed. Values of J.B. statistics presented in the Table 2 imply that variables are not normally distributed. This is due to the reason that J.B. statistics are significantly greater than zero, which is against the requirement for normality.[5] So H_0 is rejected in case of all variables' J.B. statistics presented in Table 2. It corresponds to the fact highlighted by Mandelbrot (1963), suggesting that all data series have more extreme values and have greater volatility.

The stock market is affected by countless factors. These factors might be internal or external. Among external factors, the exchange rate, and gold and oil prices have remained dominant throughout history. The Karachi stock exchange came into being soon after Independence in 1947, to facilitate the trade of ordinary shares, redeemable certificates, and corporate bonds in the country (Alam & Muzafar, 2014). In 2002, the international magazine 'Business Week' pronounced KSE as the best performing market in the world because of high liquidity and improved administration and management. During the period of global financial crisis 2008 KSE-100 index had declined slightly, however overall performance of KSE remained the least affected relative to the other Asian stock exchange markets.

In Figure 1, KSE is exhibiting increasing trend overall while the series is not showing mean reversion behaviour. Graph of $RKSE$ in Figure 2 revealed mean reversion behaviour indicating that the series is stationary. Graph of volatility of $RKSE$ series in Figure 3 is characterised by random changes and is volatile till the start of 2010. The volatility seems to change over time as well. However, the series has experienced a somewhat calm period from 2010 to onward. According to an edition of Quartz,[6] KSE is declared as 5th best performing market in the world in July 20, 2016 (Karnik, 2016). Plot of $RKSE$ and volatility of $RKSE$ is showing volatility clustering[7] during 1998 only. In 1998, due to the nuclear test and economic sanctions, market capitalisation fell.

The plot of *EXR* against time in Figure 7 is displaying a constant increasing trend and the series is not showing mean reversion behaviours. However, *REXR* graph in Figure 8 has displayed a mean reversion behaviour indicating that the series is stationary. In Figure 9, the plot of volatility of *REXR* series displays random changes and is volatile overall. However, *REXR* has experienced a somewhat tranquil period from mid-2001 to 2007(Musharraf's rule, 1999 to 2007). This was due to heavy remittance inflow and foreign direct investment during this period. Volatility clustering has been experienced by *REXR* and volatility of *REXR* in the period of nuclear explosion (1998) and financial crisis (2008).

[5]If the J. B. statistics are very low i.e. significantly different from zero we reject the null hypothesis. However, if the J.B. statistics are close to zero we cannot reject (accept) the null hypothesis **(**Gujarati and Porter, 2009**)**.

[6]Quartz is an Indian, digital magazine of global business news publication.

[7]Period of high volatility followed by period of high volatility and period of low volatility followed by period of low volatility, of either sign (Mandelbrot, 1963).

Fig. 1. Distribution of KSE-100 Index

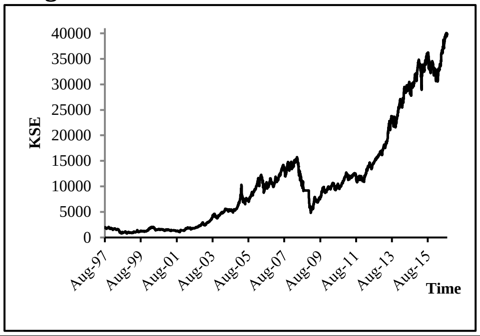


Fig. 2. Distribution of RKSE

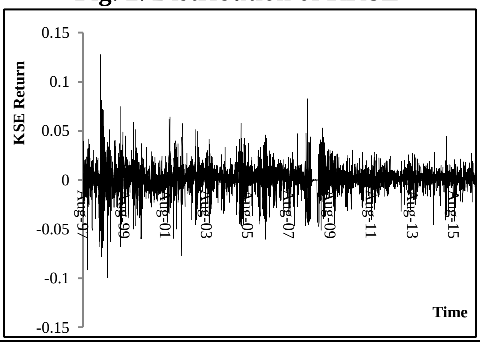


Fig. 3. Distribution of Volatility of RKSE

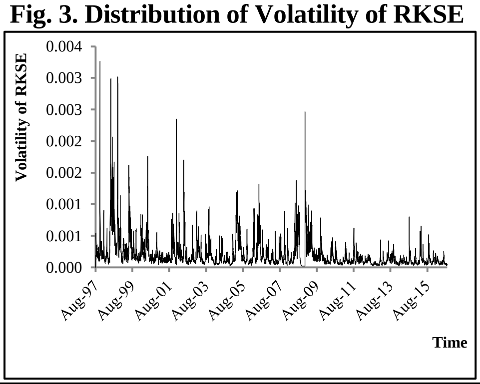


Fig. 4. Distribution of OP

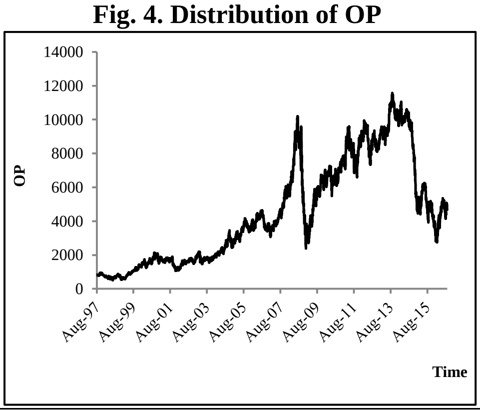


Fig. 7. Distribution of EXR

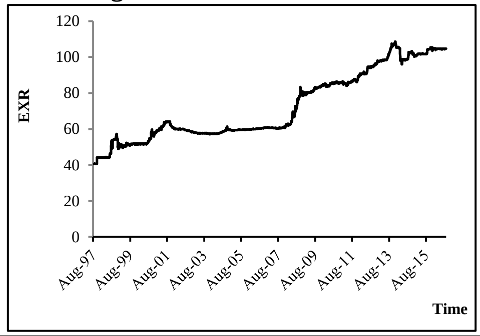


Fig. 8. Distribution of REXR

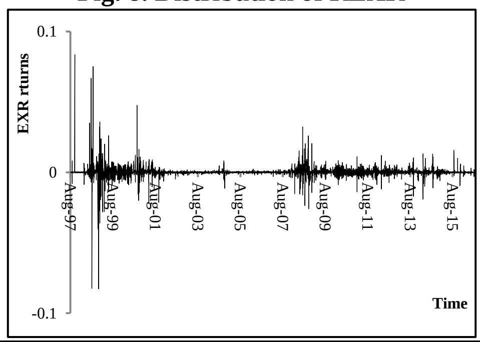


Fig. 9. Distribution of Volatility REXR

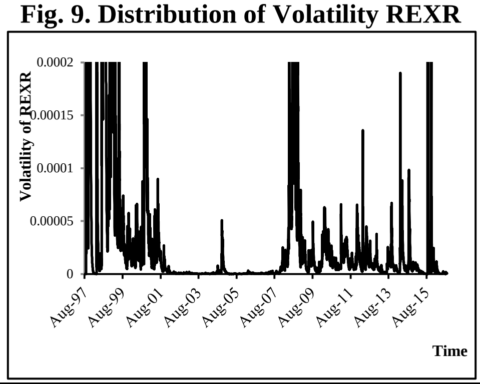


Fig. 10. Distribution of GP

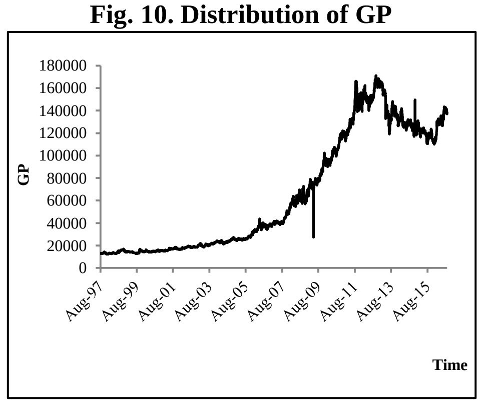


Fig. 5. Distribution of ROP

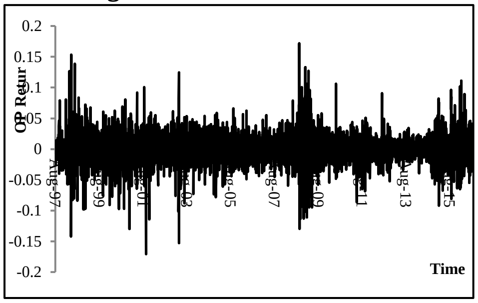


Fig. 11. Distribution of RGP

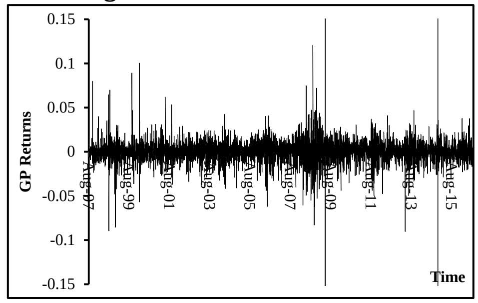


Fig. 6. Distribution of Volatility of ROP

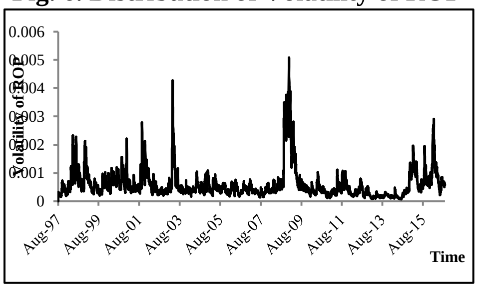
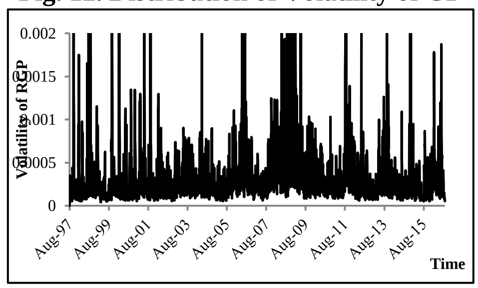


Fig. 12. Distribution of Volatility of GP



Historically, huge volatility has been observed in oil prices. However, *OP* series in Figure 4 is displaying a steady rising trend from start of the sample period till the end of 2007. The main reasons for rising oil prices were tension in the Middle East, high demand for oil from the Chinese economy, and declining oil reserves. A sudden upward surge is observed in 2008, due to the global financial crisis. *OP* series is not showing mean reversion behaviours whereas the plot of *ROP* is revealing mean reversion behaviour in Figure 5. The plot of volatility of *ROP* series in Figure 6 displays random changes and is observed as volatile overall. However, volatility of *ROP* series has exhibited a somewhat tranquil period from 2003 to 2007 and from 2010 to 2014. Aktham (2004) said that this was due to the declining value of the US dollar from 2001 to 2003. During the global financial crisis a significant jump is depicted in the *ROP* volatility series. Volatility clustering is observed in the period of nuclear explosion and financial crisis in the graph of *ROP* as well as in the graph of volatility of *ROP*.

Gold serves as a commodity as well as an investment tool (Johnson & Soenen, 1997). In Figure 10, graph of *GP* presents a smooth upward trend till the third quarter of 2008. In the fourth quarter of 2008 a sudden downward jump is observed (due to the financial crisis). After that the *GP* series again depicted an upward trend till 2012, and then a very slight down trend till 2014. In October 2012, gold prices peaked and then again revealed a gradual declining trend due to a rise in the supply of gold. From the end of 2014 onward *GP* revealed a rising trend, overall. Mean reversion behaviour has not been shown by *GP*. However, *RGP* exhibited mean reversion behaviour in figure 11. Graph of volatility of *RGP* presented in Figure 12 is characterised by random changes and is observed as volatile throughout the sample period. The main driving forces behind volatile gold prices are bouncing oil prices and the rising value of the US dollar. Volatility clustering is observed in the period of financial crisis (2008) in the graph of *RGP* as well as in volatility of *RGP*.

Before checking stationarity of the data, lag order for all the variables is checked according to the Schwarz Bayesian Information Criterion (SBIC). According to SBIC, lag order of *LKSE* is significant until the second lag, and lag length of *LEXR* and *LGP* are significant till the third lag. However, the lag order of *LOP* is significant at level. In the next step, in order to examine the stationarity of the data, Augmented Dickey and Fuller and Philips and Perron unit root tests are applied on each variable's data series included in the analysis.

Table 3

Results of Unit Root Tests

Variables	ADF-test Level	ADF-test First Difference	PP-test Level	PP-test First Difference	Order of Integration
LKSE	0.131	–44.437***	–0.039	–64.242***	I(1)
LEXR	–1.449	–43.478***	–1.422	–68.275***	I(1)
LOP	–1.687	–70.102***	–1.671	–70.174***	I(1)
LGP	–0.652	–53.774***	–0.605	–125.615***	I(1)

Source: Author's own calculations.

Note: –3.431482, –2.861925 and –2.567018 are critical values at 1 percent, 5 percent and 10 percent level of significance, respectively. Whereas, ***, ** and * indicate significance at 1 percent, 5 percent and 10 percent level of significance, respectively.

According to ADF and PP test null hypothesis that series have unit root is accepted at level, indicating that $LKSE$, $LEXR$, LOP and LGP have non-stationary at level. However, null hypothesis at first difference is rejected for all data series by the both tests, demonstrating that all variables' data series have no unit root at first difference. Stationarity of all data series at first difference implies that series are integrated of order one I(1).

The mechanism of volatility transmission between stock, currency and commodity market is captured by employing the bivariate *AR(k)-EGARCH(p, q)* model. Before applying the bivariate *AR(k)-EGARCH(p, q)* model, the underlying variables that are returns on KSE-100 index ($RKSE$), returns on bilateral nominal exchange rate ($REXR$), returns on oil prices (ROP) and returns on gold prices (RGP), have been examined for possible existence of the ARCH effect. The ARCH effect is applied to check for the presence of issues of autocorrelation and heteroskedasticity in the data set of all variables series. For this purpose, ARCH effect for the returns of all variables series has been checked by applying Breusch and Pagan test. The possible existence of ARCH effect, in all the underlying variables, is confirmed by resultant significant chi-square value. Hence, EGARCH model can be applied successfully. A suitable lag order for each bivariate *AR(k)-EGARCH(p, q)* model is determined on the basis of SBIC. Results of volatility spillover are reported in Table 4.

In Table 4 variance equation results are presented regarding volatility transmission between stock, currency and commodity markets of Pakistan. Estimated results of volatility transmission from $RKSE \rightarrow REXR$ and $REXR \rightarrow RKSE$ suggests that the volatility spillover parameter (π) is positive and significant at 1 percent level of significance. The magnitude of volatility transmission from $RKSE \rightarrow REXR$ is 0.065, which is greater than the magnitude of volatility transmission from $REXR \rightarrow RKSE$ which is 0.009. The magnitude of volatility transmission between both the markets is significant and positive. However, if magnitude of both pairs of markets are compared it can be inferred that the stock market has a dominant role in transmitting volatility to the currency market relative to the opposite case. It implies that increase in volatility of KSE-100 index returns (stock market) leads to increase in volatility of bilateral nominal exchange rate returns (currency market). From the above reported results, it can be concluded that a positive and significant bidirectional volatility spillover exists between the stock market and the currency market. The same results are confirmed by Qayyum and Kemal (2006) for Pakistan and selected Asian countries, respectively.

In panel B of Table 4, estimated results of volatility transmission from $RKSE \rightarrow ROP$, from $RKSE \rightarrow ROP$, from $RKSE \rightarrow RGP$ and from $RGP \rightarrow RKSE$ are reported. It suggests, that the volatility spillover parameter ($\boldsymbol{\pi}$) is positive and significant at 1 percent level of significance however, for $RGP \rightarrow RKSE$ volatility spillover parameter ($\boldsymbol{\pi}$) is significant at 5 percent level of significance. It depicts that bidirectional volatility spillovers exist between KSE-100 index returns' volatility (stock market) and oil prices returns' volatility (commodity market), and between KSE-100 index returns' volatility (stock market) and gold prices returns' volatility (commodity market). Kang and Yoon (2014) reported the same results for Asian countries, and Arouri et al. (2011) for GCC countries.

The magnitude of volatility transmission from $RKSE \rightarrow ROP$ is 0.009, which is less than the magnitude of volatility transmission from $ROP \rightarrow RKSE$, which is 0.036. However, as the magnitude of volatility transmission from $ROP \rightarrow RKSE$ is greater than that of the magnitude of volatility transmission from $RKSE \rightarrow ROP$, a statement can be made that volatility of the commodity market has a dominant role in volatility transmission to stock market. The magnitude of volatility transmission from $RKSE \rightarrow RGP$ is 0.943 which is greater than the magnitude of volatility transmission from $RGP \rightarrow RKSE$ which is 0.009. However, as the magnitude of volatility transmission from $RKSE \rightarrow RGP$ is greater than magnitude of volatility transmission from $RGP \rightarrow RKSE$, it can be inferred that volatility of stock market has a dominant role in transmitting volatility to the commodity market. Jaiswal and Varonina (2011) supported the same results.

In panel C of Table 4, results of volatility transmission from $REXR \rightarrow ROP$, from $ROP \rightarrow REXR$, from $REXR \rightarrow RGP$ and from $RGP \rightarrow REXR$ are presented. It suggests, that volatility spillover parameter (π) is insignificant for $REXR \rightarrow ROP$. This result is also reported by Arezki et al. (2012) for South Africa. It implies that volatility spillover does not exist from volatility of $REXR$ (currency market) to ROP volatility (commodity market). Whereas, volatility spillover parameter (π) for the volatility transmission from $ROP \rightarrow REXR$, from $REXR \rightarrow RGP$ and from $RGP \rightarrow REXR$ is significant at 1 percent level of significance. It depicts that there exists bidirectional volatility transmission between all the pairs of two markets except for the case of volatility spillover from $REXR \rightarrow ROP$ where unidirectional volatility spillover exists. However, volatility spillover parameter (π) for $RGP \rightarrow REXR$ is negative implying that increase in volatility of RGP causes volatility of $REXR$ to decrease.

Table 4

Volatility Spillover between Stock, Currency and Commodity Markets

$$log(h_t^x) = \omega + \sum_{i=1}^{p} \gamma_j \, logh_{t-j}^x + \sum_{m=1}^{r} \theta_m \frac{\mu_{t-m}}{\sqrt{h_{t-m}}} + \sum_{j=1}^{q} \rho_j \left| \frac{\mu_{t-j}}{\sqrt{h_{t-j}}} \right| + \pi_y logh_t^y$$

Panel A: Volatility Spillover between stock market and currency market		
Coefficients	RKSE → REXR	REXR → RKSE
ω	–0.029***	–0.752***
	(–2.81)	(–6.94)
γ_1	0.955***	0.913***
	(689.55)	(7.44)
γ_2		0.017
		(0.15)
ρ_1	0.640***	0.430***
	(53.75)	(23.70)
ρ_2	–0.474***	–0.107***
	(–43.01)	(–2.83)
θ	0.013**	–0.078***
	(3.77)	(–6.62)
π	0.065***	0.009***
	(39.99)	(3.62)
SBIC	–9.005	–6.051
AR(k)-EGARCH(p,q)	*AR(1)-EGARCH(1,2)*	*AR(1)-EGARCH(2,2)*

Panel B: Volatility Spillover between stock market and commodity market				
Coefficients	RKSE → ROP	ROP → RKSE	RKSE → RGP	RGP → RKSE
ω	–0.193***	–0.649***	–7.226***	–0.751***
	(–8.09)	(–7.50)	(–88.81)	(–6.55)
γ_1	0.981***	0.827***	–0.853***	0.923***
	(377.45)	(6.44)	(–375.94)	(7.39)
γ_2		0.099		0.012
		(0.83)		(0.10)
ρ_1	0.167***	0.423***	0.157***	0.441***
	(18.21)	(20.99)	(79.18)	(24.46)
ρ_2		–0.061		–0.114***
		(–1.41)		(–2.89)
θ	–0.056***	–0.085***	–0.0002	–0.077***
	(–10.25)	(–7.18)	(–0.096)	(–6.79)
π	0.009***	0.036***	0.943***	0.009**
	(4.19)	(5.11)	(120.03)	(2.26)
SBIC	–4.829	–6.061	–5.532	–6.051
AR(k)-EGARCH(p, q)	*AR(1)-EGARCH(1,1)*	*AR(1)-EGARCH(2,2)*	*AR(1)-EGARCH(1,1)*	*AR(1)-EGARCH(2,2)*

Panel C: Volatility Spillover between currency market and commodity market				
Coefficients	REXR → ROP	ROP → REXR	REXR → RGP	RGP → REXR
ω	–0.225***	–0.022***	0.079***	–0.658***
	(–8.42)	(–3.75)	(23.48)	(–78.97)
γ_1	0.983***	1.005***	1.005***	1.006***
	(391.22)	(2270.09)	(9537.44)	(2686.82)
ρ_1	0.168***	2.199***	0.071***	0.955***
	(18.72)	(136.19)	(79.23)	(93.13)
ρ_2		–1.832***		–0.589***
		(–121.23)		(–63.26)
θ	–0.054***	–0.084***	0.005***	0.137***
	(–9.99)	(–34.16)	(5.91)	(53.01)
π	0.002	0.015***	0.006***	–0.060***
	(1.31)	(16.01)	(20.04)	(–67.02)
SBIC	–4.827	–9.268	–5.629	–9.707
AR(k)-EGARCH(p, q)	*AR(1)-EGARCH (1, 1)*	*AR(1)-EGARCH (1, 2)*	*AR(1)-EGARCH (1, 1)*	*AR(1)-EGARCH (1, 2)*

Source: Author's own calculations. Note: Values in parenthesis are z-Statistics. Whereas, ***, ** and * indicate level of significance at 1 percent, 5 percent and 10 percent, respectively.

Nair, et al. (2015) reported similar results for India. The magnitude of volatility transmission from $REXR \rightarrow ROP$ is 0.002 which is insignificant and less than the magnitude of volatility transmission from $ROP \rightarrow REXR$ which is 0.015 and significant. The magnitude of volatility transmission from $REXR \rightarrow RGP$ is 0.006 that is less than the magnitude of volatility transmission from $RGP \rightarrow REXR$ which is 0.060. Between both pairs of markets, magnitude of volatility transmission is significant. But in case of $RGP \rightarrow REXR$ magnitude of volatility transmission is negative. It means that increase in volatility of currency market causes increase in volatility of commodity market. However, a rise in volatility of commodity market induces low volatility in currency market. As magnitude of volatility transmission from $RGP \rightarrow REXR$ is greater than magnitude of volatility transmission from $REXR \rightarrow RGP$, it can be inferred that volatility of RGP (commodity market) has a dominant role in transmitting volatility to returns' volatility of bilateral nominal exchange rate $REXR$ (currency market). Hegerty (2016) for Indonesia, Chile and Philippines also suggests similar results.

6. CONCLUSION

Over the last few decades, financial markets volatility is the subject matter of many researchers in the world. In the 1990s, after financial sector reforms in Pakistan, major markets of the country have become more interdependent. Zapatero (1995) argued that in perfectly integrated and interdependent financial markets, explicit linkages always exist among the volatility of markets.

Keeping in view the importance of these issues, the objective of this study is to investigate the magnitude and mechanism of volatility transmission between stock, currency, and commodity markets of Pakistan. Hypothesis of the study is tested by applying bivariate EGARCH model on daily data of KSE-100 index, bilateral nominal exchange rate, oil prices and gold prices. According to the results provided by the EGARCH model, bidirectional positive volatility spillover exists between all the possible pairs of the three markets except in the case of volatility spillover from bilateral nominal exchange rate returns' volatility to oil prices returns' volatility. Whereas, in the case of volatility spillover from gold prices returns' volatility to bilateral nominal exchange rate returns' volatility, spillover parameter is negative.

For further research it is recommended that analysis of volatility transmission should be done by using more comprehensive models. Regime switching models (like MCMS model, SWARCH model, SWGARCH model etc.) are more comprehensive models in which a variety of mechanisms of volatility transmission can be studied in detail. Moreover, the same research can be extended for panel data analysis, as less body of literature is available in this regard.

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