1. Time series analysis
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MODELLING FINANCIAL TIME SERIES IN THE PRESENCE OF OUTLIERS

PhD Econometrics

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DECLARATION

I hereby declare that this thesis, neither as a whole nor as a part thereof, has been copied out from any source. It is further declared that I have carried out this research by myself and have completed this thesis on the basis of my personal efforts under the guidance and help of my supervisors. If any part of this thesis is proven to be copied out or earlier submitted, I shall stand by the consequences. No portion of work presented in this thesis has been submitted in support of any application for any other degree or qualification in International Islamic University or any other university or institute of learning.

Muhammad Irfan Malik

DEDICATION

To

My Parents

My Family

&

Kids

APPROVAL SHEET

Modelling Financial Time Series in the Presence of Outliers

by

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Reg. No: 24-SE/PhD(Et)/S12

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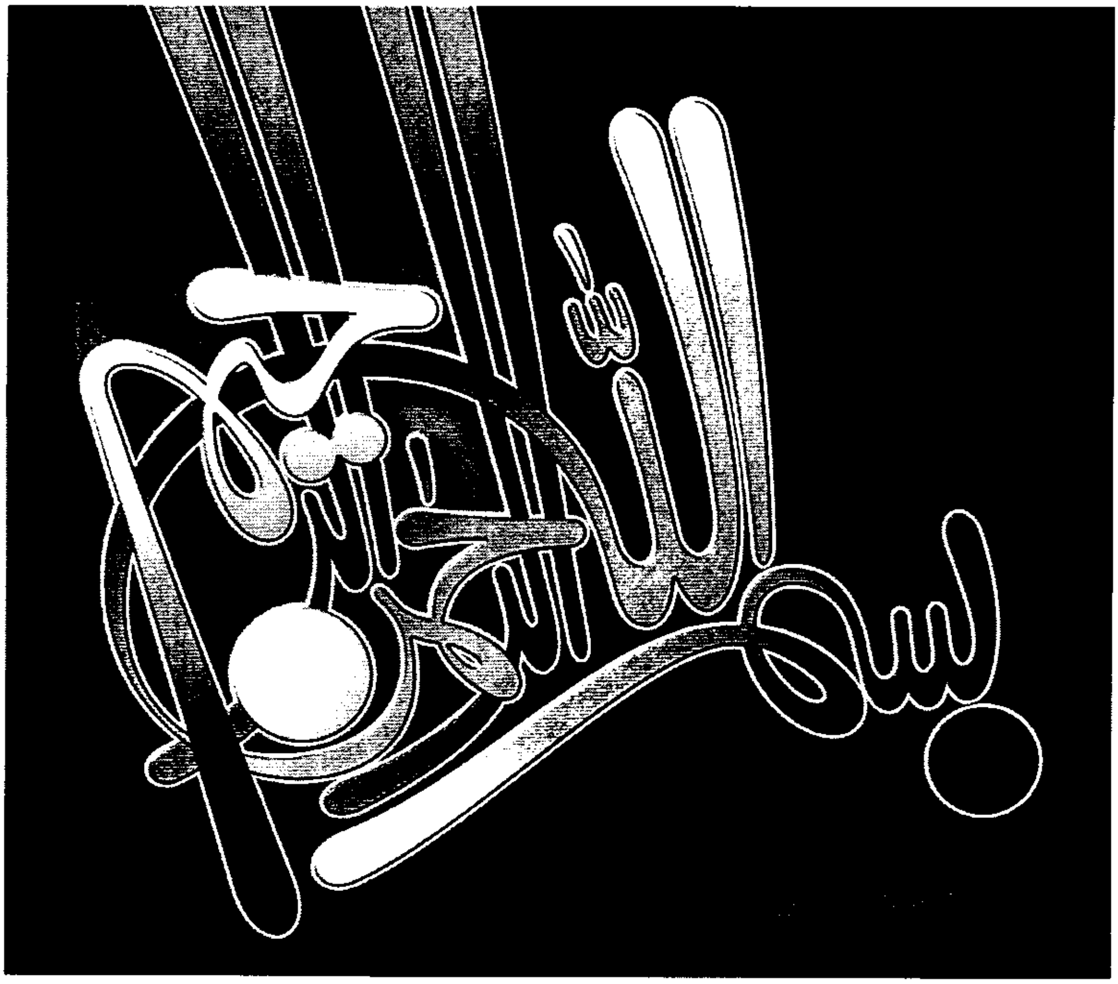
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ABSTRACT

Modelling of return and volatility as well as their dynamic spillovers between different financial markets at aggregated and disaggregated level has gained increasing interest among Financial economists. Alternative univariate and multivariate specifications have been exploited by empirical researchers to measure returns and volatility and their spillovers. However, financial markets are responsive to some specific events that have distorting effect on the model estimates. These unexpected events are depicted as outliers in the data. The estimates of GARCH type models are sensitive to the presence of outliers (Carnero et al., 2016; Charles, 2008; Charles and Darné, 2014). Studying the distortionary effects of outliers is important for the policy makers, hedge fund managers as well as investors. However, it is hard to find any study which investigates the impact of outliers and spillovers keeping in view the sensitivity of GARCH type models to the outliers in context of Pakistan Stock Exchange (hereafter PSX). This study firstly examines the effect of outliers on the returns, volatility and their dynamic spillovers between Pakistan Stock Exchange and world selected stock markets., Secondly, among different sectors of Pakistan Stock Exchange and thirdly, between sectors of Pakistan Stock Exchange and Brent oil market. Finally, the optimal portfolio weights and hedge ratios for both outliers contaminated returns and outliers adjusted returns are calculated.

This study employs the Laurent et al. (2016) method and the Charles and Darné (2005) methods for the detection and correction of outliers. To quantify the dynamics of returns, volatility and their spillovers for unadjusted and adjusted returns, the model of Ling and McAleer (2003) and McAleer et al. (2009) are estimated. Furthermore, daily data sampled from January 01, 2001 to December 31, 2015 was retrieved from DataStream for estimation.

The results of the study at market level indicate that the estimates of conditional mean and conditional variance of Pakistan Stock Exchange are insensitive to the choice of foreign stock market. Furthermore, these coefficients did not change with the correction or non-correction of outliers except intercept of volatility equation. The presence of outliers results in overestimation of intercept term in volatility equation of Pakistan Stock Exchange in all pairs with selected stock markets. The developed stock markets and Indian stock market have significant return spillovers effect to Pakistan Stock Exchange; however, they were slightly overvalued due to the presence of outliers in the data. It was evident that the markets shocks of the US and Euro region spillovers to Pakistan Stock Exchange. In contrast, shocks and volatility of Pakistan Stock Exchange spillovers to Indian stock market only for both unadjusted and adjusted returns. Outliers adjusted returns reduced these spillovers marginally. Presence of outliers did not show significant effect on the estimated values of optimal portfolio weights and hedge ratios.

Sectoral analysis of Pakistan Stock Exchange leads to the conclusion that first and second conditional moments of a sector were sensitive to the choice of other sector in the pair. The outliers' adjustment has sensitivity reducing effect on conditional mean and variance of sectoral returns. The intercept terms in all sectoral stock return volatility equations were well above its market counterpart. Moreover, the estimates of GARCH coefficients revolve around market volatility estimates. Although return spillovers have been observed in some of the sectors but overall the return spillovers are insignificant for both unadjusted and adjusted returns. In contrast to the market level, short run and long run volatility spillovers are sensitive to the presence of outliers. The results also showed that adjustment of outliers have significant impact on the estimates of optimal portfolio weights and hedge ratio.

Finally, we study the effect of outliers on the returns and volatility as well as their spillovers between Brent oil and Pakistan Stock Exchange. The analysis revealed that mean and volatility estimates of Pakistan Stock Exchange bench mark index returns, and oil market returns are non-responsive to presence of outliers. Short run price spillover is found significant from oil market to Pakistan stock market both at market and sectoral levels. Whereas, no transmission of short run as well as long run volatility exist between these two markets for both unadjusted and adjusted returns. The optimal portfolio weights and hedge ratios remains identical for both unadjusted and adjusted returns. The findings are worth interesting for the investors and policy makers.

Keywords: Pakistan Stock Exchange, Outliers, Bivariate AGARCH, Return Spillovers, Volatility Spillovers, Portfolio Weights, Hedge Ratios.

JEL Classifications: C01, C3, C5, C32, C58, D53, E44, F15, F56, G11, G15, Q43

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List of Acronyms

AO	Additive Outliers
ADF	Augmented Dickey Fuller
ARCH	Auto Regressive Conditional Heteroscedasticity
ARMA	Autoregressive Moving Average
BEKK	Baba-Engle-Kraft-Kroner
BIP	Bounded Innovation Propagation
CCC	Constant Conditional Correlation
CD	Charles- Darné
CSE	Colombo Stock Exchange
DCC	Dynamic Conditional Correlation
EGARCH	Exponential Generalized Auto Regressive Conditional Heteroscedasticity
GARCH	Generalized Auto Regressive Conditional Heteroscedasticity
GFC	Global Financial Crisis
GJR	Glosten-Jagannathan-Runkle
IO	Innovative Outliers
LLH	Log Likelihood
LLP	Laurent-Lecourt-Palm
LM	Lagrange Multiplier
NSE	National Stock Exchange
PSX	Pakistan Stock Exchange
QML	Quasi Maximum Likelihood
S&P	Standard & Poor
VAR	Vector Auto Regressive
UCC	Unconditional Correlation

Chapter 1: Introduction

1.1 Introduction

Shocks are hallmark of financial time series, that have a dramatic impact on modelling financial time series (Bali and Guirguis, 2007; Balke and Fomby, 1994; Charles and Darné, 2005). These types of events include, for example, financial slumps, oil price shocks, wars, frequent amendments in the policy regimes, and in some cases natural disasters These erratic and unstable incidents have significant influences on various financial indicators, therefore, these unusual events are regarded as major exogenous shocks and are also categorized as outliers[1]. Johnson and Wichern (2002) and Theodossiou and Theodossiou (2008) express outlier as an observation, which is not consistent with the rest of data and over time it is observed randomly. Many researchers theoretically and empirically found that the presence of outliers have unwanted effects on the model estimates, regularity conditions, forecast of volatility, detection of variance breaks, test of heteroscedasticity etc. (Carnero et al., 2001; Charles, 2004, 2008; Carnero et al., 2016; van Dijk et al., 1999; Charles and Darné, 2005, 2014; Franses et al., 1998; Verhoeven and McAleer, 2000). Outliers can bias the estimates of volatility parameters, regularity conditions of GARCH types models, detection of variance breaks and volatility persistence (Charles and Darné, 2014). The outliers has unwanted effects on the volatility estimates, identification of model and the volatility forecasts (Charles, 2004, 2008; Charles and Darné, 2005).

We find a bulk of empirical literature in which return and volatility including their spillovers between various financial markets for instance equity market, forex market,

[1] These outliers are also known as influential observations.

oil market, gold market etc. has been investigated both at aggregated and disaggregated level (Awartani and Maghyereh, 2013; Abbas et al., 2013; Arouri et al., 2010; Scheicher, 2001; Aloui and Mabrouk, 2010; Balli et al., 2013; Salisu and Oloko, 2015; Savva et al., 2004; Shahwan, 2015; Singh et al., 2010; Singhania and Prakash, 2014; Syriopoulos et al., 2015 and others). However, existing literature is deficient of multivariate studies on the impact of outliers on the return and volatility and their transmission among different financial markets.

Advancements in the information technology along with deregulation and globalization altogether have radically changed the structure of financial markets of the world. Through international trade and finance, the national economies have become more integrated and which has led to increase in interaction of financial markets. Therefore, all stakeholders including monetary authorities, policy makers, hedge funds, portfolio managers, and investors etc. needs to understand the nature and degree of dynamic relationship among financial markets. When referring to international financial market integration, practitioners and economists not only examine return and volatility dynamics, but also investigate the extent of linkages between them.

The return and volatility spillovers among financial markets are critical for several reasons. First, it unveils the evidence concerning market efficiency. In an efficient market it is not possible to forecast future returns from the current returns of another market (Chan et al., 1997). Second, knowledge of return and volatility transmission helps in strategic allocation of assets, market selection and portfolio management. Third, inclusion of volatility reciprocity may meliorate our estimates of conditional volatility, which is beneficial for certain applications in finance, such as value at risk, option pricing, portfolio optimization and hedging. This thesis explores the effects of outliers on the return and volatility, and their spillovers between Pakistan Stock Exchange (hereafter PSX) and world's selected stock markets (developed and regional), between sectors of Pakistan Stock Exchange and lastly between world oil prices and Pakistan Stock Exchange (aggregate and sectoral level). Finally, this study also examines the effect of outliers on the optimal portfolio weights and hedge ratios.

1.2 Motivation

The diffusion of technology and increased international capital flows are the major offshoots of globalization. Therefore, comprehension about the nature and degree of relationship between various financial markets is of import for portfolio managers, financial institutions, monitory authorities and policy makers. Chuang et al., (2007) have expostulated that both return, and volatility linkages are of import for international investors for devising investment decisions.

The distortionary effects of the presence of outliers on the estimates of financial models are well documented in the univariate context (Charles, 2008; Charles and Darné, 2005; Nazlioglu et al., 2015; Carnero et al., 2016). Outliers may also have important implications for financial models in multivariate framework. Hence, it is critical to know how outliers affect the modeling of financial time series in a multivariate framework. In the literature, number of studies exists in which thr phenomena of return and volatility, and their transmission at aggregated as well as disaggregated level between different financial markets have been investigated. No such study has been found specifically in which the effects of outliers have been investigated on the estimates of return and volatility, and their spillovers simultaneously in the context of multivariate framework. There are two alternative plans to handle the outliers. The first one is to locate and correct outliers before calculating the parameters. The second one is to use robust methods to estimate the parameters. Charles (2008) has pointed out that even robust methods are relatively straightforward, but these methods perform well in certain situations but poorly in others. This study fills the gap by estimating the return and volatility, and their dynamic transmission by taking into account the presence of outliers.

1.3 Objectives of the Study

Outliers have adverse effects on the model identification, tests of conditional heteroscedasticity as well as on the estimates of GARCH family models. It is expected that outliers will also affect the parameter estimates of return and volatility, and their spillovers among different financial markets. Therefore, this study examines the distortionary effects of outliers on the estimates of return and volatility, and their transmission between financial markets at aggregated as well as disaggregated level. This study has following objectives in the context of Pakistan Stock Exchange.

- First objective is to identify and adjust the outliers from the returns of Pakistan Stock Exchange at market and sectoral level, world selected stock markets and Brent oil market returns.
- Second objective is to explore the effect of outliers on the estimates of returns and volatility, and their spillovers between Pakistan Stock Exchange and selected world stock markets. To achieve this objective, we model the returns and volatility and their dynamic spillovers between Pakistan Stock Exchange and world selected stock markets (the US, UK, the Euro region, Japan, China, India and Sri Lanka) for unadjusted and outlier adjustment returns and results are compared. The KSE-100 Index of Pakistan, S&P-500 Index of the USA, FTSE-100 Index of the UK, S&P-

Euro of Europe, Nikkei Index of Japan, Shanghai Composite Index of China, Nifty Index of India and CSE All Share Index of Sri Lanka are taken as representative of respective markets.

- Third objective focuses at evaluating the influence of outliers on the parameter estimates of return and volatility, and their transmission between sectors of Pakistan Stock Exchange. Five major sectors of equity market of Pakistan have been considered for empirical analysis. We estimate return and volatility and their spillovers between sectors both for outlier contaminated returns and outlier adjusted returns. Finally, we compare the results of model for unadjusted and adjusted returns.
- Fourth objective is to quantify the effect of outliers on the relationship between first and second conditional moments of crude oil prices and Pakistan Stock Exchange at market and sectoral level. The crude oil price has been proxied by the spot price of Brent oil. For Pakistan Stock Exchange, the following sectors: Oil and Gas sector, Healthcare sector, Industry sector, Financial sector, Basic Material sector, Utility sector, Telecom sector and Consumer Goods sector have been considered for analysis along with Market Index (KSE-100).
- Fifth and final objective is to gauge the effect of outliers on the optimal portfolio weights and hedge ratios. Optimal portfolio weights and hedge ratios for both adjusted and unadjusted returns have been constructed based on the estimates of second, third and fourth objective.

1.4 Significance of the Study

Portfolio diversification is an effective way to obtain risk-adjusted returns. This strategy assumes that the financial markets have lower level of co-movement. Thus, investors with diversified portfolio may reduce specific risk but remain in danger of common shocks. Benefits of portfolio diversification heavily depend upon the relative size, frequency, and persistence of a market's own and common shocks. The weights in the portfolio and hedging coefficient depends upon the estimates of conditional variances and co-variances between them.

Professional practitioners are curious to study 'volatility' with a view to measure the risk linked with different financial assets (Merton, 1980) and to ease the evaluation of several financial products along with the development of different hedging techniques (Ng, 2000). As far as academics are concerned, they believe that the changes in volatility infer the arrival of new information (Ross, 1989)

Serious implications on the estimates of return and volatility have been observed due to the presence of the outliers which may lead to misleading conclusions (Charles, 2008; Charles and Darné, 2014; Carnero et al., 2016). This study investigates the effects of outlier on the estimates of return and volatility, and transmission of return and volatility across different financial markets/assets. The correct estimation of volatility is the issue, which increases the ability to generate an accurate out-of-sample forecast for policymakers. It will also facilitate the Value at Risk management strategies for financial traders, policy makers, financial managers and investors.

From international investors point of view, this study enhances the understanding about the relationship of PSX with the leading world and regional stock markets. This research will also help the portfolio managers, and financial institutions to get a better understanding of co-movement of return and volatility between PSX and other financial markets for example international and regional stock, oil market to adjust their portfolio investment and to derive optimal weights and hedge ratio. Now the sector specific investment is very popular in the equity market. This research is also helpful to those who are interested to invest in a specific sector. This study facilitates the local investors to get knowledge of return and volatility linkages among the sectors of PSX, who look for investment opportunities and want to diversify their portfolios.

1.5 Organization of Thesis

This thesis has been organized as follows. After reviewing the relevant literature in Chapter 2, Chapter 3 includes the empirical methodology in detail. A discussion on return and volatility dynamics and their transmission between Pakistan Stock Exchange and selected stock markets of the world (developed and regional) with and without outliers has been undertaken in Chapter 4. The effect of outliers on return and volatility and their linkages between sectors of Pakistan Stock Exchange has been investigated in Chapter 5. The return and volatility linkages between Pakistan Stock Exchange (market and sectoral level) and World oil market (Brent oil) are discussed in Chapter 6, and finally conclusions and recommendations have been reported in Chapter 7.

Chapter 2: Review of Literature

Introduction

The introduction about outliers and its types are presented in Section 2.1. Literature on the effects of outlier on GARCH family of models has been presented in Section 2.2. Section 2.3 discusses the outlier detection and correction procedures that are available in existing literature. In Section 2.4, those studies on Pakistan Stock Exchange are examined which investigate its linkages with other financial markets. The he summary of chapter has been presented in Section 2.5.

2.1 Outliers and its Types

Outliers are regarded as an observation that seems to deviate strikingly from other observations of the sample. Similarly, Johnson and Wichern (2002) and Theodossiou and Theodossiou (2008) have stated that "outlier is an observation which is inconsistent with the rest of data and overtime it is observed randomly". These outliers affect the analysis of data must be treated with caution. The first formal classification and definition of outliers for time series data was advocated by Fox (1972). Before Fox's article, an assumption of independently and identically distributed observations were usually made in outlier analysis. However, the assumption of independent and identical distribution is not appropriate for time series data because it deals with random sample procedures. Fox (1972) classified time series outliers into two broad categories, namely; Additive Outlier (hereafter AO) where a single observation is affected and Innovative Outlier (hereafter IO) an innovation to the process affect the observation and subsequent series. Tsay (1988) defines three other types of outliers as well, namely level shifts, transient changes and variance changes. However, according to Tolvi (2000), these level and variance changes are structural changes rather than outliers.

Identification of outliers is critically important in financial modeling due to their consequences such as violation of regularity conditions and biasedness in parameter estimations etc. Outliers have been proven to have adverse effects both theoretically and empirically in many situations. Examples include linear ARMA models (Chen and Liu, 1993; Tsay, 1986; Ledolter, 1989;), ARCH tests and models (van Dijk et al., 1999; Sakata and White, 1998; Franses and van Dijk, 1999; Tolvi, 2000), tests for unit roots and co-integration (Hoek et al., 1995; Franses and Haldrup, 1994), nonlinearity tests and nonlinear models (Franses and Ghijsels, 1999), and bi-linearity (Chen, 1997; Gabr, 1998). The study Carnero et al., (2012) concluded that presence of outliers can lead to biased volatility estimates and biased estimated volatilities in non-linear way. Slight bias in estimates does not promise small bias in estimated volatilities. In all probabilities, the outliers may deform the results of testing and estimation.

2.2 Implications of Outliers

The GARCH family of models have been extensively used for estimation of the volatility parameters in financial time series data and has shown to embody effectively the daily returns of most financial time series (Andersen and Bollerslev, 1998). Even if the GARCH family models are capable of capturing the dynamics of returns, they are unable to capture excess kurtosis. Excess kurtosis can also be explained by the existence of outliers (Baillie and Bollerslev, 1989). Many authors (Charles, 2004; Charles and Darné, 2005, 2014; Ané et al., 2008; Carnero et al., 2016; Laurent et al., 2016; Franses and Ghijsels, 1999; van Dijk et al., 1999; Verhoeven and McAleer, 2000) studied theoretically as well as empirically the consequence of outliers on the volatility estimates, test of conditional heteroscedasticity, asymmetry, regularity conditions of the models, out of sample forecast and portfolio optimization using different procedures. van Dijk et al. (1999) analyzed the properties of Engle (1982) test of conditional heteroscedasticity, their results indicated that investigator may find ARCH effects, when none are present, because of outliers. Franses et al., (2004) showed that just a few short patches of outliers can cause a specious ARCH effect, as signalled by the standard LM-ARCH test. It is also possible that someone did not find the true ARCH effect due to outliers existence in the data (Li and Kao, 2002; Mendes, 2000; van Dijk et al., 1999).

Simulation results of Carnero et al., (2006) showed that ARCH parameter can be bimodal due to the outliers. For GARCH (1,1) model, maximum likelihood estimators have very large dispersion. They also revealed that the intercept of volatility equation is always overvalued by the model. The bias in the ARCH and GARCH parameter estimates depends upon the nature of outliers (i.e. isolated or consecutive). They finally concluded that when estimating GARCH type models to conditional heteroscedastic series, it is recommended to check for outliers. Recently, Carnero et al. (2016) discovered that single outlier can wipe out true asymmetry, and even two big outliers can cause spurious asymmetries or asymmetries with wrong signs. The studies (Franses and Ghijsels, 1999; Balke and Fomby, 1994; Franses et al., 2004) reached to the same conclusion using real time series of macroeconomics and financial variables. Failure to account for presence of outliers in the data may lead to biased estimation of parameters, violation of regularity and non-negativity conditions of GARCH type models (Fox, 1972; Verhoeven and McAleer, 2000; van Dijk et al., 1999). Ané et al. (2008) have devised a procedure for detection and correction of outliers. They applied their proposed method using data of five Asian market indices and showed that correction of outliers improves forecasting ability of GARCH model. Charles (2008) studied the effect of outliers on GARCH model estimates using daily data of seventeen French stocks and CAC40 market index. She discovered that when outliers are not taken into account the volatility parameter estimates are biased. Grané and Veiga (2010) proposed an outlier's detection method based of wavelet methodologies. Using daily data of Dow Jones, FTSE-100 and S&P500 indices, they showed empirically that correction of outliers reduced the skewness and kurtosis of return series. Behmiri and Manera (2015) perused the impact of outliers on the estimates of GARCH models using spot price data of different metals namely: lead, aluminum, palladium, copper, tin, zinc, nickel, platinum, gold, and silver. They found that the presence of outliers biases the estimation of GARCH and GJR models and correction of outliers improves volatility modelling.

Any possible outlier should be taken seriously while examining economic data, no matter what the eventual objective or the model being used is (Tolvi, 2001). The existing studies investigated the effect of outliers on the estimates of univariate GARCH type models. Even after examining a plethora of studies, we were unable to find any study which has investigated the impact of outliers in multivariate framework of GARCH models. One way to handle outliers in multivariate financial time series is to detect and correct outliers from returns series individually and then model them jointly Tsay et al., (2000). This study empirically quantifies the consequences of outlier on the estimates of GARCH family models in multivariate framework.

2.3 Outliers Detection and Correction Procedures

After the seminal work of Fox (1972), various outliers detection and correction procedures have been proposed for linear and nonlinear time series. Several outliers detection and correction methods has been proposed in the literature for nonlinear (GARCH) models. These include the methods of Franses and van Dijk (2000), Franses and Ghijsels (1999), Sakata and White (1998), Doornik and Ooms (2005), Charles and Darné (2005), Zhang and King (2005), Ané et al. (2008), Hotta and Tsay (2012). Zhang and King (2005) pointed out that the prevailing tests suffers from so-called "masking effect". This phenomenon is very common while dealing with real data when one outlier hides others from being detected. These methods are based on the intervention methodology originally suggested by Box and Tiao (1975) and Chen and Liu (1993). Therefore, vulnerable to the same criticisms: a recursive procedure that needs to re-estimate GARCH model several times, with the risk that the estimates of the parameters may be affected by the presence of other outliers. A wavelet based approach for detection and correction of additive outliers in the financial data, based on the test of Bilen and Huzurbazar (2002), was proposed by Grané and Veiga (2010).

Recently Laurent et al. (2016) proposed a semi-parametric robust outlier detection method for additive outliers from daily data. They standardized their test statistics using the conditional volatility based on a robust GARCH volatility estimates and a robust conditional mean estimate. They showed through Monte Carlo simulations that their proposed test behaves well to detect outliers. As we have discussed in Section 2.2, outliers have different types in time series data. Most often only additive and innovative outliers are considered in the literature. It seems that additive outliers are more troublesome in comparison with other types of outliers. It is an established fact that the effects of innovative outliers on the dynamic properties of the series are less important as they are transmitted by the same dynamics as in the rest of the series (Carnero et al., 2006; Pena, 2001).

This thesis focuses on the identification and correction of AO's in the daily financial data. For this purpose, we used recently proposed method of Laurent et al. (2016) and method of Charles and Darné (2005) for detection and correction of outliers from the returns of market indices, sectoral indices and Brent oil. The details of these procedures of detection and correction are presented in Section 3.2 of Chapter 3.

2.4 Empirical Studies about Pakistan Stock Exchange

Most of the studies in the existing literature, explored the short run and the long-run relationship of Pakistan Stock Exchange with other financial markets (Ali et al., 2011; Husain and Saidi, 2000; Amin and Orlowski, 2014; Hussain et al., 2012; Iqbal et al., 2011; Khan, 2013; Narayan et al., 2004). They used co-integration, Granger causality and vector error correction models, variance decomposition and impulse response. Very few studies are available in the existing literature which have investigated the spillovers between Pakistan Stock Exchange and other financial markets (Abbas et al., 2013; Amin and Orlowski, 2014; Khan, 2013; Singh et al., 2010; Wang and Gunasekarage, 2005). A majority of the exiting studies assayed the volatility spillovers between Pakistan Stock Exchange and other financial markets using augmented univariate GARCH family models. In depth review of literature failed to find a single study which investigates the impact of outliers on both returns and volatility spillovers between Pakistan Stock Exchange and other financial markets simultaneously at aggregate and disaggregate level.

Iqbal et al. (2011) explored the association between the stock markets of Pakistan, India and the US using daily data. Using different econometric techniques such as co-integration, Granger causality and variance decomposition, they ended that no association in the long run exist among these stock markets. They discovered unidirectional return spillover from the equity market of the US to the equity market of Pakistan. Exploiting the same methodology, Tahir et al. (2013) shed light on the long run and the short run relationship among four South Asian stock markets and the developed stock markets i.e. the USA, the UK, Australia and Japan. They concluded that PSX has no long run relationship with developed and regional stock markets. Similarly, Haroon et al. (2012) examined the long run and the short run relationship among India, Pakistan, Bangladesh and Sri Lanka. Based on monthly data, they found that there is no short run and long run association between these four markets of South Asia. Meanwhile, applying asymmetric Granger causality and asymmetric co-integration econometric techniques, Shahzad et al. (2015) discovered causality in mean from Sri Lankan stock market to Bangladeshi stock market and Indian stock market to PSX. Also, they found long run association between equity markets of India and Pakistan. The studies mentioned above investigated the relationship between the first moments of the stock markets only but ignored the most common feature of financial data, i.e. volatility clustering. Also, these studies have not considered the existence of outliers in the return series.

Empirical literature on the topic of return and volatility spillovers between Pakistan Stock Exchange and other financial markets is very sparse. Majority of the studies in the existing literature applied augmented univariate GARCH family models. Wang and Gunasekarage (2005) explored the transmission of return and volatility from world and regional developed stock markets to South Asian stock markets. They proxied the world stock market by the US stock market and regional stock market by Japanese stock market. They estimated univariate augmented EGARCH model for each South Asian stock exchange. Their findings suggested that regional factors had played prominent role during Asian Financial Crisis and global factor were more important during Global Financial Crisis (hereafter GFC). Similarly, Abbas et al. (2013) used the same methodology to study the volatility spillover among equity markets of Pakistan, India, the UK, China, Japan, Singapore and the US. They found volatility spillover from Indian stock exchange to Pakistani stock exchange and vice versa unidirectional volatility spillovers from stock markets of Singapore and the UK to Pakistani stock market and from Pakistani stock market to Sri Lankan stock market. Mukherjee and Mishra (2010) studied return and volatility transmission between share market of India and twelve selected stock markets (Sri Lanka, Hong Kong, Malaysia, China, Thailand, Pakistan, Korea, Indonesia, Taiwan, and Japan). Their results showed that in case of open to close returns, significant bidirectional return and volatility spillovers between India and Pakistan prevail. In case of overnight returns (i.e. close to open), their results exhibited significant return spillover from India to Pakistan and reciprocal volatility spillovers between these two neighbor stock markets.

Whereas, Singh et al. (2010) revealed no price spillovers between stock market of Pakistan Stock Exchange and other stock markets using daily data of fifteen stock markets of world including Pakistan. However, they found significant price spillovers from Pakistan to Singapore and Canada and no significant price spillovers to Pakistan in case of open to open returns. Jan and Jebran (2015) explored the volatility transmission from G5 (Japan, Germany, France, the US and, the US) countries stock markets to PSX using two step GARCH model. The study found long run relationship between PSX and stock markets of Germany and the UK respectively. They also observed significant volatility spillovers from all G5 countries to Pakistan Stock Exchange. Recently, Jebran and Iqbal (2016) investigated the return and volatility linkages between Asian stock markets countries (Sri Lanka, Pakistan, India, China, Hong Kong and Japan). They found significant return spillovers from China and Hong Kong to Pakistan and no significant volatility spillovers from Asian countries to Pakistan. Whereas, significant spillovers from Pakistan to Japan, Sri Lanka and Hong Kong had been observed. On the other hand, Balli et al. (2015) following the methodology of Diebold and Yilmaz (2009) found significant spillover from the stock markets of the US, Europe and Japan to Pakistani stock market.

Using multivariate BEKK-GARCH-M model, Beirne et al. (2010) investigated the return and volatility spillovers between global (mature) and regional (emerging) markets on local markets of Middle East, Asia, Latin America, and Europe. They calculated the return of mature market as weighted average of the returns of the USA, France, Germany, the UK and Japan, and emerging market returns as weighted average return of all the emerging markets excluding local market. They found significant returns and volatility spillovers from regional and global stock markets to Pakistani stock market. Recently Khan (2013) employed VAR (1)-BEKK (1,1) model to study the return and volatility spillovers among four share markets of South Asia. The study found bidirectional return spillovers between Indian share market and Pakistani share market and return spillovers from Pakistani market to Sri Lankan market. while, volatility spillovers from Indian stock market were found significant directly and indirectly and no volatility spillovers from Pakistani market to Sri Lankan and Indian markets was observed.

2.5 Summary

It is evident from the literature that researcher have paid least attention to the linkages of stock market of Pakistan with other stock markets of the world (regional and developed). Studies conducted in this area have focused on linkages of PSX between international and regional markets using return (mean) equation. Studies investigating return and volatility spillovers between stock market of Pakistan with regional and international stock markets have overlooked the application of Multivariate GARCH models.

To the best of knowledge, no study has exclusively targeted the Pakistan Stock Exchange in the recent times using advanced econometric techniques. Also, no study has been found in the existing literature in which the effect of outliers has been investigated in multivariate framework. This thesis yearn to fill up the gap and contribute to the available literature on the linkages between Pakistan Stock Exchange (both market and sectoral level) with other financial markets (stock market and world oil market) and effects of outliers on the estimates of models that account for dynamics of returns and volatility.

This study desires at exploring return and volatility spillovers between Pakistan Stock Exchange regional (China, Sri Lanka and India) and developed (the USA, the UK, Europe and Japan) stock markets considering the outliers. This research also investigates the linkages of first and second moments among sectors of PSX. Lastly, transmission of return and volatility among crude oil and sectoral stock of Pakistan Stock Exchange. For this purpose, recently proposed outlier detection and correction procedure is employed and VAR-GARCH and VAR-AGARCH model have been used to estimate return and volatility. These models are capable to examine linkages of return and volatility among different markets/sectors. The estimate of these models are used for further analysis for construction of optimal portfolio weights and hedge ratio.

Chapter 3: Methodology and Data

Introduction

This chapter discusses the data and methodology utilized to explore the return and volatility dynamic linkages among several financial markets and stock sectors mentioned in section 1.3 of chapter 1. The methodology used for the detection and correction of outliers has been given in section 3.1. In Section 3.2 details of econometric models that are used to quantify the returns and volatility, and their spillovers have been mentioned. The estimation of optimal portfolio weights and hedge ratios are outlined in section 3.3 of the chapter. Lastly, a brief description of data has been endorsed in Section 3.4.

The empirical hierarchy is explained by the flowchart outlined in Figure 3.1. The flow chart clearly describes our plan of empirical analysis. After calculating returns series, we apply outlier detection and correction procedures (discussed in section 3.2). Then we estimate our models (see section 3.4) both for outliers unadjusted and adjusted returns. These estimates of model for unadjusted and adjusted returns will be used to construct the optimal portfolio weights and hedge ratios. Finally, we discuss and compare the empirical results of outliers unadjusted and outliers adjusted returns.

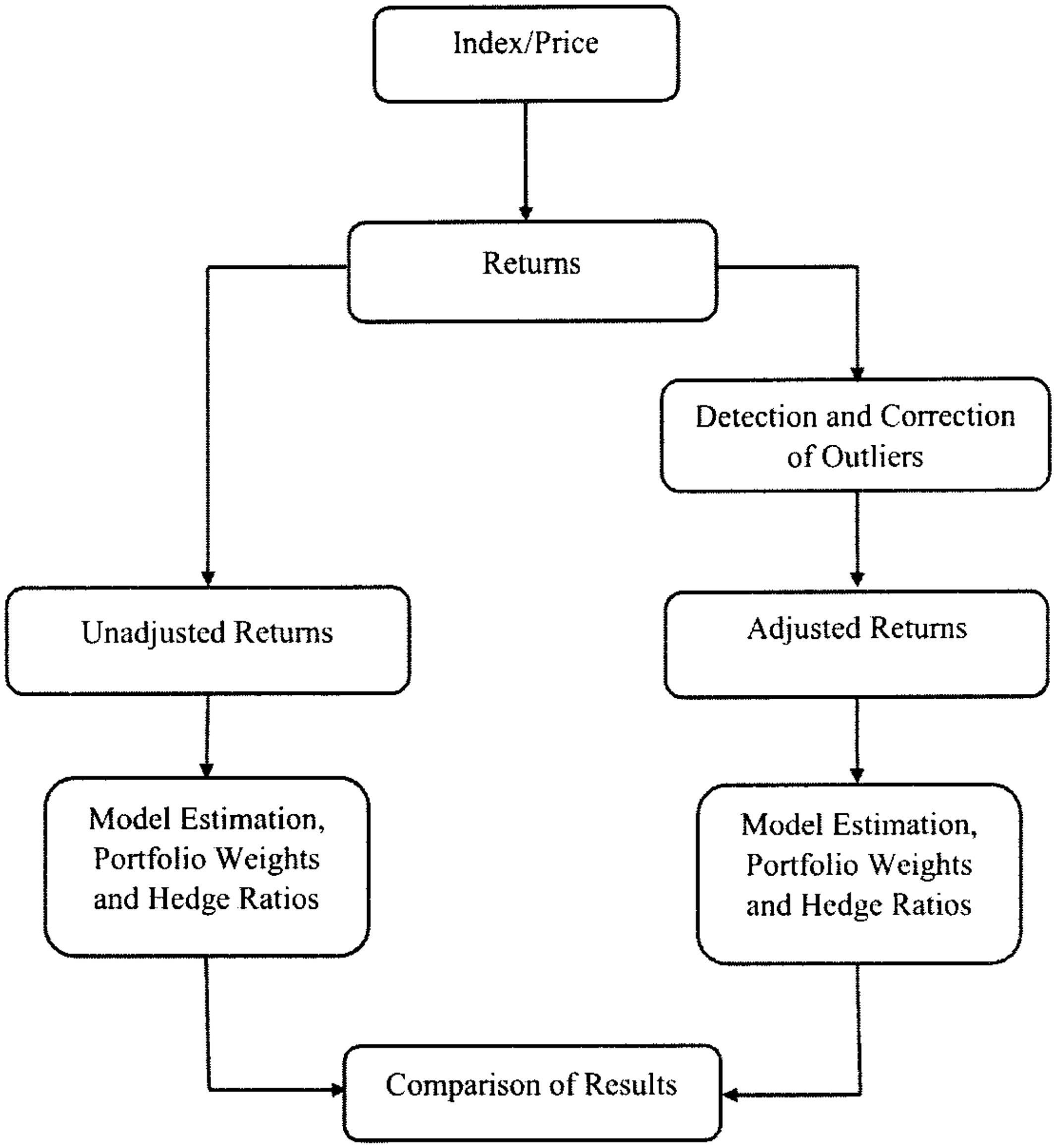

Figure 3.0-1: Flow Chart of Empirical Analysis

3.1 Detection and Correction of Outliers

We have discussed in section 2.2 of chapter 2, number methods have been proposed in the literature for the detection and correction of outliers in context of GARCH family models. Majority of the available procedures are based on the idea of Chen and Liu (1993). They have suggested an iterative outlier detection and correction method for ARMA model. This study applies two methods for the detection and correction of outliers from the data. One is recently proposed semi parametric outliers detection and correction method of Laurent et al. (2016) and second is outliers detection procedure for GARCH model that was advocated by Charles and Darné (2005). The details of these outliers detection and correction methods are given in following section sections 3.2.1 and 3.2.1.

3.1.1 Laurent, Lecourt, and Palm Outliers Detection and Correction Method

This method was recently suggested by Laurent et al. (2016) (hereafter LLP)[2]. The test is based on the standardization of returns: returns are scaled through the estimation of their expectation and volatility in a robust way. The proposed test is similar to the non-parametric test introduced by Lee and Mykland (2008) and Andersen et al. (2007) for daily data.

Consider the return series r_t which is described as

$$r_t = [\log(p_t) - \log(p_{t-1})] \times 100$$

where p_t is closing price at time t and p_{t-1} is the price observed at time $t-1$ considering the ARMA(p, q)-GARCH(1,1) model:

$$\phi(L)(r_t - \mu) = \theta(L)\varepsilon_t \quad (3.1)$$

$$r_t = \mu_t + \varepsilon_t \quad (3.2)$$

where L is the lag operator, $\phi(L) = 1 - \sum_{i=1}^{p} \phi_i L^i$ and $\theta(L) = 1 - \sum_{i-1}^{q} \theta_i L^i$ are polynomials of orders p and q, respectively, which represent coefficients of the autoregressive (AR) and moving average (MA) terms (with root outside the unit circle) such that $\mu_t = \mu + \sum_{i=1}^{\infty} \zeta_i \varepsilon_{t-i}$ is the conditional mean of r_t where ζ_i are the coefficients of $\zeta(L) = \phi^{-1}(L)\theta(L) = 1 + \sum_{i=1}^{\infty} \zeta_i L^i$

$$\varepsilon_t = \sigma_t z_t \text{ and } z_t \sim N(0,1) \quad (3.3)$$

[2] The test is not available in any of econometric software. We write the codes of the test in RATS™ 9.

$$\sigma_t^2 = w + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \quad (3.4)$$

σ_t^2 is the conditional variance of r_t. The terms w, $\alpha_1$and $\beta_1$respresent the constant, past squared shock effect and past volatility effect in the conditional variance of r_t.

Consider the return series with an independent additive outlier component $a_t I_t$, with outlier size a_t

$$r_t^* = r_t + a_t I_t \quad (3.5)$$

Where r_t^* is the observed financial return and $I_t$is binary variable taking values 1 in case of outlier at time t and 0 otherwise and a_t is the size of outlier (negative or positive). It is assumed that $a_t$and $I_t$are independent from each other. The model for r_t^* has the properties that an outlier $a_t I_t$ does not affect σ_{t+1}^2 and it allows for non-Gaussian fat tailed conditional distribution of r_t^*.

Let us denote $\tilde{\mu}_t$ and $\tilde{\sigma}_t$ as estimates of μ_t and σ_t that are robust to the presence of potential additive outliers $a_t I_t$ and estimated using r_t^* not r_t.

$$\tilde{J}_t = \frac{r_t^* - \tilde{\mu}_t}{\tilde{\sigma}_t} \quad (3.6)$$

is the standardized return on day t. If $a_t I_t = 0$ on day t, then $\tilde{J}_t$follows standard normal distribution asymptotically.

To test the null hypothesis, we have

$H_0: a_t I_t = 0$ for $t = 1, \dots, T$

against

$H_1: a_t I_t \neq 0$

Laurent et al. (2016) proposed to compute $|\tilde{J}_t|$ and reject the null if $|\tilde{J}_t| > g_{T,\lambda}$, where $g_{T,\lambda}$ is the critical value of the test.

In case of null hypothesis is rejected, the outlier detection rule is as follows

$$\tilde{I}_t = I(|\tilde{J}_t| > g_{T,\lambda}) \quad (3.7)$$

where $I(.)$ is the indicator function, with $\tilde{I}_t = 1$ when outlier is detected at observation t and 0 otherwise, and critical value $g_{T,\lambda}$ defined as

$$g_{T,\lambda} = -\log(-\log(1-\lambda)\, b_T + c_T \tag{3.8}$$

with $b_T = 1/\sqrt{2\log T}$ and $c_T = (2\log T)^{\frac{1}{2}} - [\log\pi + \log(\log T)/[2(2\log T)^2]$, here T represent the length of time series. Therefore, following equation (3.8), all the returns for which $|\tilde{J}_t| > k$ are considered as affected by additive outliers. Following the Laurent et al. (2016), $\lambda = 0.5$ was set. Given $\tilde{I}_t$, detected outliers can be sieved form r_t^* as follows

$$\tilde{r}_t = r_t^* - (r_t^* - \tilde{\mu}_t)\tilde{I}_t \tag{3.9}$$

Estimation of Conditional ($\tilde{\mu}_t$) Mean and Conditional Variance ($\tilde{\sigma}_t^2$)

Laurent et al. (2016) have proposed to use robust estimation of $\tilde{\mu}_t$ and $\tilde{\sigma}_t$based on the BIP[3]-ARMA as suggested by Muler et al. (2009) (hereafter MPY) and the BIP-GARCH(1,1) proposed by Muler and Yohai (2008) (hereafter MY) respectively. The specification of conditional mean and variance are as follows.

$$\tilde{\mu}_t = \mu + \sum_{i=1}^{\infty} \zeta_i\, \tilde{\sigma}_{t-i}\omega_{k_\delta}^{MPY}(\tilde{J}_{t-i}) \tag{3.10}$$

$$\tilde{\sigma}_t^2 = \omega + \alpha_1\tilde{\sigma}_{t-1}^2 c_\delta \omega_{k_\delta}^{MPY}(\tilde{J}_{t-1})^2 + \beta_1\tilde{\sigma}_{t-1}^2 \tag{3.11}$$

where the function $\omega_{k_\delta}^{MPY}(\tilde{J}_{t-i})$ is the weight function and c_δ a factor ensuring the conditional expectation of the weighted squared unexpected shocks to be the conditional variance of r_t in the absence of jumps. The typical value for δ are 0.99, 0.975, 0.95 and c_δ= 1.0185, 1.0465, and 1.0953 against the values of δ.

$$\omega_{k_\delta}^{MPY}(\tilde{J}_{t-i}) = \text{sign}(\tilde{J}_{t-i})\min(|\tilde{J}_{t-i}|, k_\delta) \tag{3.12}$$

[3] BIP stand for Bounded Innovation Propagation

The model underlying equations (3.10) and (3.11) with weight function given in equation (3.12) is called BIP-ARMA-BIP-GARCH model because the effect of outliers on future values is bounded. MPY and MY show respectively that QML estimation of a BIP-ARMA with constant variance and BIP-GARCH with zero conditional mean is not efficient in the presence of large additive outliers. They recommend using a M-estimator that minimizes the average value of an objective function $\rho(.)$ evaluated at the log-transformation of squared standardized returns, in this case objective function is defined as

$$\tilde{Q}^{M} = \underset{\theta \in \Theta}{\operatorname{argmin}} \frac{1}{T}\sum_{i=1}^{T} \rho\left(2\log\left|\frac{r_t^{*}-\tilde{\mu}}{\tilde{\sigma}_t}\right|\right) \quad (3.13)$$

$\rho(.)$ needs to be down weighted to extreme observations and hence jumps. The choice of $\rho(.)$ is a tradeoff between efficiency and robustness. Boudt and Croux (2010) have recommended $\rho_{t_4}(z)$ that associated with the student $-$ t density function with $v = 4$ degree of freedom (t_4) and is given as

$$\rho_{t_4}(z) = -z + 0.8260(1+v)\log\left(1+\frac{\exp(z)}{v-2}\right) \quad (3.14)$$

where z in equation (3.14) is defined as $z = \left(2\log\left|\frac{r_t^{*}-\tilde{\mu}}{\tilde{\sigma}_t}\right|\right)$.

Step by Step Procedure

There are following steps involved in Laurent et al. (2016) method for detection and correction of outliers from the data.

1. Estimation of BIP-ARMA-BIP-GARCH model given in equations (3.10) and 3.11 with δ=0.975 by minimizing objective function given in equation (3.13) with $\rho(.) = \rho_{t_4}(.)$.
2. Computation of test statistic (equation 3.6) where $\tilde{\mu}$ and $\tilde{\sigma}_t$are obtained from step 1
3. At a critical level $(\lambda = 0.50)$ and apply the jump detection rule given in equation (3.7) using critical values computed from equation (3.8).

3.1.2 Charles and Darné Outliers Detection and Correction Method[4]

This method was proponed by Charles and Darné (2005) (hereafter CD) for the detection and correction of Innovative outliers (IO) and Additive outliers (AO) simultaneously. Their method encompassed the method of Franses and Ghijsels (1999) for innovative outliers that was originally proposed for additive outliers only which is based on Chen and Liu (1993) approach. This is an iterative method with consist of estimation-detection-removal cycle.

Consider the return series r_t which is described as

$$r_t = [\log(p_t) - \log(p_{t-1})] \times 100$$

where p_t is closing price at time t and p_{t-1} is the price observed at time $t-1$

and considered the GARCH (1,1) model

$$r_t = z_t\sqrt{h_t} \tag{3.15}$$

$$z_t \sim N(0,1) \tag{3.16}$$

$$h_t = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{3.17}$$

where $\alpha_0 > 0, \alpha_1 \geq 0,\ \beta_1 \geq 0$, and $\alpha_1 + \beta_1 < 1$ such that the model is covariance stationary. The GARCH(1,1) model can be rewritten as an ARMA(1,1) model for ε_t^2 (Bollerslev, 1986)

$$\varepsilon_t^2 = \alpha_0 + (\alpha_1 + \beta_1)\varepsilon_t^2 + v_t - \beta_1 v_{t-1} \tag{3.18}$$

where $v_t = \varepsilon_t^2 - h_t$. As exhibited by Franses and Ghijsels (1999) this analogy of the GARCH model with an ARMA model allows one to directly adapt the methodology

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[4] The test is not available in any of econometric software. We write the codes of the test in MatLab.

of Chen and Liu (1993) to detect and correct AOs and IOs in the GARCH model. Suppose that instead of the true series r_t one observed the series e_t

$$e_t^2 = r_t^2 + \omega_t \xi_i(B) I_t(\tau) \text{ with } i = 1,2 \tag{3.19}$$

Where $I_t(\tau)$ is the indicator function defined as $I_t(\tau) = 1$ if $t = \tau$ and zero otherwise where τ is the position of the outliers and ω_t is the magnitude of the outlier effect. $\xi_i(B)$ represents the dynamic pattern of outlier defined as

$$\xi_1(B) = 1 \text{ for AO} \tag{3.20}$$

$$\xi_2(B) = \frac{1-\beta_1 B}{1-(\alpha_1+\beta_1)B} = \psi(B) = \pi(B)^{-1} \text{ for IO} \tag{3.21}$$

An AO is related to an exogenous change that directly affect the series and only its level of the given observation at time $t = \tau$ and IO outlier is possibly generated an endogenous change in the series, an affect the series after time τthorugh the memory process.

The residual η_t of the observed series r_t^2 are given by

$$\eta_t = -\frac{\alpha_0}{1-\beta_1 B} + \pi(B)e_t^2 = v_t + \pi(B)\xi_i(B)\omega_i I_t(\tau) \tag{3.22}$$

where $\pi(B) = (1-(\alpha_1+\ \beta_1)B)(1-\beta_1 B)^{-1}$. The above expression can be written as a regression model for η_t

$$\eta_t = \omega_i x_{it} + v_t \tag{3.23}$$

where $x_{it} = 0$ for $i = 1,2$ and $t < \tau$, $x_{it} = 1$ for $i = 1,2$ and $t = \tau$, $x_{1,\tau+k} = -\pi_k$(for AO) and $x_{1,\tau+k} = 0$ (for IO) for $t > \tau$ and $k > 0$

Outliers detection is based on the maximum value of standardized statistics of the outlier effects:

$$\text{AO: } \hat{\tau}_1(\tau) = \left(\frac{\omega_1(\tau)}{\hat{\sigma}_v}\right)\left(\sum_{t=\tau}^{n} x_{1t}^2\right)^{\frac{1}{2}} = \left[\frac{(\sum_{t=\tau}^{n} x_{1t}\eta_t)(\sum_{t=\tau}^{n} x_{1t})^{-1}}{\hat{\sigma}_v}\right]\left(\sum_{t=\tau}^{n} x_{1t}^2\right)^{\frac{1}{2}} \quad (3.24)$$

$$\text{IO: } \hat{\tau}_2(\tau) = \frac{\hat{\omega}_t}{\hat{\sigma}_v} = \frac{\eta_t}{\hat{\sigma}_v} \quad (3.25)$$

where $\hat{\sigma}_t^2$ denotes the estimated variance of residuals

Step by Step Procedure

There are following steps involved in Charles and Darné (2005) to detect and correct outliers from the returns.

1. Estimate the GARCH (1,1) model for the observed series r_t and obtain estimates of the conditional variance $\hat{h}_t$ and $\hat{\eta}_t = r_t - \hat{h}_t$.
2. Obtain estimated values of $\hat{\omega}_t(i = 1,2)$ for all possible $\tau = 1,2, \dots, n$ and compute $\hat{\tau}_{max} = max_{1 \le \tau \le n}|\hat{\tau}_i|$. If the value of test statistics is greater than critical value C, an outlier is detected at the observation for which $\hat{\tau}$ is maximum.
3. Replace r_t^2 with

$$\text{AO: } r_t^{*2} = r_t^2 - \hat{\omega}_1$$

$$\text{IO: } r_{t+j}^{*2} = r_{t+j}^2 - \hat{\omega}_2\psi_j \text{ with } j > 0$$

Where $\psi = \pi(B)^{-1}$. The outliers corrected series e_t^* is defined as

$$\text{AO: } r_t^* = \begin{cases} r_t, & \text{for } t \neq \tau \\ \text{sign}(r_t)\sqrt{r_t^{*2}}, & \text{for } t = \tau \end{cases}$$

$$\text{IO: } r_t^* = \begin{cases} r_t, & \text{for } t < \tau \\ \text{sign}(r_t)\sqrt{r_t^{*2}}, & \text{for } t = \tau + j, \quad j > 0 \end{cases}$$

4. Return to the step (1) to re-estimate GARCH(1,1) model for the series r_t^* and repeat all the steps until no $\hat{\tau}_{max}$ test statistics exceeds the critical value.

A critical value $C = 10$ is used which is based on the simulation experiment proposed by Franses and van Dijk (2000).

3.2 Econometric Models

The autoregressive conditional heteroscedasticity (hereafter ARCH) model due to Engle (1982) and the generalized autoregressive conditional heteroscedasticity (hereafter GARCH) model suggested by Bollerslev (1986), have been widely appreciated by applied researchers in financial time series for the modeling of the second conditional moment of returns. These models are cable to capture the stylized features of financial time series, such as volatility clustering, fat tails and shock persistence. They are used for the assessment of forecast performance (Sadorsky, 2006; Cheong, 2009; Agnolucci, 2009; Mohammadi and Su, 2010; Kang et al., 2009) and for the estimation of values at risk (VaR) (Sadeghi and Shavvalpour, 2006; Aloui and Mabrouk, 2010; Arouri et al., 2010; Cabedo and Moya, 2003).

When the purpose of modeling, however, is to study the interdependence of return and volatility in different financial time series, then these univariate models are not appropriate. Rather, multivariate models, such as VEC model of Bollerslev et al. (1988), the BEKK–MGARCH model of Engle and Kroner (1995), the constant conditional correlation (CCC) GARCH models of Bollerslev (1990), the dynamic conditional correlation (DCC)-GARCH model of Engle (2002), the VAR-GARCH model of Ling and McAleer (2003), and the VAR-AGARCH model of McAleer et al. (2009) are widely recognized by the applied researchers to model the financial time series data.

One drawback of the VEC and BEKK model is that the number of parameters increase exponentially as the number of variable increases, and that it often faces convergence problems. While the BEKK model provides a multivariate GARCH (1,1) framework with dynamic covariances and dynamic correlations, this model does not have a VAR attached to it because the BEKK VAR distribution has not been examined theoretically (McAleer et al., 2008). Moreover, VEC and BEKK models are too excessive in parameters, many of which lack empirical explanations.

On the other hand, the CCC-MGARCH of Bollerslev (1990) and DCC-MGARCH of Engle (2002) respectively have no cross terms in their conditional variance equations. So, they cannot capture the volatility spillovers across different financial market or financial assets. For the same reasons, the multivariate VAR(k)–(A)GARCH(p,q) represents an interesting alternative. Constant Conditional Correlation (CCC-GARCH) model of Bollerslev (1990) has embedded by this model as a special case.

The use of VAR–AGARCH model have number of advantages. First, the estimation of parameters is less expensive, which allows the researcher to focus more on expressive and interpretable parameter estimates. Second, it is flexible to examine conditional volatility dynamics, shock transmission and volatility spillovers effects between financial markets. It also provides an efficient estimate of mean and variance equations without the complexity of computation that most multivariate models undergo. In the empirical literature many researchers (Jouini, 2013; Lin et al., 2014; Arouri et al., 2011; Bouri, 2015; Chang et al., 2013; Syriopoulos et al., 2015; Arouri et al., 2011, 2012; Mensi et al., 2013) estimated VAR(1)- GARCH(1,1) or VAR(1)- AGARCH(1,1) to investigate the issue of return and volatility spillovers between different financial markets at aggregate and disaggregate level.

3.2.1 VAR(k)-GARCH(p,q) Model

The VAR(k)-GARCH(p,q) model for m markets/assets has the following equations for the conditional mean:

$$Y_t = \mu + \sum_{i=1}^{k} \Phi_i Y_{t-i} + \varepsilon_t \qquad (3.26)$$

In equation (3.26), $Y_t = (Y_{1t}, Y_{2t}, \dots, Y_{mt})'$ and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \dots, \varepsilon_{mt})'$ is a vector of disturbances, $\mu = (c_1, c_2, \dots c_m)'$is $m \times 1$vector of constant of mean equation and Φ_i are $m \times m$ matrices. Elements on diagonal captures the own lagged effect and off-diagonal elements measure the return spillovers.

$$\varepsilon_t = D_t \eta_t \qquad (3.27)$$

In equation (3.27), $D_t = \text{diag}\left(\sqrt{h_{1t}}, \sqrt{h_{2t}}, \dots, \sqrt{h_{mt}}\right)$ and $\eta_t = (\eta_{1t}, \eta_{2t}, \dots, \eta_{mt})'$ is a sequence of independently and identically distributed random vectors with $E(\eta_t) = 0$, and $\text{Var}(\eta_t) = I_N$.

For the conditional variance, the equation is

$$H_t = W + \sum_{j=1}^{p} A_j \vec{\varepsilon}_{t-j} + \sum_{k=1}^{q} B_k H_{t-k} \qquad (3.28)$$

In equation (3.28), $W = (w_1, w_2, \dots, w_m)'$ is $m \times 1$vector of constant of conditional variance equation. $A_j$and B_l are $m \times m$ matrices. Elements on the diagonal assess own past squared shock and past volatility effects and off diagonal elements measure the spillovers of past squared shock and past volatility respectively. $H_t = (h_{1t}, h_{2t}, \dots, h_{mt})'$ are conditional variances and $\vec{\varepsilon_t} = (\varepsilon_{1t}^2, \epsilon\varepsilon_{2t}^2, \dots, \varepsilon_{mt}^2)'$are squared shocks.

3.2.2 VAR(k)-AGARCH(p,q) Model

The multivariate VAR–GARCH model assumes that shocks, whether positive or negative, have similar impact on the conditional variance, which may be seen as restrictive. To address this issue, McAleer et al. (2009) have suggested a VAR–AGARCH models. Specifically, the conditional variance is defined as follows instead of equation 3.28:

$$H_t = W + \sum_{j=1}^{p} A_j \vec{\varepsilon}_{t-j} + \sum_{l=1}^{r} D_l I_{t-l} \vec{\varepsilon}_{t-l} + \sum_{k=1}^{q} B_k H_{t-k} \qquad (3.29)$$

D are $(m \times m)$ diagonal matrices, and $I_t = diag(I_{it}, \ldots \ldots, I_{mt})$ is an indicator function, given as

$$I_t = \begin{cases} 1, & \varepsilon_{it} < 0 \\ 0, & \varepsilon_{it} \geq 0 \end{cases} \qquad (3.30)$$

If $m = 1$, then the models collapse into GJR model of Glosten et al. (1993). Above model reduced to VAR-GARCH model when $D_l = 0$ for all l. When A_j and $B_k$are diagonal matrices for all j and k then this model reduces to the CCC model of Bollerslev (1990). The structural and statistical properties of the model including necessary and sufficient condition for stationary and ergodicity of VAR-AGARCH are explained by McAleer et al. (2009). Theoretically, GARCH(1,1) captures an infinite-order ARCH process (Bollerslev, 1986). The above equation entwines that the conditional variance of each market depends upon the past shock and past volatility as well as on the past shock and volatility of other market. The conditional covariance $(h_{i,j,t})$ between two markets is given as

$$h_{i,j,t} = \rho\sqrt{h_{i,t}}\sqrt{h_{j,t}} \text{ where } i \neq j \text{ and } i, j = m \qquad (3.31)$$

ρ is constant conditional correlation between two assets returns.

The conditional mean specification for VAR (1)-AGARCH (1,1) model for two assets returns is given below.

The conditional mean of two assets model is as

$$\begin{bmatrix} R_{i,t} \\ R_{j,t} \end{bmatrix} = \begin{bmatrix} C_i \\ C_j \end{bmatrix} + \begin{bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{bmatrix} \begin{bmatrix} R_{i,t-1} \\ R_{j,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{i,t} \\ \varepsilon_{j,t} \end{bmatrix} \qquad (3.32)$$

$R_{i,t}$ and $R_{j,t}$ represent returns from 1st and 2nd asset respectively; $\Phi_{11}$and $\Phi_{22}$are the coefficients of own past lag of 1st and 2nd assets respectively. However, $\Phi_{12}(\Phi_{21})$ measure the return spillovers effect from 1st (2nd) on the returns of 2nd (1st). The conditional variance specification for two assets is given as

$$\begin{bmatrix} h_{1,t} \\ h_{2,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} (\varepsilon_{1,t-1})^2 \\ (\varepsilon_{2,t-1})^2 \end{bmatrix} + \begin{bmatrix} d_1 & 0 \\ 0 & d_2 \end{bmatrix} \begin{bmatrix} I_{1,t-1}(\varepsilon_{1,t-1})^2 \\ I_{2,t-1}(\varepsilon_{2,t-1})^2 \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} h_{1,t-1} \\ h_{2,t-1} \end{bmatrix} \quad (3.33)$$

The coefficients $\alpha_{11}$and α_{22} measure the degree to which own past shocks contribute to the current volatility of 1st asset and 2nd asset returns, and large values of these coefficients imply strong volatility reactions to market movements. The $\beta_{11}$and β_{22} coefficients capture own past volatility effects and large values of these coefficients show that volatility shocks take long time to fade away. The coefficients $\alpha_{12}(\alpha_{21})$ and $\beta_{12}(\beta_{21})$ measure shocks and volatility spillovers from 1st (2nd) asset to 2nd(1st) asset respectively. $I_{i,t}$ $(i = 1,2)$ is an indicator take value 1 when $\varepsilon_{i,t} < 0, (i = 1,2)$ and zero otherwise. $D_1$and d_2 capture the leverage effect in 1st and 2nd asset respectively. Finally, the conditional covariance between two asset returns is given as

$$h_{1,2,t} = \rho\sqrt{h_{1,t}}\sqrt{h_{2,t}} \quad (3.34)$$

ρ is constant conditional correlation between 1st asset and 2nd asset returns. Assuming normally distributed errors, the model is estimated by maximizing the following log likelihood function (LLF):

$$l(\theta) = -T\ln(2\pi) - \frac{1}{2\sum_{i=1}^{T}(\ln(|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t)} \quad (3.35)$$

where T is the number of observations and maximization is done using BFGS[5] algorithm. We use RATS™ 9 to estimate the models.

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[5] Broyden–Fletcher–Goldfarb–Shanno

3.3 Portfolio Weight and Hedge Ratio.

The results of the VAR (1)-GARCH (1, 1), and VAR (1)-AGARCH (1, 1) models can be employed to compute the optimal portfolio weights and hedge ratios. We follow Kroner and Ng (1998) to estimate the optimal portfolio weights. Separately, we estimate the weights as follows:

$$W_{1,t} = \frac{h_{2,t} - h_{1,2,t}}{h_{1,t} - 2h_{1,2,t} + h_{2,t}} \tag{3.36}$$

$$W_{1,t} = \begin{cases} 0, & \text{if } W_{1,t} < 0 \\ W_{1,t} & \text{if } 0 < W_{1,t} < 1 \\ 1, & \text{if } W_{1,t} \geq 1 \end{cases}$$

$W_{1,t}$ is the weight of 1st asset and $1 - W_{1,t}$ is the weight of 2nd asset in a portfolio. Following Kroner and Sultan (1993), the optimal hedge ratio for a two assets portfolio calculated by using the following formula.

$$\beta_{1,t} = \frac{h_{1,2,t}}{h_{2,t}} \tag{3.37}$$

In a two assets portfolio, $\beta_{1,t}$indicates that the investment risk will be minimum if investor take one-dollar long position in first asset and $\$\beta_{1,t}$short position in second asset. Hedging is a technique used to demote the risk of a financial asset. Whereas, the derivatives are the instruments that are used for hedging in finance. Different types of derivatives are used for hedging purpose, more commonly used derivative are forward contract, future contracts, options and swabs etc. This study only calculates the hedge ratios using model estimates.

3.4 Data

This thesis uses the daily data sampled from the 1st January 2001 to the 31st December 2015. The data has been obtained from the DataStream of Thomson Reuters. For market analysis, the data of KSE-100 index of Pakistan, S&P-500 index of the US, FTSE-100 index of the UK, S&P Euro[6] index of Europe, Nikkei index of Japan, Shanghai Composite Index of China, Nifty index of India, and CSE All Share Index of Sri Lanka are used as reference indices of respective countries. DataStream categorizes the firms listed at share market of Pakistan among eight different sectors with respect to their business and function. The sectors are Consumer Goods, Oil and Gas, Basic Material, Utility, Financial, Industry, Healthcare, and Telecom. All the stock data dominated into rupees to avoid the exchange rate distortion (Khan, 2010). The data for oil market is the spot price of Brent oil which is widely used as reference price of oil. The Brent oil price is expressed in US$. The use of daily data is motivated to be consistent with earlier studies (Arouri, Lahiani, et al., 2011). Daily returns give precise estimates as it yields more degree of freedom for estimates of parameters. Using daily data one can get forecast of long horizons using daily data but reverse is not true Hassan and Malik (2007). The statistical and time series properties of data are discussed in the analysis part of the thesis.

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[6] S&P-Euro is the weighted index of stock markets of Spain, Austria, Portugal, Belgium, Netherland, Finland, Luxemburg, France, Italy, Germany and Ireland.

Chapter 4: Effect of Outliers on Return and Volatility Linkages Between Pakistan Stock Exchange and Selected Stock Markets of the World

4.1 Introduction

This chapter explores the effect of outliers on the dynamics of returns and volatility as well as their spillovers between Pakistan Stock Exchange and selected stock markets of the world. Domestic economic activity and international investors are influenced by the extent of linkage in the stock markets. Intermarket connections among the equity markets may lessen the isolation of the markets but endanger these economies to external shocks due to spillover effects. The spillover effect leads to diffusion of external shocks from market to another. These spillovers limit the autonomy of the policy makers in adopting policies peculiar to indigenous environment. However, gains from international portfolio diversification are diluted in presence of strong intermarket association. On the contrary, gains from international portfolio diversification will soar in presence of weak intermarket linkages. Finally, intermarket linkages may provide profit making opportunity to those investors who exploit the price differential arisen due to inefficiency of market to return and risk changes in the other markets. The quantification of return and volatility transmission has always remained a point of focus for all stakeholders including policy makers, monetary authorities, portfolio managers and investors.

The organization of remaining of chapter is as under: Section 4.2, briefly describes the statistical and time series properties of outlier adjusted and unadjusted data. Section 4.3 puts forth the empirical findings for both unadjusted and outliers adjusted returns. Optimal portfolio weights and hedge ratios are reported in Section 4.4 and lastly there is a summary of empirical findings in Section 4.5.

4.2 Graphical and Descriptive Analysis

The target of this chapter is to make an empirical analysis of the impact of outliers on the return and volatility spillover between Pakistan Stock Exchange and selected stock markets of the world. We considered S&P-500 index of the US stock market, FTSE-100 index of London Stock Exchange of the UK, S&P-Euro to represent the Euro region (Spain, Austria, Portugal, Belgium, Netherland, Finland, Luxemburg, France, Italy, Germany and Ireland), Nikkei index of Japanese stock market, Shanghai index of Chinese stock market, Nifty index of National Stock Exchange of India, and CSE all share index of Colombo Stock Exchange of Sri Lanka and KSE-100 index of Pakistan Stock Exchange of Pakistan. The time series graphs of KSE-100 with other indices have been presented in Figure 4.1 to Figure 4.7. The thick (black) line represents the KSE-100 index and thin (red) line represents the index price of foreign market.

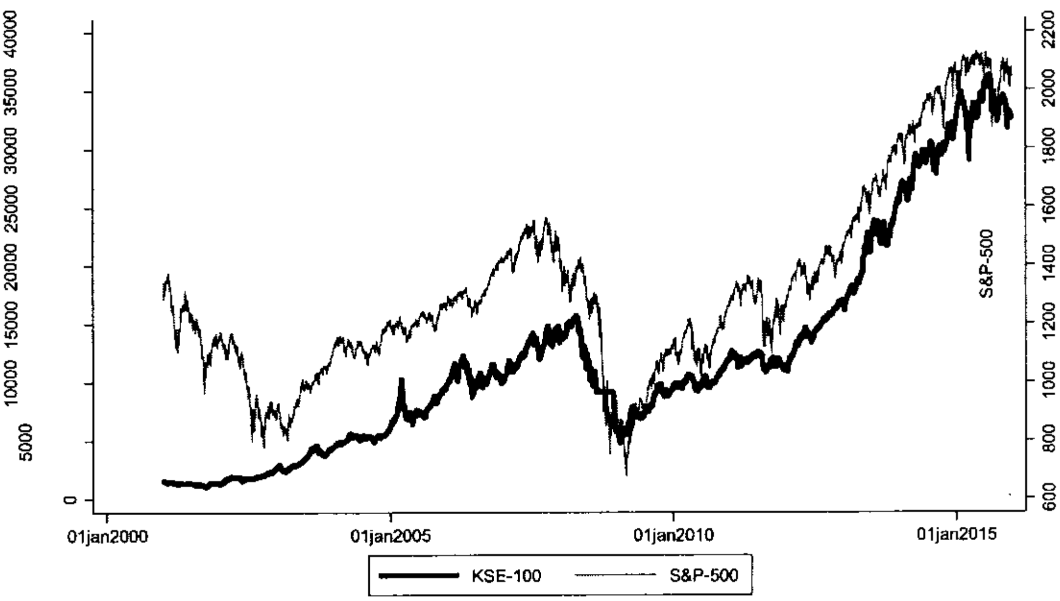

Figure 4-1: KSE-100 Index and S&P-500 Index

Figure 4.1 reveals that in the beginning US market index slope downward and Pakistani market index showed increasing trend. From the year 2003 both indices move in the same direction and gap between these two indices remains the same till the onset of Global Financial Crisis. During the GFC, S&P-500 index drops very sharply as compared to KSE-100 index of Pakistan. After the GFC, both markets showed upward trend but the gap between the market indices is marginally less than that of before GFC. Overall markets showed very strong relationship in price movement.

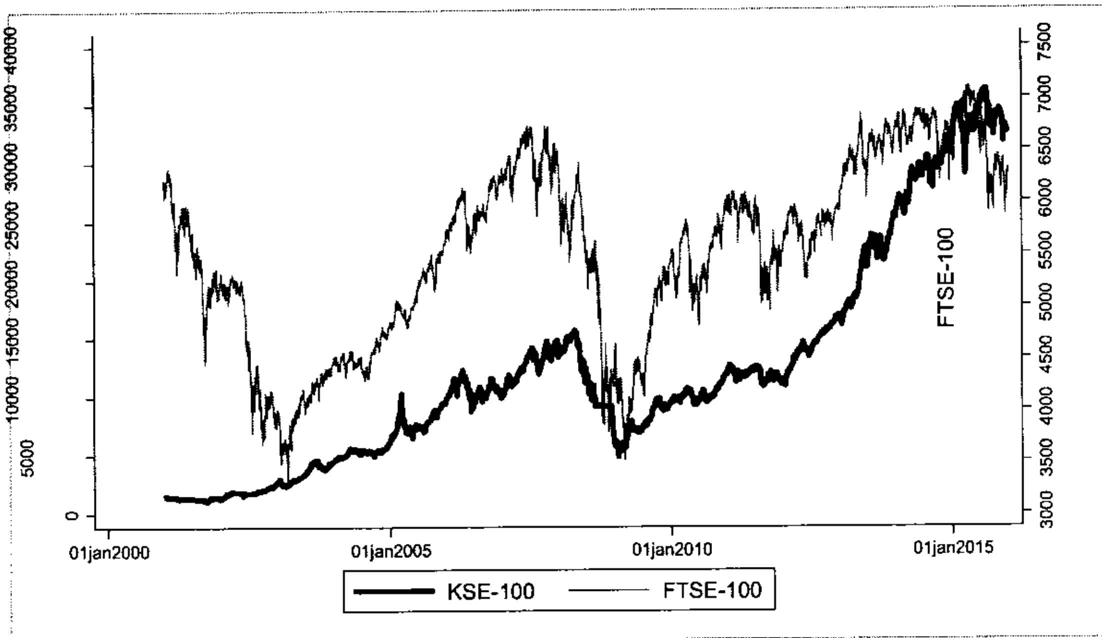

Figure 4-2: KSE-100 Index and FTSE-100 Index

Figure 4.2 clearly portrays that from the beginning of the sample to the first quarter of year 2003, the FTSE-100 index declines sharply and KSE-100 index shows slight upward trend. Subsequently , both indices exhibit rising trend but their gap becomes wider and wider until GFC arrives. The market worth of PSX increases at a snails pace as compared to the UK stock market. After GFC, both indices show an upward trend but for FTSE-100 index the recovery rate is higher than the KSE-100 index.

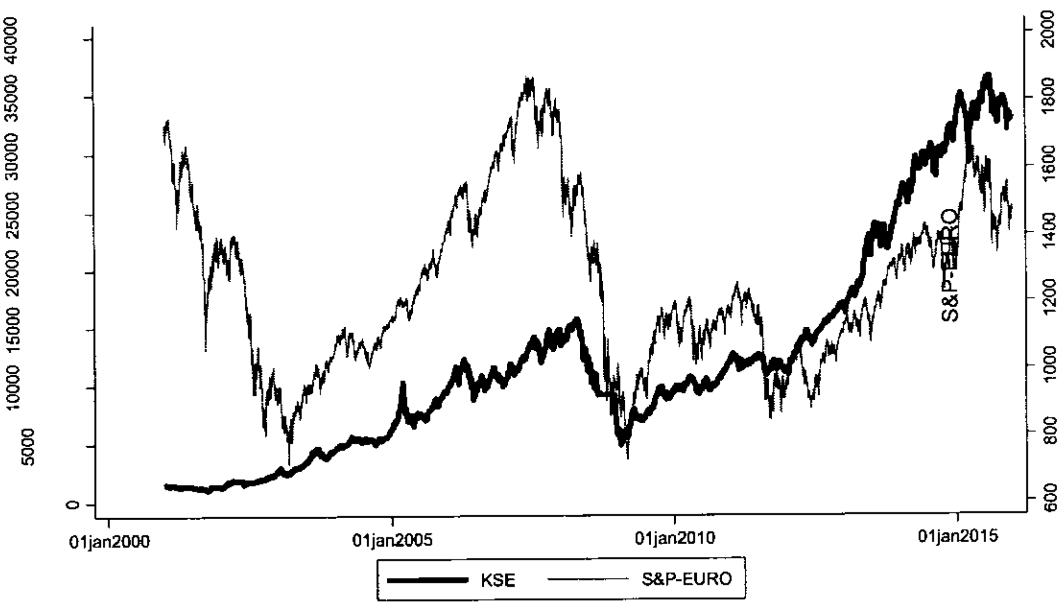

Figure 4-3: KSE-100 Index and S&P-Euro Index

The price movement in the S&P-Euro is nearly identical to FTSE-100 index before the start of GFC as shown in Figure 4.3. During GFC, S&P-Euro index drops sharply as contrasted to KSE-100 index. After GFC, the recovery of S&P-Euro is swift than KSE-100 index but it dropped again during the last quarter of the year 2011. On the other hand, KSE-100 index moves upward slightly.

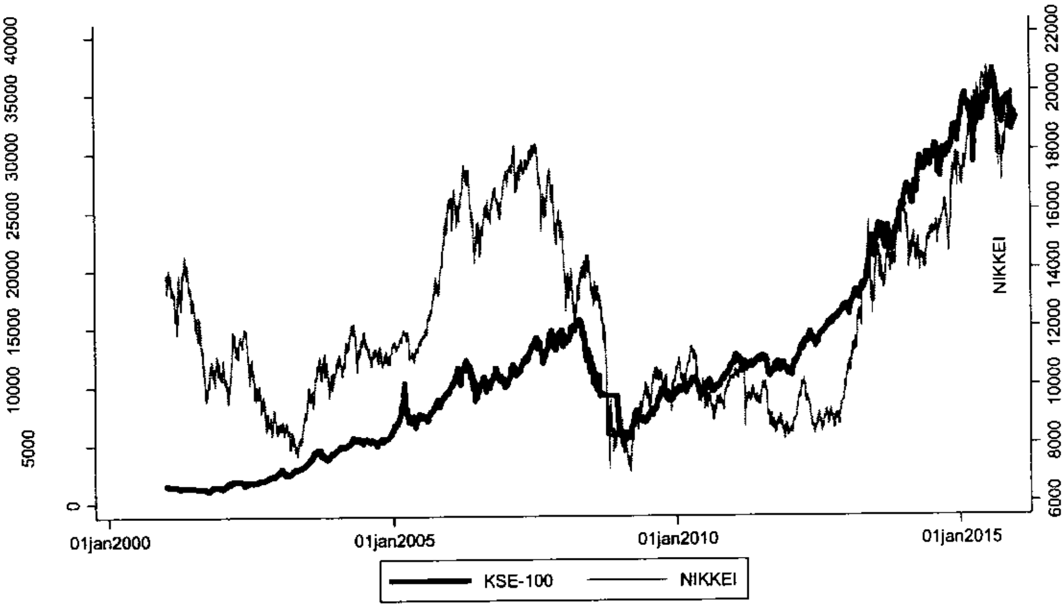

Figure 4-4: KSE-100 Index and Nikkei Index

The KSE-100 index of Pakistan and Nikkei index of Japan are plotted in Figure 4.4. From the start of sample both indices move in opposite direction. The market capitalization of PSX increased very slowly and market capitalization of Japanese stock market dropped very sharply till the first quarter of year 2003. After that Japanese market showed very sharp recovery till the start of GFC. During and after GFC both market indices move side by side but PSX is more stable than Japanese market.

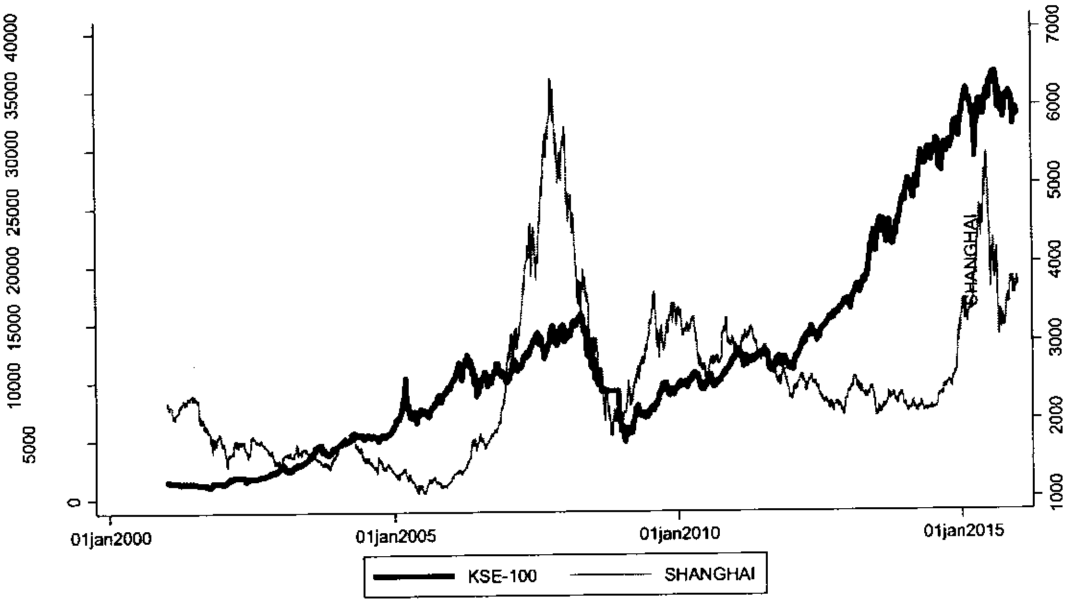

Figure 4-5: KSE-100 Index and Shanghai Index

Figure 4.5 illustrates the movements of benchmark indices of stock market of Pakistan (KSE-100) and Chinese stock market (Shanghai index). Both indices move in the opposite direction till the mid of year 2005. Afterwards, Shanghai Stock Market showed some recovery and in year 2007, its market index touches all-time high. There is no pattern of co-movement in the indices of both markets over the analysis period. Most of the time both stock indices move in opposite direction.

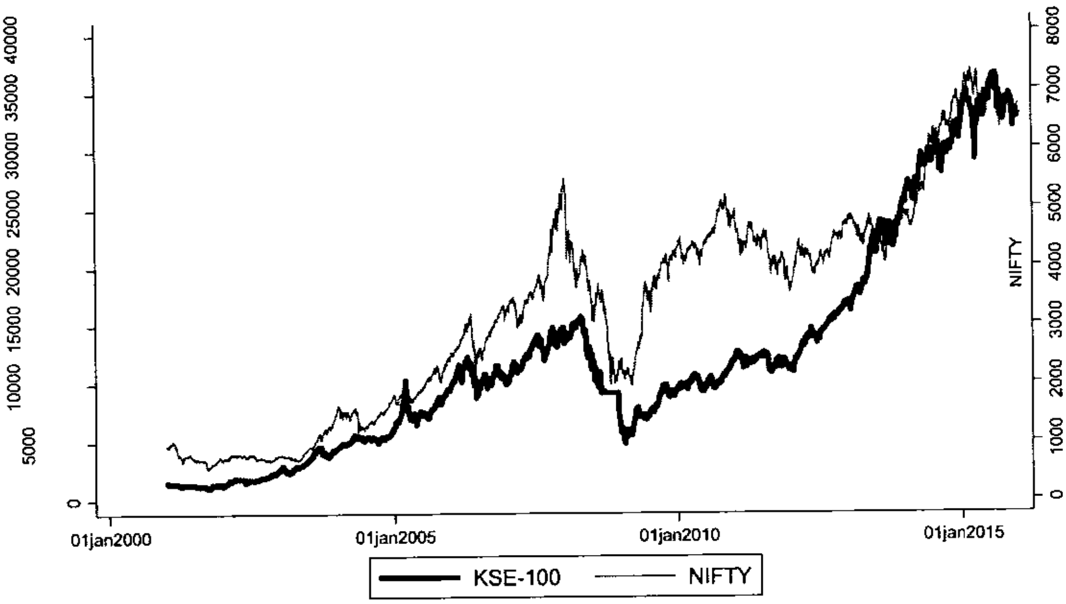

Figure 4-6: KSE-100 Index and Nifty Index

Time series price graph of KSE-100 index of PSX and Nifty index of National Stock Exchange (NSE) of India is plotted in Figure 4.6. Both stock indices of two neighbor markets move side by side during the whole sample period except for a short span of time after GFC. They showed a strong relationship even during GFC. After GFC, the recovery in PSX is bit slow as compared to NSE. From the last quarter of year 2013 the movement in both stocks is nearly identical except a short slump in KSE-100 index during first quarter of the year 2015.

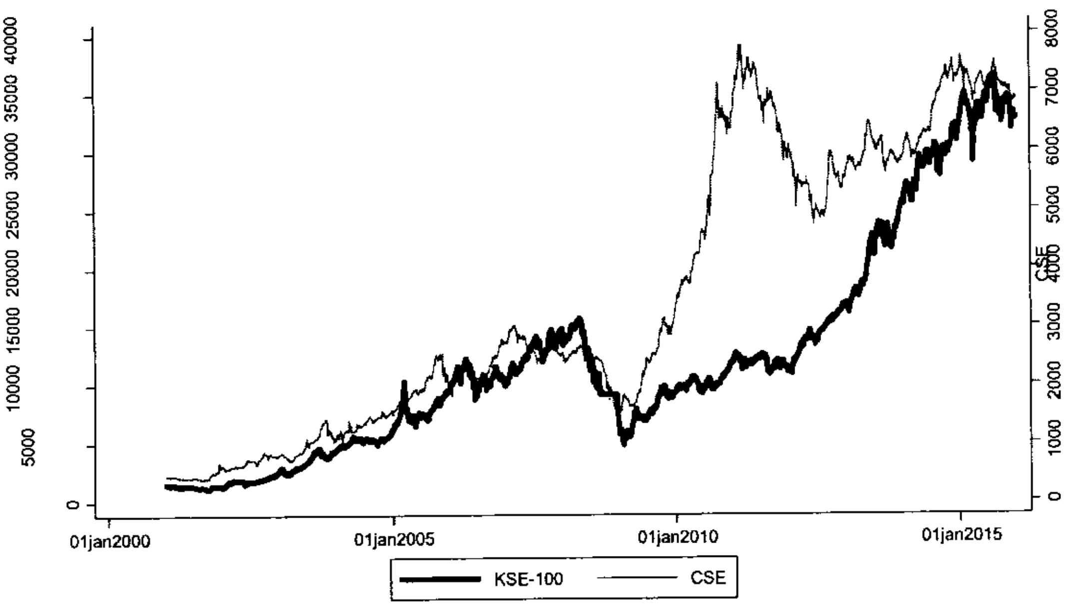

Figure 4-7: The Graph of KSE-100 Index and CSE Index

From the Figure 4.7 that both the stock indices follow each other even in the GFC period. After the FC, the recovery in Lankan market is very fast as compared to its regional counterpart. During the mid of year 2011 price of CSE index showed downward trend. After a small period of low market activity of about two years both markets move in the same direction.

From these graphs, PSX market index shows different price relationship with developed and regional stock markets. It is observed that PSX have visible price relationship with regional indices (Japanese, Indian and Sri Lankan) than the US, the UK and the European region.

The returns of these stock market indices are adjusted for outliers using outliers detection and correction method of Laurent et al. (2016) and Charles and Darné (2005). The statistical and time series properties of unadjusted and adjusted returns have been shown in Table 4.1 and Table 4.2., when returns are cleaned for outliers using Laurent et al. (2016) method. The daily unadjusted average percentage return of these stock markets ranges from -0.004% (S&P-Euro index) to 0.079% (KSE-100 index). Average percentage return of Pakistan Stock Exchange (KSE-100 index) is about 0.079%, which is greater than the average percentage returns of other selected stock markets followed by CSE index of Sri Lanka and Nifty index of India. The average return of Sri Lankan stock market is about 0.070% and Indian stock market is 0.051% respectively. The standard deviation, which is a crude measure of volatility, shows that Chinese stock market is more volatile (1.602%) followed by Japanese stock market (1.506%). All the equity market returns are negatively skewed except Sri Lankan stock market; its returns are positively skewed. Negative skewness suggests that large negative returns are more likely than positive returns in these stock markets. The value of JB statistics, a test of normality, rejects the normality condition of these stock market returns. When returns are corrected for outliers, the average percentage returns of all stock indices are positive and greater than those for unadjusted returns except for Sri Lankan stock market. It may be possible that Sri Lankan market returns have positive outliers. While, the Standard Deviation (SD) of all stock market reduced in comparison when returns are cleaned for outliers. The coefficient of skewness is considerably less than that for unadjusted returns and it becomes insignificant for the US market returns. This showed that presence of outliers in the returns account for large asymmetry in the return of these stock markets. We found that outlier correction results in thick tail distribution as compared to unadjusted returns distribution of these sectors. Finally, the normality of all sectoral stock adjusted returns is rejected as well. But the values of JB statistic are considerably less for adjusted returns. This showed that adjusted returns are more towards normality than unadjusted returns. As the skewness is negative and kurtosis is high, which shows that non-normality is not fully controlled by outliers.

Table 4-1: Distributional Properties of Unadjusted and Adjusted Returns

Country	Return	Mean	SD	Skewness	Kurtosis	JB-Statistics
Pakistan	Unadjusted	0.106	1.244	-0.196*	3.342*	1845.9*
	Adjusted	0.079	1.32	-0.337*	4.115*	2833.8*
US	Unadjusted	0.024	1.204	-0.023	8.871*	12830.5*
	Adjusted	0.011	1.235	-0.203*	9.090*	13495*
UK	Unadjusted	0.004	1.192	-0.186*	6.403*	6706.3*
	Adjusted	0.000	1.212	-0.159*	6.739*	7419.7*
Euro	Unadjusted	0.002	1.362	-0.043	3.90*	2515*
	Adjusted	-0.004	1.407	-0.049	4.716*	3627.9*
Japan	Unadjusted	0.028	1.411	-0.191*	3.192*	1685.4*
	Adjusted	0.008	1.506	-0.408*	6.936*	7948*
China	Unadjusted	0.023	1.487	-0.317*	3.589*	2165.2*
	Adjusted	0.014	1.602	-0.315*	4.774*	3779.3*
India	Unadjusted	0.071	1.358	-0.471*	4.390*	3287.4*
	Adjusted	0.051	1.453	-0.559*	9.288*	14264*
Sri Lanka	Unadjusted	0.059	0.934	-0.241*	6.802*	7581.8*
	Adjusted	0.070	1.155	0.424*	32.810*	175586*

*indicates significance at 5% level

The large values of Q-Statistics (Ljung and Box, 1978) indicate significant autocorrelation in stock sector returns (See Table 4.2). To test the conditional heteroscedasticity LM-ARCH (Engle, 1982) test has been applied. The estimates showed that variance of unadjusted return of these stock markets are time dependent. The ADF test (Dickey and Fuller, 1979) provides evidence that sectoral stock returns are stationary. When returns are adjusted for outliers, the time series properties of the returns remain the same as indicated. The test of autocorrelation, test of conditional heteroscedasticity and test of unit root reject their null hypothesis.

Table 4-2: Time Series Properties of Unadjusted and Adjusted Returns

Index of country	Return	Q-Stat	ARCH Test	ADF Test
Pakistan	Unadjusted	49.46*	166.58*	-24*
	Adjusted	57.5*	134.7*	-23.6*
US	Unadjusted	44.99*	254.64*	-28.65*
	Adjusted	41.9*	229.0*	-27.6*
UK	Unadjusted	65.35*	247.56*	-28.03*
	Adjusted	64.7*	219.3*	-28.3*
Euro	Unadjusted	44.03*	158.64*	-27.46*
	Adjusted	40.1*	158.0*	-27.8*
Japan	Unadjusted	10.46*	222.16*	-27.16*
	Adjusted	9.4*	270.6*	-26.4*
China	Unadjusted	23.15*	94.36*	-24.69*
	Adjusted	21.6*	58.0*	-25.3*
India	Unadjusted	28.58*	157.23**	-25.54*
	Adjusted	45.3*	93.4*	-25.6*
Sri Lanka	Unadjusted	117.57*	123.13*	-23.86*
	Adjusted	125.7*	41.4*	-24.8*

Note: *shows significance at 5% level.

The unconditional correlation (hereafter UCC) between returns (unadjusted/adjusted) of stock market Pakistan and selected stock markets of the world (developed and regional) are given in Table 4.3. The correlation provides a rough idea about the kind of the association between the returns of selected stock markets of world with Pakistan Stock Exchange.

Table 4-3: Unconditional Correlation Between returns Pakistan Stock Exchange and World Selected Stock Markets

	Pakistan	
Country	Unadjusted Returns	Adjusted Returns
US	0.007(0.657)	-0.001(0.929)
UK	0.049(0.002)*	0.045(0.005)*
Euro	0.05(0.002)*	0.048(0.003)*
Japan	0.078(0.000)*	0.065(0.000)*
China	0.061(0.000)*	0.055(0.001)*
India	0.106(0.000)*	0.089(0.000)*
Sri Lanka	0.025(0.123)	0.025(0.122)

Note: *shows significance at 5% level.

Table 4.3 depict that correlation between returns (unadjusted/adjusted) of Pakistan Stock Exchange and world selected markets is very low and surprisingly insignificant with the US stock market and Sri Lankan stock market. Even though graph between

KSE-100 index and S&P-500 index shows very good relationship. During the whole period included in the sample, the correlation between PSX and world selected stock markets ranges from 4.9% (4.5%) to 10.6% (8.9%) for unadjusted (adjusted) returns of Pakistan/UK and Pakistan/India respectively. This reveals that PSX returns have relatively stronger relationship with its neighbors except stock market of Sri as compared to developed western stock market returns. When the correlation is insignificant, it means that they have no linear relationship but it does not mean that they are independent (Reilly and Brown, 2011). For adjusted returns, the value of unconditional correlation coefficient marginally reduced as compared to its value for unadjusted returns, but their significance does not change.

4.3 Results and Discussion

We estimated bivariate VAR(1)-GARCH(1,1) model of Ling and McAleer (2003) and VAR-AGARCH(1,1) model that was proposed by McAleer et al. (2009) for unadjusted and adjusted returns of Pakistan Stock Exchange and world selected stock markets. The conditional mean and conditional volatility equations have been estimated jointly by BFGH maximization algorithm with robust standard errors of Bollerslev and Wooldridge (1992). It has been observed that parameter VAR (1)-AGARCH (1,1) Estimatesfor outliers adjusted returns are almost identical when outliers are adjusted using LLP and CD methods respectively. This showed that the empirical estimates of the models are robust to the method used for the detection and correction outliers In this section, the results of VAR (1)-AGARCH (1,1) when LLP method was used for the detection and correction of outliers have been discussed. These estimates (unadjusted and adjusted) of bivariate VAR (1)-AGARCH (1,1) have been tabulated in Table 4.4 to 4.10. Estimates of VAR (1)-AGARCH (1,1) for different pairs of Pakistan

Stock Exchange with selected foreign stock markets when returns are adjusted for outliers using CD method are given in Table A-1-1 to Table A-1-8, Appendix 1. The coefficients $\Phi_{1,1}$and $\Phi_{2,2}$ in conditional mean captures its own return spillover or lagged return effect and coefficients $\Phi_{1,2}$and $\Phi_{2,1}$measure the return relationship between two stock markets. Similarly, in volatility equation coefficients $\alpha_{1,1}$and $\alpha_{2,2}$estimates its own past shock (ARCH) effect and $\alpha_{1,2}$and $\alpha_{2,1}$measure shock spillover across the markets. Volatility persistence (GARCH) is measured by $\beta_{1,1}$and $\beta_{2,2}$, and volatility transmission from PSX (other) to other (PSX) is represented by $\beta_{2,1}(\beta_{1,2})$. The coefficients $d_1$and d_2 exhibits the asymmetric effect of shocks on the volatility.

Table 4-4: VAR (1)-AGARCH (1,1) Estimates for Pakistan and the USA

	Unadjusted Returns		Adjusted Returns	
	Pakistan	US	Pakistan	US
Panel A: Mean Equation				
$C_{1.0}$	0.095(0.000)*		0.116(0.000)*	
$\Phi_{1,1}$	0.097(0.000)*		0.093(0.000)*	
$\Phi_{1,2}$	0.060(0.000)*		0.053(0.005)*	
$C_{2,0}$		0.010(0.449)		0.021(0.099)
$\Phi_{2,2}$		-0.052(0.002)*		-0.059(0.000)*
$\Phi_{2,1}$		0.002(0.812)		-0.012(0.326)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.077(0.000)*		0.053(0.000)*	
$\alpha_{1,1}$	0.101(0.000)*		0.109(0.000)*	
$\alpha_{1,2}$	0.054(0.040)*		0.056(0.000)*	
$\beta_{1,1}$	0.775(0.000)*		0.776(0.000)*	
$\beta_{1,2}$	0.581(0.522)		1.085(0.690)	
d_1	0.135(0.000)*		0.148(0.000)*	
$\alpha_{2.0}$		0.016(0.000)*		0.013(0.000)*
$\alpha_{2,2}$		-0.024(0.000)*		-0.012(0.154)
$\alpha_{2,1}$		-0.006(0.369)		-0.008(0.308)
$\beta_{2,2}$		0.934(0.000)*		0.930(0.000)*
$\beta_{2,1}$		-0.210(0.287)		-0.411(0.520)
d_2		0.159(0.000)*		0.149(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	10.89(0.053)	5.639(0.343)	10.35(0.066)	10.512(0.062)
ARCH Test	0.505(0.772)	2.100(0.062)	0.829(0.529)	2.111(0.061)
LLH	-11281		-10918	

Note: 1 symbolizes Pakistan and 2 symbolizes the US. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of bivariate VAR (1)-AGARCH (1,1) model of Pakistan/US pair are reported in Table 4.4. The estimates of conditional means of both markets for unadjusted and adjusted returns are given in Panel A, Table 4.4. From the conditional mean equations for unadjusted returns the results show that the coefficients $\Phi_{1,1}$and $\Phi_{2,2}$ are statistically significant but $\Phi_{2,2}$ is negative. This reveals that the future return of both Pakistan and the US stock markets can be forecasted (on average) from their present values i.e. about 0.097% and -0.052% respectively. The lagged effect is more apparent in PSX as compared to the US stock market. The negative sign of the coefficient of its own lag return in the conditional mean of the US is supported by the results of Amin and Orlowski (2014). Regarding return spillovers, the coefficient $\Phi_{1,2} = 0.06$ is significant. This demonstrates that one percent increase in the US stock markets return is likely to increase the future returns of PSX about 0.060%. No return spillover is found from PSX to the US stock market. These findings are in line with the outcomes of Amin and Orlowski (2014). The results for outliers adjusted returns shows that the coefficients associated with its own lagged return and return spillovers ($\Phi_{1,2}$) from the US stock market to PSX are significant for adjusted returns and their values are marginally less than that of unadjusted returns. The correction of outliers has no effect on the estimates of first conditional moments of Pakistani stock market and the US stock market.

The conditional volatility estimates for unadjusted and adjusted returns of Pakistani and the US stock markets have been presented in Panel B, Table 4.4. The coefficients $\alpha_{1,1}$, $\alpha_{2,2}$, $\beta_{1,1}$, and $\beta_{2,2}$ are statistically significant for unadjusted returns. Which shows that its own past unexpected shocks that affect the returns dynamics and its own past volatility have significant effect on the current volatility in both markets respectively. The contribution of past shocks and past volatility to the volatility of Pakistan Stock Exchange is about 0.101 and 0.775, respectively. Whereas, the contribution of past unexpected shocks and past volatility is 0.024 and 0.934 to the current volatility of the US market. The leverage effect which is symbolized by d_i (i=1,2) is significant in both stock markets. This reveals that on an average negative shock in Pakistani and the US markets are likely to increase volatility by about 0.135 and 0.159. The parameter estimates of volatility (ARCH and GARCH) when the returns are adjusted for outliers, approximately remain the same for PSX, whereas, the ARCH effect becomes insignificant in the volatility of the US stock market and GARCH effect remains the same approximately. This suggests that the model wrongly suggests the presence of

ARCH effect in the conditional variance of the US market. The leverage effect is marginally underestimated (overestimated) by the model because of outliers in the returns of PSX (the US) stock market.

The results regarding shock and volatility spillovers between these two stock markets reveal significant short run volatility (shock) spillover ($\alpha_{1,2}$) from the US stock market to Pakistan Stock Exchange. This implies shock spillover from the US stock market towards Pakistan Stock Exchange. When returns are adjusted for possible outliers, the shock spillovers from US stock market found to be significant. The value of coefficient $\alpha_{1,2}$ is 0.056 which is slightly greater than that for unadjusted returns. The coefficients $\alpha_{2,1}$, $\beta_{1,2}$, and $\beta_{2,1}$remains insignificant for adjusted returns as well. It reveals that the correction of outliers does not have any effect on the estimates of lagged returns coefficients and on return spillovers parameter estimates. Whereas, model wrongly suggested the significance of ARCH effect in the US market conditional volatility.

Table 4-5 VAR (1)-AGARCH (1,1) Estimates for Pakistan and the UK

	Unadjusted Returns		Adjusted Returns	
	Pakistan	UK	Pakistan	UK
Panel A: Mean Equation				
$C_{1,0}$	0.098(0.000)*		0.115(0.000)*	
$\Phi_{1,1}$	0.093(0.000)*		0.092(0.000)*	
$\Phi_{1,2}$	0.065(0.007)*		0.052(0.022)*	
$C_{2,0}$		-0.001(0.929)		0.002(0.857)
$\Phi_{2,2}$		-0.041(0.012)*		-0.044(0.016)*
$\Phi_{2,1}$		-0.012(0.269)		-0.013(0.244)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.079(0.000)*		0.061(0.000)*	
$\alpha_{1,1}$	0.101(0.000)*		0.103(0.000)*	
$\alpha_{1,2}$	0.061(0.049)*		0.03(0.084)	
$\beta_{1,1}$	0.786(0.000)*		0.78(0.000)*	
$\beta_{1,2}$	0.011(0.978)		0.023(0.956)	
d_1	0.127(0.000)*		0.154(0.000)*	
$\alpha_{2,0}$		0.019(0.000)*		0.015(0.000)*
$\alpha_{2,2}$		-0.012(0.086)		-0.01(0.243)
$\alpha_{2,1}$		-0.006(0.557)		-0.003(0.790)
$\beta_{2,2}$		0.907(0.000)*		0.913(0.000)*
$\beta_{2,1}$		0.000(0.997)		0.011(0.867)
d_2		0.175(0.000)*		0.163(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	12.816(0.025)	4.492(0.481)	12.388(0.030)	4.712(0.452)
ARCH Test	0.482(0.79)	1.284(0.268)	0.582(0.714)	1.319(0.253)
LLH	-11290		-10952	

Note: 1 symbolizes Pakistan and 2 symbolizes UK. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Empirical estimates of VAR (1)-AGARCH (1,1) for the Pakistan/ the UK pair is given in Table 4.5. The conditional mean estimates are given in Panel A, in Panel B, estimates of conditional variance, and finally in Panel C consists of residuals diagnostic tests result. From Panel A, the coefficients $\Phi_{1,1}$and $\Phi_{2,2}$ are statistically significant at the 5% and 1% level respectively. The significance of these estimates suggest that index price of both stock markets can be forecasted from their past index price about 0.093% and 0.041% in the short run. Whereas, coefficient $\Phi_{1,2}$ is significant (1%) suggesting that the lagged price of the UK spillovers to Pakistan in the short run (0.065). The coefficients $\Phi_{1,1}$, $\Phi_{2,2}$ and $\Phi_{1,2}$ are significant for adjusted returns but their estimated values are somewhat different from those of unadjusted returns. The coefficient (0.052) of adjusted return spillovers from the UK to Pakistan is about 25% overestimated due to the presence of outliers. The estimates of other coefficients approximately remain the same.

From Table 4.5, Panel B, parameter estimates of conditional volatility depict that $\alpha_{1,1}$, $\beta_{1,1}$, and $\beta_{2,2}$ are statistically significant. The significance of these estimates demonstrates that the conditional volatility of unadjusted returns of Pakistan Stock Exchange are significantly affected by its own past market unexpected squared shocks (0.101) which affects the dynamics of returns and its past volatility (0.786). However, the conditional volatility of the UK stock market is affected by its own past volatility is (0.907) only. The coefficient (d_i) values which represent leverage effect are 0.128 and 0.175 in the volatility of Pakistan and the UK, respectively and are statistically significant. When the returns are adjusted for outliers, the estimates of volatility parameters are approximately identical to estimates for unadjusted returns of both markets. Apart from this, the leverage effect coefficients (d_i) increased to 0.154 from 0.127 and reduced to 0.163 from 0.175 in the volatility of PSX and the UK stock market. This shows that due to outlier model underestimate asymmetric effect of shocks in Pakistan Stock Exchange and overestimate asymmetric effect of shocks in UK stock market.

The results about volatility spillovers disclose that only past shock in the UK stock market have significant effect (0.061) on the volatility of Pakistan Stock Exchange for unadjusted returns, which is significant at 5% level. Similarly, when the returns of both stock markets are adjusted for possible outliers, no shock spillovers from the UK stock market to PSX is found significant. This shows that model incorrectly suggest shock spillover from UK stock market to Pakistan Stock Exchange due to the outliers. No volatility spillover exists between PSX and the UK market for unadjusted and adjusted returns respectively.

Table 4-6: VAR (1)-AGARCH (1,1) Estimates for Pakistan and the Euro Region

	Unadjusted Returns		Adjusted Returns	
	Pakistan	EURO	Pakistan	EURO
Panel A: Mean Equation				
$C_{1,0}$	0.096(0.000)*		0.115(0.000)*	
$\Phi_{1,1}$	0.094(0.000)*		0.093(0.000)*	
$\Phi_{1,2}$	0.053(0.000)*		0.044(0.002)*	
$C_{2,0}$		0.005(0.758)		0.013(0.449)
$\Phi_{2,2}$		-0.020(0.232)		-0.016(0.175)
$\Phi_{2,1}$		-0.001(0.957)		-0.006(0.645)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.078(0.000)*		0.059(0.000)*	
$\alpha_{1,1}$	0.099(0.000)*		0.103(0.000)*	
$\alpha_{1,2}$	0.053(0.014)*		0.039(0.007)*	
$\beta_{1,1}$	0.786(0.000)*		0.781(0.000)*	
$\beta_{1,2}$	0.044(0.901)		0.024(0.948)	
d_1	0.131(0.000)*		0.153(0.000)*	
$\alpha_{2,0}$		0.023(0.000)*		0.020(0.000)*
$\alpha_{2,2}$		-0.029(0.000)*		-0.022(0.000)*
$\alpha_{2,1}$		-0.015(0.162)		-0.005(0.579)
$\beta_{2,2}$		0.928(0.000)*		0.930(0.000)*
$\beta_{2,1}$		-0.042(0.591)		-0.047(0.504)
d_2		0.178(0.000)*		0.161(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	2.093(0.836)	4.349(0.500)	5.785(0.323)	5.898(0.316)
ARCH	0.459(0.807)	0.705(0.620)	0.715(0.612)	0.961(0.440)
LLH	-10975		-11633.76	

Note: 1 symbolizes Pakistan and 2 symbolizes Euro. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of conditional mean, conditional variance, and residuals diagnostic tests results of bivariate VAR (1)-AGARCH (1,1) model of Pakistan/Euro have been presented in Panel A, B, and C of Table 4.6. The parameter estimates of conditional mean of both stock markets unadjusted returns depict that only the stock returns of Pakistani stock exchange depend on its past returns. The coefficient ($\Phi_{1,1}$) associated with lagged returns is significant and its value is 0.094. In case of Pakistan/Euro pair, future returns of PSX can be forecasted to be (0.094) from its current returns. The coefficients $\Phi_{1,2}$and $\Phi_{2,1}$ represent the returns spillovers effects from Pakistan to the Euro and the Euro to Pakistan, respectively. In Pakistan and Euro pair, there exists unidirectional returns spillovers $(\Phi_{1,2} = 0.053)$ from the Euro to Pakistani stock market. Similarly, no return spillover is found significant from Pakistan to the Euro region. For adjusted returns, the dynamic structure of both markets conditional mean approximately remains the same except minor difference in the return spillovers coefficient from the Euro region to Pakistan. The return spillovers coefficient is 0.044 which is 0.001 less than of the coefficient of unadjusted returns.

In conditional variance of Pakistani stock market returns, the coefficient associated with past squared shocks and past volatility are 0.099 and 0.756. Similarly, in conditional variance of the Euro these coefficients are 0.029 and 0.928, respectively. The model results show that asymmetric effect of shocks in both markets is significant at 5% level. Both markets become more volatile due to negative shocks as compared to positive shocks of the same intensity. In Pakistani stock market, the negative shocks are likely to increase the volatility (0.131) more than the positive shocks of equal magnitude. While, the Euro stock market negative shocks will increase the volatility by 0.078 than a positive shock of the same magnitude. The values of ARCH and GARCH coefficients are approximately identical to those of unadjusted returns of both Pakistan Stock Exchange and the Euro region index when returns are adjusted for outliers. Apart from this, the model underestimated the leverage effect (0.153) of shocks in Pakistani stock exchange and overestimated the leverage effect (0.161) of shocks in Euro stock market. Turing to the volatility spillovers between these two stock markets, the coefficients $\alpha_{1,2}(\alpha_{2,1})$ and $\beta_{1,2}(\beta_{2,1})$ capture the short run and the long run volatility spillovers from the Euro (Pakistani) stock market to Pakistani (the Euro) stock market. Only the shocks

($\alpha_{1,2}$) transmission from the Euro is significant at the 5% level. The shock transmission from the Euro stock index to Pakistan stock index volatility is 0.053. When the returns are cleaned for outliers the shock spillover coefficient decreases from 0.053 to 0.039.

Table 4-7: VAR (1)-AGARCH (1,1) Estimates for Pakistan and Japan

	Unadjusted Returns		Adjusted Returns	
	Pakistan	Japan	Pakistan	Japan
Panel A: Mean Equation				
$C_{1.0}$	0.094(0.000)*		0.116(0.000)*	
$\Phi_{1,1}$	0.092(0.000)*		0.094(0.000)*	
$\Phi_{1,2}$	0.029(0.053)		0.035(0.004)*	
$C_{2,0}$		0.019(0.346)		0.034(0.104)
$\Phi_{2,2}$		-0.019(0.31)		-0.023(0.169)
$\Phi_{2,1}$		0.014(0.435)		0.018(0.221)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.085(0.000)*		0.047(0.002)*	
$\alpha_{1,1}$	0.100(0.000)*		0.107(0.000)*	
$\alpha_{1,2}$	-0.022(0.210)		-0.003(0.843)	
$\beta_{1,1}$	0.784(0.000)*		0.770(0.000)*	
$\beta_{1,2}$	-0.002(0.996)		0.218(0.546)	
d_1	0.139(0.000)*		0.156(0.000)*	
$\alpha_{2,0}$		0.044(0.000)*		0.028(0.000)*
$\alpha_{2,2}$		0.040(0.001)*		0.028(0.001)*
$\alpha_{2,1}$		0.004(0.818)		0.008(0.510)
$\beta_{2,2}$		0.885(0.000)*		0.916(0.000)*
$\beta_{2,1}$		0.053(0.501)		-0.005(0.932)
d_2		0.097(0.000)*		0.083(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	14.72(0.012)	1.87(0.867)	12.903(0.024)	1.066(0.957)
ARCH Test	0.36(0.876)	0.764(0.576)	0.574(0.72)	0.59(0.708)
LLH	-12550		-12125	

Note: 1 symbolizes Pakistan and 2 symbolizes Japan. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of VAR (1)-AGARCH (1,1) of Pakistani and regional developed stock market i.e. Japanese market pair have been exhibited in Table 4.7. From Panel A of unadjusted returns, only $\Phi_{1,1}$ is significant which shows that the future returns can be forecasted (0.092%) from its current returns. On the other hand, the fact that coefficient $\Phi_{2,2}$ is statistically insignificant implies that future returns of Japanese stock market cannot be predict from their current returns. When returns are cleaned of outliers only the lagged returns coefficient of PSX is significant and have the same value. Apart from this, the return spillovers ($\Phi_{I,2} = 0.035$) from Japanese to Pakistan Stock Exchange become significant. This shows that the model is unable to capture the return spillovers from Japanese market to PSX because of outliers.

From Panel B of Table 4.7, both ARCH ($\alpha_{1,1}$and $\alpha_{2,2}$) and GARCH ($\beta_{i,1}$ and $\beta_{2,2}$) coefficients are significant at the 1% level for unadjusted and adjusted returns respectively. The estimated values of these coefficients in conditional variance of Pakistan Stock Exchange are alike to those when PSX is paired with other stock markets. Whereas, the influence of past squared innovations and past volatility of Japanese stock market on the current is about 0.04 and 0.885, respectively for unadjusted returns. When the returns are adjusted for outliers, the innovation effect decreased to 0.028 from 0.04 and volatility persistence increased from 0.885 to 0.916. These results show that model overestimate the ARCH coefficient and underestimate the GARCH coefficient due to the presence of outliers. Asymmetry is statistically significant indicating that negative innovations increased the volatility of Japanese stock markets more by 0.097 as compared to the positive innovations of same magnitude. When the returns are adjusted for outliers the leverage effect decreased from 0.097 to 0.083.

The coefficients $\alpha_{1,2}$, $\alpha_{2,1}$, $\beta_{1,2}$, and $\beta_{2,1}$are statistically insignificant which reveal that no volatility spillovers between these two stock markets both in the short run as well as in the long run. Similar results are found when returns are adjusted for outliers. The volatilities of these two stock markets are independent of each other.

Table 4-8: VAR (1)-AGARCH (1,1) Estimates for Pakistan and China

	Unadjusted Returns		Adjusted Returns	
	Pakistan	China	Pakistan	China
Panel A: Mean Equation				
$C_{1.0}$	0.093(0.000)*		0.114(0.000)*	
$\Phi_{1,1}$	0.094(0.000)*		0.097(0.000)*	
$\Phi_{1,2}$	0.017(0.098)		0.009(0.267)	
$C_{2,0}$		0.001(0.972)		0.012(0.609)
$\Phi_{2,2}$		0.011(0.492)		0.013(0.431)
$\Phi_{2,1}$		0.011(0.461)		-0.003(0.858)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.081(0.000)*		0.057(0.000)*	
$\alpha_{1,1}$	0.098(0.000)*		0.103(0.000)*	
$\alpha_{1,2}$	-0.011(0.479)		-0.015(0.318)	
$\beta_{1.1}$	0.791(0.000)*		0.778(0.000)*	
$\beta_{1.2}$	0.001(0.998)		0.139(0.757)	
d_1	0.128(0.000)*		0.157(0.000)*	
$\alpha_{2.0}$		0.021(0.033)*		0.018(0.002)*
$\alpha_{2,2}$		0.053(0.000)*		0.054(0.000)*
$\alpha_{2,1}$		-0.033(0.015)*		-0.007(0.536)
$\beta_{2,2}$		0.912(0.000)*		0.926(0.000)*
$\beta_{2,1}$		0.335(0.081)		0.128(0.334)
d_2		0.030(0.022)*		0.012(0.289)
Panel C: Residuals Diagnostic				
Q-Stat	4.762(0.446)	5.664(0.340)	3.016(0.700)	4.276(0.510)
ARCH Test	0.367(0.872)	0.309(0.908)	0.657(0.656)	0.391(0.855)
LLH	-12863		-12275	

Note: 1 symbolizes Pakistan and 2 symbolizes China. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Empirical findings of VAR (1)-AGARCH (1,1) model for Pakistani Stock Exchange and Chinese stock market pair have been reported in Table 4.8. The results of conditional mean equations of both market returns are presented in Panel A, which show that coefficient ($\Phi_{1,1}$) is significant at 1% level. This infers that the future Pakistan Stock Exchange returns can be forecasted from current returns about 0.094% and 0.097% for unadjusted and adjusted returns, respectively. Apart from this, all other coefficients in mean equations are insignificant. There is no price spillover in the short-run between PSX and Chinese stock market. Our results do not support the findings of Jebran and Iqbal (2016). They found significant return spillovers from Chinese stock market to Pakistani stock market using univariate model.

Conditional volatility estimates of both markets are given in Panel B. The coefficients $\alpha_{1,1}$ and $\beta_{1,1}$in conditional volatility of Pakistan Stock Exchange and $\alpha_{2,2}$ and $\beta_{2,2}$in conditional volatility of Chinese stock exchange are significant for unadjusted and adjusted returns. The sensitivity of Chinese stock market volatility to its own unexpected shocks is 0.054 (0.054) as compared to Pakistan Stock Exchange in which shocks affect its future volatility approximately by 0.098 (0.103) for unadjusted (adjusted) returns. In contrast to this, its own market volatility spillovers in Chinese stock market is nearly 0.926 (0.912) but in Pakistani stock market, spillovers effect is just 0.791 (0.778) respectively of unadjusted(adjusted) returns. The estimated coefficients $d_1$and d_2 are significant of unadjusted returns. Due to its own negative shocks both markets become more volatile (0.129 and 0.003), respectively than positive shocks of the same intensity. However, when returns have been cleaned for outliers the coefficient d_2 become statistically insignificant. This showed that the model erroneously suggest asymmetry in volatility of Chinese market due to outliers in the data. Apart from this, the model also underestimates the leverage effect in the volatility of Pakistan Stock Exchange. The coefficient value of leverage effect increased from 0.129 to 0.157. These findings suggest that the presence of outliers falsely suggest the asymmetry in the Chinese stock market volatility and underestimate the asymmetry of Pakistan Stock Exchange.

The results regarding volatility spillovers for unadjusted returns reveal that no volatility spillovers between two markets neither in the short nor in the long run. The coefficients of spillovers $\alpha_{1,2}, \alpha_{2,1}$, $\beta_{1,2}$, and $\beta_{2,1}$are statistically insignificant. Similar results are found when returns are adjusted for outliers. There is no risk transmission between Pakistani stock market and Chinese stock market.

Table 4-9: VAR (1)-AGARCH (1,1) Estimates for Pakistan and India

	Unadjusted Returns		Adjusted Returns	
	Pakistan	India	Pakistan	India
Panel A: Mean Equation				
$C_{1.0}$	0.097(0.000)*		0.113(0.000)*	
$\Phi_{1,1}$	0.092(0.000)*		0.093(0.000)*	
$\Phi_{1,2}$	0.036(0.006)*		0.035(0.030)*	
$C_{2,0}$		0.05(0.019)		0.064(0.000)*
$\Phi_{2,2}$		0.117(0.000)*		0.106(0.000)*
$\Phi_{2,1}$		0.010(0.306)*		0.004(0.818)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.072(0.000)*		0.066(0.000)*	
$\alpha_{1,1}$	0.100(0.000)*		0.104(0.000)*	
$\alpha_{1,2}$	-0.017(0.421)		0.010(0.447)	
$\beta_{1,1}$	0.778(0.000)*		0.792(0.000)*	
$\beta_{1,2}$	0.229(0.448)		-0.201(0.483)	
d_1	0.124(0.000)*		0.152(0.000)*	
$\alpha_{2,0}$		0.038(0.010)*		0.04(0.000)*
$\alpha_{2,2}$		0.050(0.000)*		0.038(0.000)*
$\alpha_{2,1}$		0.030(0.043)*		0.027(0.012)*
$\beta_{2,2}$		0.837(0.000)*		0.848(0.000)*
$\beta_{2,1}$		0.452(0.028)*		0.38(0.024)*
d_2		0.117(0.000)*		0.126(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	6.923(0.226)	8.014(0.155)	12.34(0.03)	5.646(0.342)
ARCH Test	0.391(0.855)	0.199(0.963)	0.651(0.661)	0.824(0.532)
LLH	-12243		-11765	

Note: 1 symbolizes Pakistan and 2 symbolizes India. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of the bivariate model of Pakistani stock market and Indian stock market pair are given in Table 4.9. From Panel A, the coefficients ($\Phi_{1,1}$ an $\Phi_{2,2}$) associated with its own lagged returns are significant at the 1% level for both unadjusted and adjusted return. The lagged return coefficient of PSX is approximately the same that we have already found in the previous tables. The short run predictability in both markets is nearly the same. The price predictability is 0.117% and 0.106% in Indian stock market for unadjusted and adjusted returns. Looking at the return spillovers coefficients, only coefficient $\Phi_{1,2}$ is significant of unadjusted and adjusted returns. The significance of $\Phi_{1,2}$ is an evidence that unadjusted (adjusted) returns of Indian stock market affect approximately 0.035 (0.036) unadjusted (adjusted) returns of Pakistani stock market.

From Pane B, the volatility estimates of Pakistan Stock Exchange are significant and have approximately the same values that we have already observed in other pairs. However, the $\alpha_{2,2}$, and $\beta_{2,2}$ are significant at 1% level and $\alpha_{2,1}$, and $\beta_{2,1}$coefficients are significant at the 5% level of significance, respectively. Significance of these estimates indicates that Indian stock market volatility is a function of its own as well as unexpected shocks that effect the dynamics of returns and the past volatility of Pakistan Stock Exchange. Both its own past shock and past volatility of Indian stock market affect the current volatility by about 0.050 (0.038) and 0.837 (0.848) respectively of unadjusted (adjusted) returns. Similarly, the shock and volatility spillovers from PSX is 0.030 and 0.452 to Indian stock market. The coefficient of asymmetry (d_2) is positive and significant and its value is 0.117 (0.126) of unadjusted (adjusted) returns. The negative shock in Indian stock market likely to increase the volatility by 0.117 and 0.126 of unadjusted and adjusted returns respectively. When returns are adjusted of outliers the shock and volatility spillovers from Pakistan Stock Exchange decreased from 0.030 to 0.027 and 0.453 to 0.381, respectively. This reveals that due to outlier's model overvalued the spillovers effect from PSX to Indian stock market.

From above discussion, we can conclude that due the outliers, the Autoregressive (AR) coefficient in the conditional mean of Indian stock market is overestimated. The correction of outliers has an effect on both GARCH and asymmetry coefficients of Pakistan Stock Exchange and both coefficients are underestimated by the model. On the other hand, ARCH coefficient is overestimated and GARCH and asymmetry is underestimated by the model because of outliers in the returns. The correction of outliers from returns has a significant effect on the estimates of volatility spillovers coefficients (past shocks and past volatility). Both innovations and volatility spillovers coefficients are overestimated by the model due the presence of outliers. The shocks spillovers effect drops from 0.030 to 0.027 and volatility spillovers drop from 0.452 to 0.381 when returns are cleaned of outliers

Table 4-10: VAR (1)-AGARCH (1,1) Estimates for Pakistan and Sri Lanka

	Unadjusted Returns		Adjusted Returns	
	Pakistan	Sri Lanka	Pakistan	Sri Lanka
Panel A: Mean Equation				
$C_{1.0}$	0.094(0.000)*		0.114(0.000)*	
$\Phi_{1,1}$	0.105(0.000)*		0.101(0.000)*	
$\Phi_{1,2}$	0.015(0.000)*		0.008(0.516)	
$C_{2,0}$		0.037(0.015)*		0.042(0.000)*
$\Phi_{2,2}$		0.234(0.000)*		0.215(0.000)*
$\Phi_{2,1}$		0.020(0.115)		0.003(0.841)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.059(0.000)*		0.058(0.000)*	
$\alpha_{1,1}$	0.084(0.000)*		0.102(0.000)*	
$\alpha_{1,2}$	-0.019(0.566)		-0.018(0.468)	
$\beta_{1,1}$	0.782(0.000)*		0.778(0.000)*	
$\beta_{1,2}$	0.689(0.086)		0.270(0.606)	
d_1	0.148(0.000)*		0.157(0.000)*	
$\alpha_{2,0}$		0.020(0.105)		0.021(0.005)*
$\alpha_{2,2}$		0.259(0.000)*		0.157(0.000)*
$\alpha_{2,1}$		-0.016(0.502)		-0.029(0.064)
$\beta_{2,2}$		0.758(0.000)*		0.762(0.000)*
$\beta_{2,1}$		0.445(0.191)		0.676(0.125)
d_2		-0.006(0.901)		0.075(0.008)*
Panel C: Residuals Diagnostic				
Q-Stat	3.28(0.72)	5.46(0.35)	2.79(0.63)	3.32(0.50)
ARCH Test	1.05(0.39)	0.34(0.89)	0.60(0.70)	0.96(0.44)
LLH	-10975		-10120	

Note: 1 symbolizes Pakistan and 2 symbolizes Sri Lanka. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Finally, the estimate of parameters of VAR (1)-AGARCH (1,1) model of Pakistani stock market and Sri Lankan stock market pair have been depicted in Table 4.10. The results regarding the conditional mean equation of both markets show that the coefficient of its own lagged returns ($\Phi_{1,1}$and $\Phi_{2,2}$) is significant for both markets. Return spillovers in Sri Lankan stock market is about 0.234% and 0.215%, respectively for unadjusted and adjusted returns. No return spillover exist between these two markets as the return spillovers coefficients ($\Phi_{1,2}$and $\Phi_{2,1}$) are insignificant in case of unadjusted and adjusted returns. However, the empirical findings of conditional variance equations of both markets illustrate that its past innovations ($\alpha_{1,1}$and $\alpha_{2,2}$) and its past volatility $\beta_{1,1}$and $\beta_{2,2}$ have significant effect on the volatility of the markets. The conditional volatility estimates of Sri Lankan stock market reveal that presence of outliers affect the ARCH estimates ($\alpha_{2,2}$). Its value reduced to 0.1573 from 0.2586 when returns are adjusted of outliers. But presence of outliers has no significant effect on the long-run volatility estimate. The asymmetric effect of shock on the volatility is significant for Pakistani stock market for both unadjusted and adjusted returns, whereas, asymmetric effect is significant only for adjusted returns of Sri Lanka. The adjusted negative innovations increase the volatility of the Lankan stock market by 0.075 more than the positive shock of the same scale. The estimated result also reveals that there is no volatility spillovers in the short as well as in the long run between these stock markets.

Table 4-11 Constant Conditional Correlation (CCC) between returns of Pakistan Stock Exchange and world selected stock markets

	Pakistan	
	Unadjusted Returns	Adjusted Returns
US	0.025 (0.113)	0.011(0.481)
UK	0.061 (0.001)*	0.066(0.000)*
Euro Region	0.052(0.001)*	0.054(0.001)*
Japan	0.100(0.000)*	0.085(0.000)*
China	0.053 (0.002)*	0.051(0.007)*
India	0.082(0.000)*	0.069(0.000)*
Sri Lanka	0.022(0.208)	0.030(0.069)

Note: * shows significance at 5% level.

The constant conditional correlations between KSE-100 index of Pakistan Stock Exchange and market indices of developed and regional stock markets are reported in Table 4.11 for both unadjusted and adjusted returns. From the table above, it has been observed that the correlation between returns of Pakistan Stock Exchange and other stock market are very low even insignificant in some cases. The constant correlation between KSE100-S&P-500 and KSE-CSE is insignificant. The correlation is high for KSE-100-Nikkei followed by KSE-100-Nifty. It is observed that Pakistan Stock Exchange have strong correlation with Asian developed and regional markets than western markets. These empirical findings confirm the past results of existence of low correlation between returns in developed and emerging stock markets (Beine and Candelon, 2011; Forbes and Rigobon, 2002). From the finance theory low correlation between the stock market may offer diversification benefits to institutional and international investors.

Residual-based diagnostic tests have been applied which are given in Panel C of Table 4.4 to Table 4.10. The Ljung-Box Q-statistic values are well below the critical value which is confirmed by its P-value. This suggests that standardized residuals of models are no more autocorrelation in different pairs. Similarly, the LM-ARCH test of conditional heteroscedasticity provides an evidence that the model successfully captures the heteroscedasticity in the standardized residuals of all bivariate GARCH models. These findings confirm the adequacy of the models that no standard assumption of classical regression model is violated here. The model results can be used for further analysis for example to find optimal portfolio weights and hedge ratios.

4.4 Portfolio Weight and Hedge Ratio

The findings of estimated model have been used to estimate the optimal portfolio weights and hedge ratios that minimize the risk without lowering the expected portfolio returns. The optimal portfolio weights and hedge ratios have been reported in Table

4.12 for both unadjusted and adjusted returns. The optimal portfolio weights suggest that risk of investment is minimum without lowering the expected returns if he diversifies his investment between Pakistan Stock Exchange and selected stock markets as well. Similarly, the hedge ratio suggests that the risk of portfolio will be minimum by taking long position in Pakistan stock and short position in other stock market.

Table 4-12: Portfolio Weights and Hedge Ratios

	Unadjusted Returns		Adjusted Returns	
	Weight	Hedge Ratio	Weight	Hedge Ratio
US	0.43	0.03	0.46	0.01
UK	0.43	0.08	0.46	0.08
Euro Region	0.51	0.06	0.53	0.06
Japan	0.58	0.09	0.60	0.08
China	0.60	0.05	0.60	0.04
India	0.54	0.08	0.55	0.07
Sri Lanka	0.40	0.07	0.37	0.06

Notes: Average optimal weights of Pakistani stock and hedge ratios using estimates of VAR(1)-AGARCH(1,1) Model.

The results indicate that the average values of optimal weight of PSX varies as the other stock market change in two stocks portfolio, for both unadjusted and adjusted returns. In case of unadjusted returns, the optimal holding of assets from PSX in two stock portfolio varies from 0.40 to 0.60 in KSE/CSE and KSE/Shanghai pairs, respectively. The results reveal that optimal investment in 100 $ portfolio of two stocks (Pakistan and China), investors might invest 60% of its investment in Pakistan Stock Exchange and remaining 40% in the Shanghai Stock Exchange. Contrary to this, in PSX/CSE portfolio, to minimize the investment risk without lowering the expected return, the investor ought to invest of 40% of its investment in Pakistan Stock Exchange and 60% in Sri Lankan Stock Exchange. However, in case of adjusted returns the share of investment of Pakistan Stock Exchange in two stocks portfolio increased apart from KSE/CSE portfolio. The optimal weights of PSX increased by 3% in KSE/S&P-500 and KSE/FTSE-100 and decreased by the same percentage in KSE/CSE portfolio. The hedge ratios are quite low in all pairs of stock in both for unadjusted and adjusted returns. On the average, $100 long position in PSX can be shorted by maximum of US $8 from other stock markets. In case for outliers adjusted returns, the values of hedge ratios deceased slightly (by 1%).

4.5 Summary

In this chapter, we have analyzed the return and volatility dynamics of Pakistan and the selected stock markets of the world and transmission of return and volatility considering outliers. We have also studied the effect of outliers on the estimates of optimal portfolio weights and hedge ratios as well. The market returns are adjusted for possible outliers and bivariate VAR-AGRCH is estimated for unadjusted and outliers adjusted returns. This model is capable to capture both price and volatility dynamics and volatility spillovers between Pakistan Stock Exchange and selected stock markets of the world. The empirical findings (unadjusted returns) pronounced that the dynamic structure of both conditional mean and conditional variance PSX are approximately indifferent to foreign stock market in all pairs of models. The discrepancy in the estimated values of parameters of conditional mean and conditional variance of PSX is very small. The coefficient values of its lagged return of PSX varies from 0.092 and 0.105 in all pairs and significant at 1% level. However, the past squared shock (innovation) effect is approximately 10% in six out of seven pairs (0.087 in Pakistani/Sri Lankan pair). The large value of ARCH points out that Pakistan Stock Exchange is nervous (Alexander, 2008). Similarly, the estimated values of GARCH effect lies between 0.775 and 0.791 in different pairs of PSX with selected markets of the world. The leverage effect lies between 0.124 to 0.148. The results regarding the return spillovers between Pakistan Stock Exchange and selected share markets of the world show unidirectional return spillover from the USA, the UK, the Euro, and India to Pakistan Stock Exchange only. The return spillovers from developed stock market (0.053 to 0.065) is prominent than the regional (0.036) return spillovers. Similarly, empirical findings suggested unidirectional shock spillovers from the USA, the UK and Euro to Pakistan and from Pakistan to China. On the other hand, both shock and volatility of PSX have significant effect on Indian stock market volatility. The shock spillovers from these markets to Pakistani equity market is about 0.053 to 0.061. Apart from this, past shocks of Pakistan Stock Exchange negatively affect (0.030) the volatility of Chinese stock market and both past shocks (0.03) and past volatility (0.452) of PSX affect the volatility of Indian stock market. These outcomes indicate that Indian stock market volatility is sensitive to volatility of PSX.

When the returns are cleaned for outliers, parameter estimates of conditional mean and variance of Pakistan Stock Exchange are not specific to other market in the pair. The estimated values of lagged returns parameter are very close to those for unadjusted returns. This showed that presence of outliers has no significant effect on the conditional mean of Pakistan Stock Exchange. The results pronounced that the constant in the conditional volatility of Pakistan Stock Exchange is overestimated by the model due to presence of outliers in all pairs. The findings are consistent with the findings of Carnero et al. (2006). The estimates of ARCH coefficient are marginally greater than that of unadjusted returns and vary between 0.103 and 0.107 in all pairs. Similarly, the estimates of GARCH coefficient ranges from 0.77 to 0.797. In three out of seven pairs, they are marginally undervalued by the model because of outliers in the data. These findings are consistent with (Charles and Darné, 2005; Carnero et al., 2006; Carnero et al., 2016; Charles, 2004, 2008; Li and Kao, 2002; Verhoeven and McAleer, 2000). The leverage effect of shocks in PSX volatility is undervalued in all pairs of PSX with selected stock markets due to presence of outliers. These results are consistent with Carnero et al. (2016) who show that presence of outliers can hide true asymmetry. The coefficient values of leverage effect range from 0.148 to 0.157. The model misleadingly suggests the shock significant spillovers from the UK stock market to Pakistani stock market and from Pakistani market to Chinese stock market. The shock spillovers from Pakistan to China and the UK to Pakistan wipe out when outliers are adjusted. The shock spillovers from the US and Euro to Pakistan Stock Exchange and shock and volatility spillovers from Pakistan Stock Exchange to Indian stock market remained significant but the values of their estimated coefficients are different when returns are cleaned for outliers. The shock and volatility spillovers from Pakistani market to Indian stock market reduced to 0.027 and 0.380 from 0.030 and 0.435 when returns are cleaned for outliers.

The empirical results showed that outliers have no significant impact on conditional correlation between stock market of Pakistan and selected stock markets of the world. The constant conditional correlation of stock market of Pakistan with selected stock markets of the world is very low for adjusted returns as well and marginally less than that for unadjusted returns. The CCC results disclose that Pakistan Stock Exchange has stronger relationship with regional (developed and underdeveloped) stock markets than the western stock markets. The average values of optimal portfolio weights and hedge ratios showed that in two assets portfolio, the average weights and hedge ratios vary across pair of markets. This suggests that investors should adjust the proportion of their investment at PSX when they diversify their investment by investing in other market at the same time in two assets portfolio. The hedge ratios are very low which provide hedging opportunity that minimize the risk exposure of investment. The correction of outliers marginally changes the estimated values of portfolio weights and hedge ratios.

The maximum absolute change in weights and hedge ratio is 3% and 1% respectively when returns are adjusted for outliers. These findings are very important for the investors, hedge managers, portfolio managers and policy makers. Overall, in the short-run, no significant price spillovers from Pakistani equity market to other stock markets. Similarly, there are significant price spillovers from four out of seven markets toward Pakistani stock market. The correction of outliers does not have any significant impact on the dynamics of first moment of model in all pairs of PSX with selected stock markets. The constant in volatility of PSX is always well overvalued due to the outliers. Similarly, the conditional variance stipulates the correction of outliers has no effect on the estimates of the ARCH and GARCH parameters except in case of Sri Lanka. The presence of outliers does affect the leverage coefficient in all pairs of PSX with selected stock markets. It is observed that model may misleadingly suggest or overestimate the shock and volatility spillovers between Pakistan Stock Exchange and selected equity markets of the world.

Chapter 5: Effect of Outliers on Return and Volatility Spillovers Between Sectors of Pakistan Stock Exchange.

5.1 Introduction

In the previous chapter we have analyzed the impact of outliers on the estimates of return and volatility and their spillovers between Pakistan Stock Exchange and selected stock markets of the world. The coefficient estimates of conditional mean and conditional variance of Pakistan Stock Exchange are not sensitive to other market in the pair. Their values remain the same when paired with other market selected for the analysis. It is also observed that outliers have some effects on return and volatility estimates. However, intercept in the volatility equation of Pakistan Stock Exchange, in all the pairs, is always overestimated by the model due to the outliers. The coefficient of asymmetry is sensitive to the outliers in the returns of these selected stock markets. The estimates of spillover are also affected by the outliers. This chapter empirically analyzes the effects of outlier on the return and volatility and spillover between different sectors of PSX. The remaining chapter has been outlined as follows: Section 5.2 discusses the data and its statistical as well as time series properties. Empirical findings have been reported in Section 5.3 and optimal portfolio weights and hedge ratios are given in Section 5.4. Finally, the summary of this chapter has been provided in Section 5.5.

5.2 Graphical and Descriptive Analysis

Daily closing price of five major sectoral stock indices of Pakistan Stock Exchange, namely: Industry sector, Basic Material sector, Consumer Goods sector, Oil and Gas sector and Financial sector have been used for analysis. The sectoral indices data have been extracted from DataStream in Local Currency units (rupees). The time series graphs of sectoral stock indices with KSE-100 have been plotted in Figures 5.1-5.5. The thin (red) line represents the price fluctuations of market index (KSE-100) while thick (black) line represents the price moment of sector index.

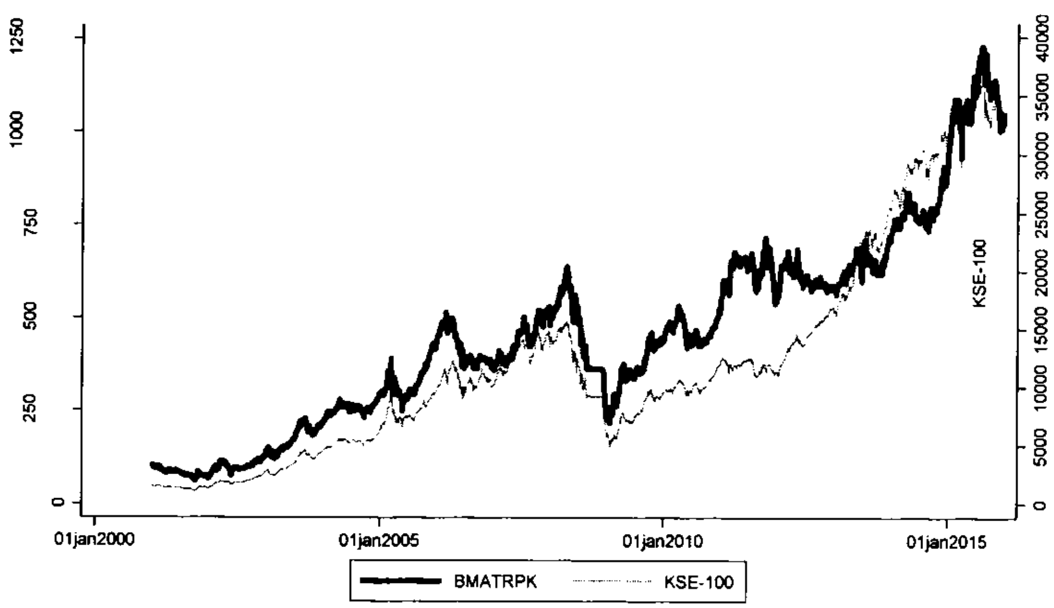

Figure 5-1: Basic Material Sector and KSE-100

Figure 5.1 depicts the time series graph of Basic Material sector index and KSE-100 index. The figure demonstrates that both indices approximately move in the same direction during whole of the sample period. The performance of Basic Material Sector has been marginally decreased as compared to market index from the middle of year 2012 till the end of year 2014.

Figure 5.2 represents the graph of Oil and Gas sector index and KSE-100 index. The movement of price in the Oil and Gas sector is roughly identical to the price movement

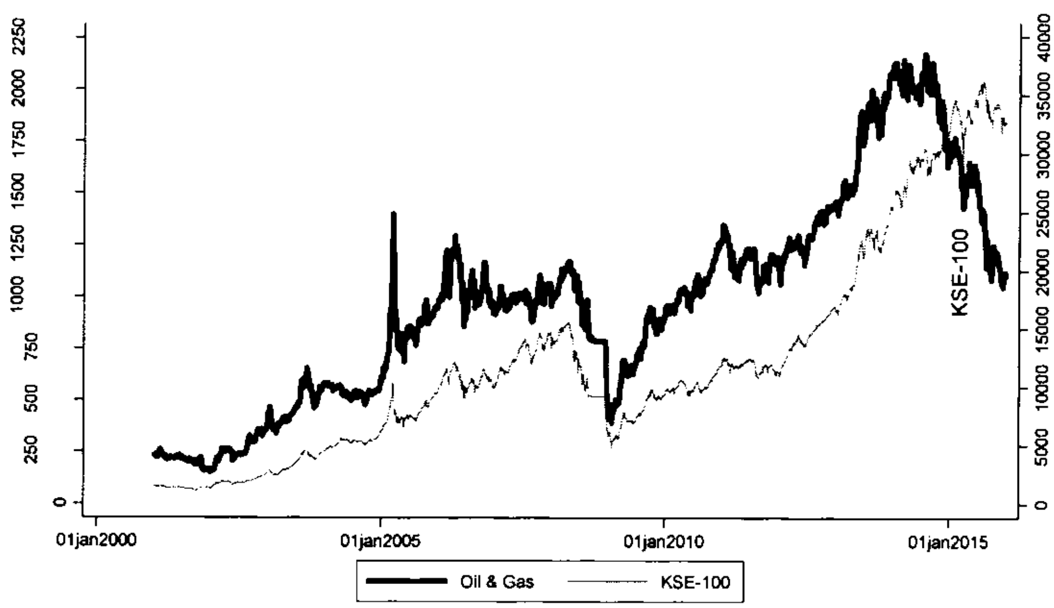

Figure 5-2: Oil and Gas Sector Index and KSE-100 Index

of KSE-100 index. The price gap between these two indices remain approximately same from the start of sample to the mid of the year 2014. From the mid of the year 2014 onwards, the Oil and Gas Sector index declined very sharply. Decline in the price of Brent oil at international market might be a cause of de this decline.

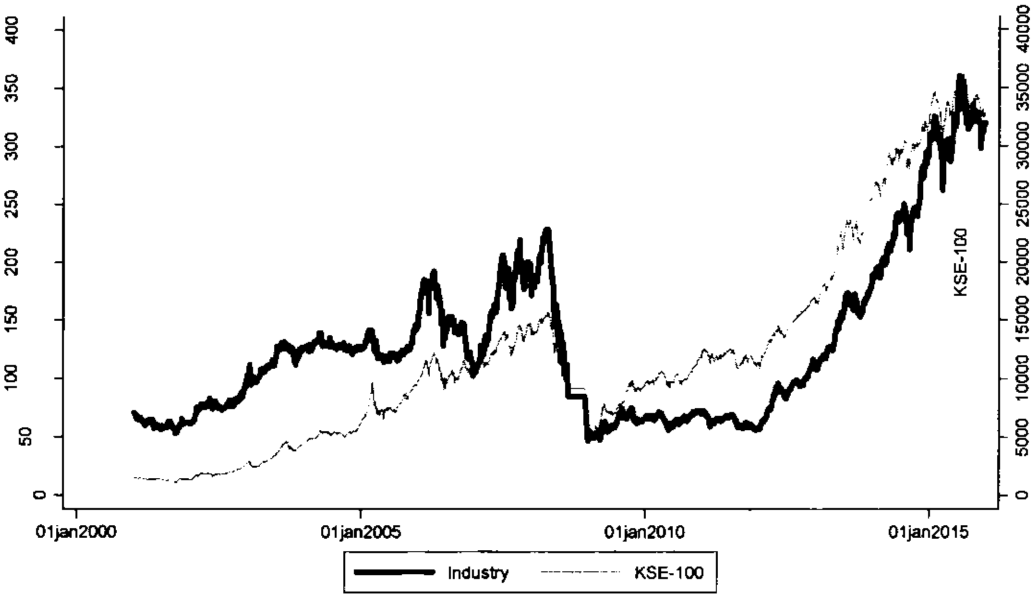

Figure 5-3: Industry Sector Index and KSE-100 Index

Figure 5.3 illustrates that both Industry Sector index and KSE-100 index move in the same direction during whole of the period. After the GFC, the share of Industry Sector in the free float market capitalization is less than that was before Global Financial Crisis. From the year 2014, performance of Industry Sector is slightly less than the aggregate market, but it follows the market index.

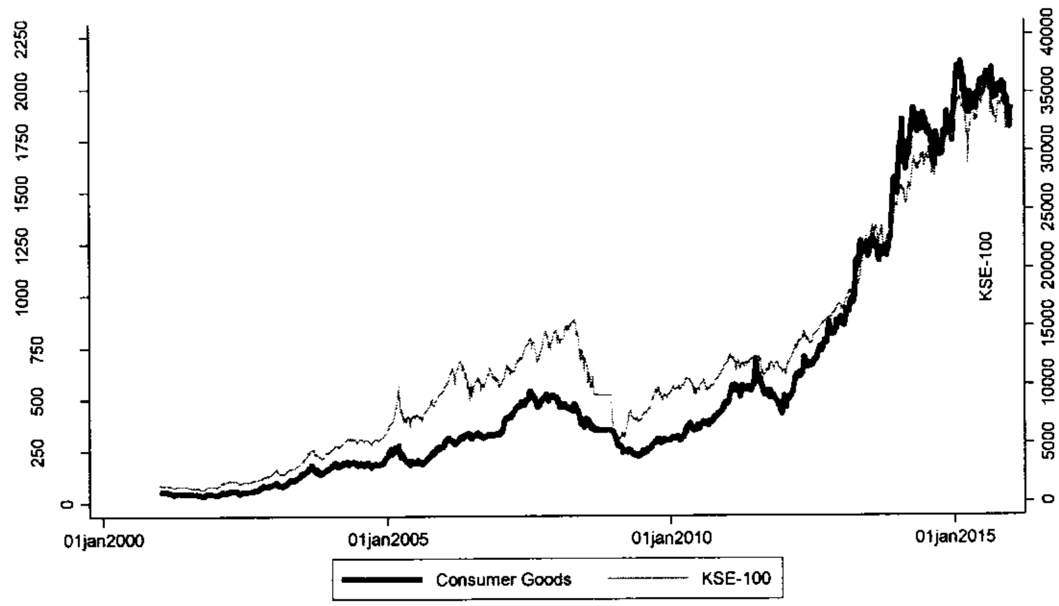

Figure 5-4: Consumer Goods Sector Index and KSE-100 Index

Cursory glance at the Figure 5.4 reveals that Consumer Good Sector index and PSX bench mark index (KSE-100 index) move in the same direction. Strong relationship has been observed between these two stock indices for the given sample period.

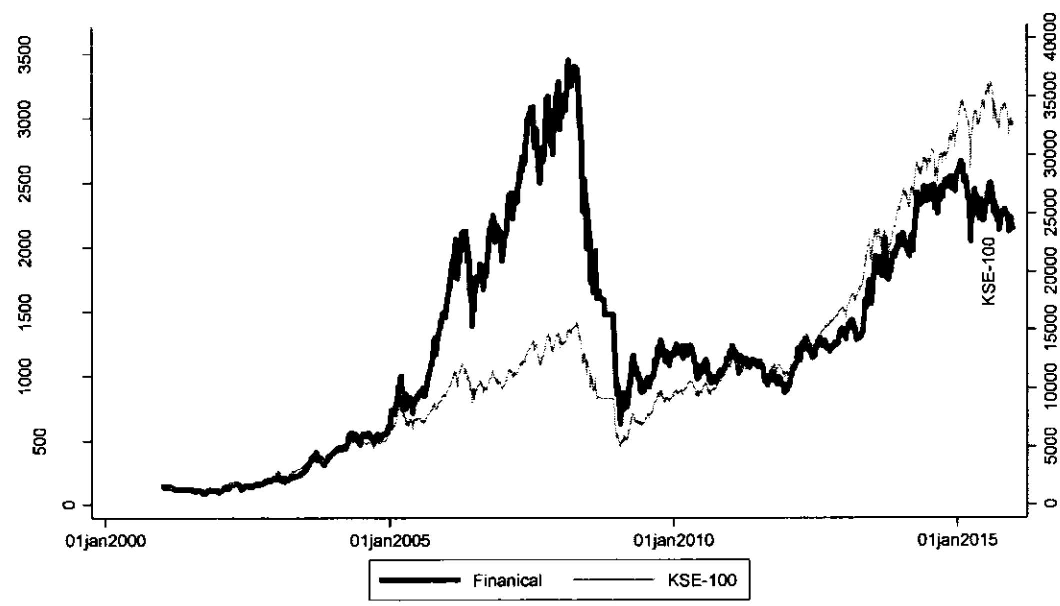

Figure 5-5: Financial Sector Index and KSE-100 Index

Finally, Figure 5.5 exhibits the index price of Financial Sector and Pakistan stock market index i.e. KSE-100 index. From the figure, the sample period can be divided into four segments. In first segment starting from January 2001and ending with the end of the year 2004, both indices closely follow each other. From the start of the year 2005 to the end of the year 2007, Financial sector has performed exceptionally well as compared to bench mark index. In third segment of sample (from beginning of 2008 to mid of the year 2014) both indices closely follow each other in the same direction and in the last segment of the sample, the share of Financial sector in market capitalization declines very sharply as compared to decline in overall market capitalization. Overall, performance of sectoral indices is quite different as compared to bench mark index of PSX.

As already stated this chapter empirically examines the impact of outliers on the estimates of return and volatility and their spillover between these selected sectors. For the detection and correction of outliers from sectoral stock returns, recently proposed method of Charles and Darné (2005) and Laurent et al. (2016) have been employed. The distributional and time series properties of outliers contaminated and outliers adjusted returns have been reported in Table 5.1 and Table 5.2 where returns are adjusted for outliers using Laurent et al. (2016). The results of Charles and Darné (2005) method have been reported in Appendix 2.

Table 5-1: Distributional Properties of Unadjusted and Adjusted Returns

Sector	Return	Mean	SD	Skewness	Kurtosis	JB-statistics
Basic	Unadjusted	0.060	1.59	0.09*	6.64*	7186.13*
Material	Adjusted	0.072	1.49	-0.04	2.44*	971.94*
Oil and	Unadjusted	0.039	1.74	-0.50*	8.30*	11401.67*
Gas	Adjusted	0.054	1.62	0.02	2.51*	1027.20*
Industry	Unadjusted	0.039	1.54	-0.71*	6.81*	7879.59*
	Adjusted	0.056	1.42	-0.26*	2.82*	1339.66*
Consumer	Unadjusted	0.091	1.31	0.13*	4.13*	2797.12*
Goods	Adjusted	0.087	1.25	0.04	2.15*	756.28*
Financial	Unadjusted	0.069	1.68	-0.16*	2.62*	1133.06*
	Adjusted	0.091	1.64	-0.03	2.43*	960.17*

Note: * shows significance at 5% level.

Average percentage returns of these sectoral stocks are positive for unadjusted and adjusted returns (see Table 5.1). It is observed that the average values of adjusted returns are greater than the unadjusted returns apart from Consumer Goods Sector. The adjusted average return of Consumer Goods sector marginally reduced to 0.087% from 0.091%. This might be due to the large positive outliers excluded from the returns of Consumer Goods sector. These results are in line with the results presented in Chapter 4. The average percentage return of unadjusted returns ranges from 0.039 to 0.091, whereas, the averages values of adjusted returns varies from 0.054 to 0.091 respectively. There is a visible difference between the average percentage return of unadjusted and adjusted returns of same sector. For example, the average value of return increased to 0.091 from 0.069 of Financial sector when outliers have been adjusted. similarly, for of Industry sector average value increased to 0.056 from 0.039. Unconditional volatility (risk) which has been proxied by standard deviation (SD) of returns. The values of SD are less for adjusted returns as compared to the unadjusted returns. Unadjusted (adjusted) returns, standard deviation ranges from 1.31 (1.25) to 1.74 (1.64) for Consumer Goods sector (Consumer Goods sector) and Financial sector (Oil and Gas sector) respectively. The sectoral stocks unadjusted returns are negatively skewed except Basic Material sector and Consumer Goods sector. The returns of Basic

Material and Consumer Goods sector are positively skewed. When returns are adjusted for outliers, the returns of these sectors are no more skewed except Industry sector. The returns of Industry sector are still negatively skewed but the coefficient value of skewness is considerably less than that of for unadjusted returns. These findings confirm the findings of Charles and Darné (2005) and Carnero et al. (2001). They pointed out the significance of skewness may be due to the outliers in the data. The JB test reject the null hypothesis of normality for both unadjusted and adjusted returns. The value of test statistics substantially drops for outliers adjusted returns. Adjusted returns are somehow near to normality than the unadjusted returns. The Ljung-Box Q-statistics is applied to examine the autocorrelation structure in the sectoral stock returns. The values of Q-statistics are greater than the critical value and test concludes that all the sectoral returns (adjusted and unadjusted) are auto-correlated. The rejection of null of no autocorrelation provide an evidence against the market efficiency. In an efficient market, current returns have no information about the future (Chan et al., 1997). All the sector returns are found to be leptokurtic i.e. fat tail therefore, the returns are examined for possible conditional heteroscedasticity (ARCH) effect. To formally test the ARCH effect, this study made use of LM-ARCH Test of Engle (1987). This test strongly rejects the null of homoscedasticity of unadjusted and adjusted returns. The Augmented Dicky Fuller (ADF) test confirms the stationarity of sectoral stock returns (unadjusted and adjusted). The data with such characteristics, GARCH family models are more suitable for analysis.

Table 5-2: Time Series Properties of Unadjusted and Adjusted Returns

Sector	Return	Q-Stat	LM-ARCH	ADF Test
Basic Material	Unadjusted	42.82*	101.08*	-25.69*
	Adjusted	44.35*	135.90*	-25.94*
Oil and Gas	Unadjusted	55.88*	44.81*	-22.78*
	Adjusted	33.24*	224.67*	-23.52*
Industry	Unadjusted	79.73*	131.63*	-25.05*
	Adjusted	58.40*	182.27*	-26.49*
Consumer	Unadjusted	68.97*	83.53*	-23.91*
	Adjusted	69.21*	86.55*	-23.90*
Financial	Unadjusted	129.12*	118.04*	-24.35*
	Adjusted	129.86*	154.29*	-24.66*

Note: * shows significance at 5% level.

Unconditional correlation between the sectoral stock returns and market returns are presented in Table 5.3. Unconditional correlation gives us an idea about the nature and strength of the association. The correlation between market returns and sectoral returns vary from 0.56 (0.61) to 0.83 (0.86) for adjusted (unadjusted) returns. Market returns have highest unconditional correlation with Financial sector 0.83 (0.86) followed by Oil and Gas sector 0.83 (0.85). Consumer Goods Sector has lowest correlation with market returns. The unconditional correlation between sectoral unadjusted (adjusted) returns varies from 0.32 (0.29) to 0.71 (0.68), respectively, for Consumer Goods (Basic Material) Sector and Industry (Financial) sector.

Table 5-3: Unconditional Correlation Between Sector Returns

		KSE-100	Basic Material	Oil and Gas	Industry	Consumer Goods
Basic Material	Unadjusted	0.82*	1.00			
	Adjusted	0.78*				
Oil and Gas	Unadjusted	0.85*	0.65*	1.00		
	Adjusted	0.83*	0.62*			
Industry	Unadjusted	0.61*	0.54*	0.48*	1.00	
	Adjusted	0.59*	0.51*	0.45*		
Consumer Goods	Unadjusted	0.61*	0.56*	0.47*	0.32*	1.00
	Adjusted	0.56*	0.51*	0.45*	0.29*	
Financial	Unadjusted	0.86*	0.71*	0.67*	0.54*	0.53*
	Adjusted	0.83*	0.68*	0.66*	0.54*	0.50*

Note: *shows the significance at 5% level.

Overall, from the above discussion, it may be inferred that presence of outliers in the sectoral stock returns has significant effect on the statistical as well as time series properties of the returns. When series is corrected for outliers, the average percentage return increases for all sectors except Consumer Goods sector whereas, SD, kurtosis, and JB reduced in all sector. However, skewness become insignificant for adjusted returns. The presence of outliers overestimates the unconditional correlation between sectoral stock returns.

5.3 Results and Discussion

The return and volatility equations were estimated jointly by BFGH algorithm with robust standard errors of Bollerslev and Wooldridge (1992). In this section, the results of VAR (1)-AGARCH (1,1) for unadjusted and adjusted returns of sectoral stock have been discussed when returns are adjusted for outliers using Laurent et al. (2016). The maximum likelihood estimates of bivariate VAR (1)-AGARCH (1,1) for unadjusted and adjusted returns are given in Table 5.4 to 5.13. The estimates of VAR(1)-AGRACH(1,1) when returns are adjusted using Charles and Darné (2005) method have been reported in Appendix 2.

5.3.1 Basic Material- Oil and Gas Sectors Pair

Table 5-4: VAR (1)-AGARCH (1,1) Estimates for Basic Material, and Oil and Gas Sectors

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Oil and Gas	Basic Material	Oil and Gas
Panel A: Mean Equation				
$C_{1,0}$	0.058(0.002)*		0.081(0.000)*	
$\Phi_{1,1}$	0.074(0.001)*		0.087(0.000)*	
$\Phi_{1,2}$	-0.006(0.726)		-0.029(0.18)	
$C_{2,0}$		0.035(0.061)		0.05(0.003)*
$\Phi_{2,2}$		0.043(0.042)*		0.015(0.507)
$\Phi_{2,1}$		0.014(0.510)		0.027(0.228)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.122(0.000)*		0.088(0.000)*	
$\alpha_{1,1}$	0.141(0.000)*		0.147(0.000)*	
$\alpha_{1,2}$	0.002(0.949)		-0.048(0.013)*	
$\beta_{1,1}$	0.667(0.000)*		0.658(0.000)*	
$\beta_{1,2}$	0.183(0.018)*		0.256(0.004)*	
d_1	0.036(0.248)		0.056(0.014)*	
$\alpha_{2,0}$		0.108(0.058)		0.045(0.114)
$\alpha_{2,2}$		0.179(0.000)*		0.174(0.000)*
$\alpha_{2,1}$		-0.062(0.068)		-0.065(0.004)*
$\beta_{2,2}$		0.671(0.000)*		0.704(0.000)*
$\beta_{2,1}$		0.261(0.042)*		0.258(0.016)
d_2		0.007(0.800)		0.019(0.386)
Panel C: Residuals Diagnostic				
Q-Stat	5.863(0.32)	10.794(0.056)	6.170(0.290)	5.646(0.342)
ARCH Test	1.239(0.288)	1.121(0.347)	0.651(0.661)	0.824(0.532)
LLH	-12929		-12533	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Oil and Gas sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Bivariate VAR-AGARCH model results have been reported in Table 5.4 for Basic Material and Oil and Gas pair for adjusted and unadjusted returns. For unadjusted returns, the empirical findings regarding the conditional mean of both sectors suggest that lagged return significantly affect the current return of these sectors. The own return spillovers effect ($\Phi_{1,1}$) in Basic Material sector is 0.074 similarly, in Oil and Gas the own lagged return spillover ($\Phi_{2,2}$) is 0.043 which is significant at the 5% level. However, no return spillover exists between these two sectors of PSX. On the other hand, for adjusted returns, the coefficients associated with its own lagged return is statistically significant only for Basic Material sector and its value is marginally greater than that of unadjusted returns. The autoregressive coefficient in Oil and Gas conditional mean equation become insignificant for adjusted returns. However, no return spillovers between these sectors is observed for adjusted returns as well. This leads to the conclusion that in the short run price movements in both sectors is independent of each other.

The estimates of conditional volatility of these sectors of Pakistan Stock Exchange have been given in Panel B. For unadjusted returns, result reveals that $\alpha_{i,i}$ and $\beta_{i,i}$ are significant at 1% percent level. In Basic Material conditional variance of Basic Material, its own past shock ($\alpha_{1,1,}$) and its own past volatility $(\beta_{1,1})$ effects are about 0.141 and 0.667, respectively. Similarly, in Oil and Gas sector, past shock and past volatility effect is 0.179 and 0.671 in the contemporaneous volatility. It has been observed that both sectors are jumpy because the ARCH effect is greater than 10% (Alexander, 2008)[7]. In volatility equations of both sectors, the coefficient of asymmetry (d_i) is insignificant. These findings suggest that unexpected negative and positive shock in each sector have identical effect on the volatility of respective sector. On the other hand, for adjusted returns, both ARCH, and GARCH coefficients are significant at the 1% level in both sectors. The results for Basic Material sector show that the value of ARCH coefficient is slightly underestimated and GARCH is marginally overestimated by the model, due to the presence of outliers. However, the ARCH is overestimated and GARCH is underestimated (4.9%) by the model due to the outliers in conditional variance of Oil and Gas sector. The leverage effect ($d_1 = 0.056$) becomes significant

[7] Alexander, C. 2008 page 283.

(5%) in the volatility of Basic Material sector. This shows that model failed to capture asymmetry due to the presence of outliers in Oil and Gas sector.

Results for unadjusted returns depict no shock but bidirectional volatility spillovers between these two sectors as the coefficient $\beta_{1,2}$and $\beta_{2,1}$ are significant at the 5% level. The Basic Material sector export volatility (0.261) to the Oil and Gas sector and Oil and Gas sector export volatility (0.183) to the Basic Material sector. When adjusted returns are used to estimate the model, the results brought forward the fact that the presence of outliers disables the model to detect reciprocal shock spillover between these sectors. Unexpected shock in Basic Material (Oil and Gas) spillover to Oil and Gas (Basic Material) about 0.065 (0.048). However, the coefficient of volatility spillovers from Basic Material sector to Oil and Gas sector remains the same for adjusted returns. However, the presence of outliers undervalued (39.9%) the volatility spillovers from Oil and Gas sector to Basic Material sector. The value of coefficient increased from 0.183 to 0.256 when returns are adjusted for outliers.

5.3.2 Basic Material- Industry Sectors Pair

Table 5-5: VAR (1)-AGARCH (1,1) Estimates for Basic Material, and Industry Sectors

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Industry	Basic Material	Industry
Panel A: Mean Equation				
$C_{1,0}$	0.061(0.001)*		0.073(0.000)*	
$\Phi_{1,1}$	0.048(0.032)*		0.053(0.004)*	
$\Phi_{1,2}$	0.039(0.054)		0.029(0.106)	
$C_{2,0}$		0.050(0.020)*		0.054(0.001)
$\Phi_{2,2}$		0.071(0.007)*		0.048(0.029)
$\Phi_{2,1}$		0.034(0.167)		0.057(0.001)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.076(0.024)*		0.060(0.001)*	
$\alpha_{1,1}$	0.158(0.000)*		0.143(0.000)*	
$\alpha_{1,2}$	-0.048(0.014)*		-0.063(0.000)*	
$\beta_{1,1}$	0.754(0.000)*		0.797(0.000)*	
$\beta_{1,2}$	0.138(0.240)		0.096(0.097)	
d_1	0.043(0.101)		0.047(0.013)*	
$\alpha_{2,0}$		0.220(0.000)*		0.067(0.005)*
$\alpha_{2,2}$		0.178(0.000)*		0.148(0.000)*
$\alpha_{2,1}$		-0.074(0.003)*		-0.038(0.049)*
$\beta_{2,2}$		0.584(0.000)*		0.76(0.000)*
$\beta_{2,1}$		0.308(0.005)*		0.133(0.005)*
d_2		0.043(0.090)		0.027(0.194)
Panel C: Residuals Diagnostic				
Q-Stat	5.457(0.363)	9.794(0.081)	5.759(0.33)	8.566(0.128)
ARCH Test	0.95(0.448)	0.55(0.738)	1.196(0.309)	0.870(0.500)
LLH	-13000		-12433	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The results for Basic Material and Industry pair have been displayed in Table 5.5. From Panel A, results of conditional mean for unadjusted returns indicate that coefficients $\Phi_{1,1}$ and $\Phi_{2,2}$ are statistically significant and $\Phi_{1,2}$, and $\Phi_{1,2}$ are insignificant. The significance and insignificance of these coefficients confirm that both sectoral returns are significantly affected by their past returns and no return spillovers exist between these two sectors in either way. The future returns of Basic Material sector are affected by (0.048) their current returns and current return of Industry sector affect (0.071) the future returns of Industry sector. While, results for adjusted returns show that the coefficient $\Phi_{2,1}$become statistically significant; which is insignificant for unadjusted returns. This presents that due to outliers, model fails to capture return spillovers from Basic Material sector to Industry sector. Similarly, own return spillover of Industry sector is overvalued by approximately 32.4%. These results confirm that both sectors return effected by their past about 0.053 and 0.482 for adjusted returns as well. The significance of $\Phi_{2,1}$indicate significant returns spillovers (0.057) from the Basic Material to the Industry sector which is insignificant for unadjusted returns.

From Panel B, the results for unadjusted returns show that ARCH and GARCH coefficients are statistically significant in both sectors volatilities. In Basic Material, the contribution of own past squared shock and own past volatility in current volatility is about 0.158 and 0.754, respectively. Similarly, estimated coefficients of ARCH and GARCH effects are 0.178 and 0.584, respectively in the volatility of Industry sector. The leverage effect coefficient is insignificant in both sectors. When returns of both sectors are cleaned for outliers, the volatility parameter estimates of both sectors change particularly for Industry sector. The estimate ARCH parameter reduced to 0.143 form 0.158 and GARCH parameter estimate increased to 0.797 from 0.754 for adjusted returns of Basic Material sector. On the other hand, for Industry sector, the past squared shock effect is overestimated (16.8%) by the model and its value reduced to 0.148 from 0.178. Similarly, the GARCH effect increased (by 30.1%) to 0.760 from 0.584 when returns are adjusted for outliers of both sectors. The coefficient of asymmetry ($d_1 = 0.047$) become statistically significant of Basic Material sector for adjusted returns.

Turning to shock and volatility spillovers, the results show that for unadjusted returns, inverse reciprocal shock spillovers are significant between these two sectors of Pakistan Stock Exchange. Moreover, the unidirectional volatility spillovers from Basic Material to Industry sector is found significant. The shock spillovers from Basic Material (Industry) to Industry (Basic Material) is 0.048 (0.075) and volatility spillovers from Basic Material to Industry sector is about 0.308. This shows that volatility of Industry sector is sensitive to the volatility of Basic Material sector. The inverse shock spillover is bidirectional between these two sectors and only volatility spillovers from Basic Material to Industry is significant for adjusted returns as well. The shock spillover from Basic Material to Industry reduced (by 48%) to 0.039 from 0.075 and from Industry to Basic Material amplified (by 23.8%) to 0.063 from 0.048. Apart from this, model over valued the volatility spillover from Basic Material to Industry sector. The volatility spillover from Basic Material to Industry reduced (by 69.1%) to 0.133 from 0.430 when outliers are aligned in returns.

5.3.3 Basic Material- Consumer Goods Sectors Pair

Table 5-6: VAR (1)-AGARCH (1,1) Estimates for Basic Material, and Consumer Goods Sectors

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Cosumer Goods	Basic Material	Cosumer Goods
Panel A: Mean Equation				
$C_{1.0}$	0.045(0.032)*		0.056(0.002)*	
$\Phi_{1,1}$	0.076(0.000)*		0.083(0.000)*	
$\Phi_{1,2}$	-0.002(0.942)		0.009(0.655)	
$C_{2.0}$		0.047(0.006)*		0.044(0.012)*
$\Phi_{2,2}$		0.097(0.000)*		0.099(0.000)*
$\Phi_{2,1}$		0.015(0.386)		0.031(0.053)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.109(0.002)*		0.046(0.029)*	
$\alpha_{1,1}$	0.139(0.000)*		0.149(0.000)*	
$\alpha_{1,2}$	-0.03(0.285)		-0.081(0.002)*	
$\beta_{1,1}$	0.690(0.000)*		0.679(0.000)*	
$\beta_{1,2}$	0.257(0.013)*		0.371(0.000)*	
d_1	0.069(0.009)*		0.094(0.000)*	
$\alpha_{2,0}$		-0.002(0.614)		0.001(0.687)
$\alpha_{2,2}$		0.118(0.000)*		0.119(0.000)*
$\alpha_{2,1}$		-0.026(0.001)*		-0.032(0.000)*
$\beta_{2,2}$		0.845(0.000)*		0.864(0.000)*
$\beta_{2,1}$		0.119(0.007)*		0.089(0.034)*
d_2		-0.006(0.795)		-0.008(0.57)
Panel C: Residuals Diagnostic				
Q-Stat	5.418(0.367)	8.035(0.154)	4.559(0.472)	8.422(0.134)
ARCH Test	0.822(0.533)	0.814(0.54)	0.53(0.754)	1.72(0.126)
LLH	-12417		-12068	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of VAR (1)-GARCH (1,1) model for Basic Material and Consumer Goods pair are presented in Table 5.6. For unadjusted returns, first conditional moment results reveal that both sector returns are dependents upon their own past returns. The coefficients associated with own lagged variable of Basic Material and Consumer Goods are $\Phi_{1,1}$=0.076 and $\Phi_{2,2}$=0.097 respectively and they are statistically significant at 1% level. This shows that past return account for 0.076% and 0.097% to current return of Basic Material and consumer good sectors. Apart from this, the results of the model do not support return spillovers between these two sectors of Pakistan Stock Exchange because coefficients $\Phi_{1,2}$and $\Phi_{2,1}$are insignificant. For adjusted returns, first conditional moment dynamics are nearly identical to those for unadjusted returns. The empirical finding confirms no return transmission between these two sectors for adjusted returns as well. In this pair of sectors, the correction of outliers does not have any impact on the conditional mean estimates.

In conditional variance of both sectors unadjusted returns, own ARCH and GARCH parameter estimates are significant at 1% level. Own past shocks and past conditional variance spillovers to current conditional variance are 0.139 and 0.690 in Basic Material sector. Similarly, these spillovers are 0.118 and 0.845 in Consumer Goods sector. The significant coefficient of asymmetry (d_1) depicts that negative shocks will increase volatility of Basic Material (0.069) more than positive shocks of same intensity. However, results of the model for outliers adjusted returns indicate that ARCH and GARCH coefficients are significant at 1% level. The parameter estimates of past squared shocks and past volatility are very close to those for unadjusted returns. Contrary to this, the leverage effect is underestimated by the model due to outliers. The leverage effect (d_1) increased (36.2%) to 0.094 from 0.069 when outliers are corrected by using the procedure discussed in Section 3.2.

Regarding shock and volatility transmission between these two sectors of Pakistan Stock Exchange, there exists significant shocks ($\alpha_{2,1}$) spillovers from Basic Material to Consumer Goods and bidirectional volatility $(\beta_{2,1}, \beta_{1,2})$ spillovers between Basic Material and Consumer Goods. The Basic Material sector past shocks spillover (0.026) and past volatility spillovers (0.118) to the volatility of Consumer Goods sector. Similarly, Consumer Goods sector past volatility affects (0.257) the volatility of Basic Material sector. When returns are cleaned for outliers, the result shows that model is unable to capture the shock spillover effect from Consumer Goods sector to Basic Material. The values of these coefficients are underestimated (overestimated) by the model due to the outliers. The shock spillovers from Consumer Goods (-0.081) is insignificant for unadjusted returns and volatility spillovers increased (by 44.3%) from 0.257 to 0.371. Similarly, shocks spillovers from Basic Material sector to Consumer Goods increased (absolute) to 0.032 from 0.026 and volatility spillovers reduced to 0.089 from 0.119.

5.3.4 Basic Material- Financial Sectors Pair

Table: 5-7 VAR (1)-AGARCH (1,1) Estimates for Basic Material and Financial Sectors

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Finanical	Basic Material	Finanical
Panel A: Mean Equation				
$C_{1.0}$	0.054(0.002)*		0.060(0.004)*	
$\Phi_{1,1}$	0.064(0.006)*		0.081(0.000)*	
$\Phi_{1,2}$	0.015(0.406)		0.001(0.955)	
$C_{2,0}$		0.056(0.016)*		0.057(0.001)*
$\Phi_{2,2}$		0.118(0.000)*		0.113(0.000)*
$\Phi_{2,1}$		0.031(0.215)		0.046(0.039)*
Panel B: Variance Equation				
$\alpha_{1.0}$	0.115(0.000)*		0.128(0.000)*	
$\alpha_{1,1}$	0.151(0.000)*		0.164(0.000)*	
$\alpha_{1,2}$	-0.033(0.120)		-0.087(0.000)*	
$\beta_{1,1}$	0.698(0.000)*		0.486(0.000)*	
$\beta_{1,2}$	0.161(0.080)		0.477(0.012)*	
d_1	0.023(0.459)		0.043(0.054)	
$\alpha_{2,0}$		0.190(0.007)*		-0.038(0.033)*
$\alpha_{2,2}$		0.122(0.000)*		0.192(0.000)*
$\alpha_{2,1}$		-0.031(0.255)		-0.116(0.000)*
$\beta_{2,2}$		0.750(0.000)*		0.449(0.018)*
$\beta_{2,1}$		0.078(0.387)		0.791(0.020)*
d_2		0.042(0.093)		0.0650(0.008)*
Panel C: Residuals Diagnostic				
Q-Stat	4.784(0.443)	4.50(0.480)	5.687(0.338)	4.013(0.548)
ARCH Test	2.178(0.054)	0.611(0.692)	2.088(0.640)	1.647(0.144)
LLH	-12802		-12496	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The VAR-AGARCH model results for Basic Material -Financial sectors pair are presented in Table 5.7 of unadjusted and adjusted returns. The conditional mean estimates for unadjusted returns of both sectors returns shows that in the short run Basic Material and Industry sectors price is predictable from their previous price by 0.064% and 0.118%, respectively. There is no return spillover between these two sectors of Pakistan Stock Exchange. For adjusted returns, only coefficient $\Phi_{1,1}$ has marginally increased (0.64 to 0.074) as compared to its value for unadjusted returns. There is no price transmission between these two sectors of PSX for adjusted returns as well.

The estimates of conditional variance of the Basic Material /Financial sectors have been reported in Panel B of Table 5.7. Both ARCH and GARCH coefficients are significant in the volatility of both sectors. The ARCH ($\alpha_{1,1}$) and GARCH ($\beta_{1,1}$) coefficients are 0.151 and 0.98 for Basic Material sector and these coefficients are $\alpha_{2,2}$= 0.122 and $\beta_{2,2}$ = 0.750 for Financial sector respectively. For adjusted returns, the significant of these remain the same but the asymmetric effect (d_2)in Financial sector become significant which is insignificant for unadjusted returns. The values of some of these coefficients are significant different from those for unadjusted returns. For example, the coefficient value of GARCH effect is 0.673 in Financial sector volatility which is 89% the coefficient value for unadjusted returns. Similarly, in Basic Material sector due to correction of outliers ARCH nearly same but GARCH coefficient reduced by 8%.

About, volatility transmission between these two sectors, the results reveal that no significant shock and volatility transmission between these two sectors for unadjusted returns. the empirical findings regarding adjusted returns, there exist reciprocal shock and volatility transmission between these two sectors and coefficient are significant. This shows that presence of outliers in the data hide the transmission of volatility between Basic Material and Financial sectors. The negative shock transmission for Basic Material (Financial) to Financial (Basic Material) is 0.086 (0.069). Similarly, the 1 increase in the volatility of Basic Material (Financial) sector likely to increase the volatility of Financial (Basic Material) sector volatility about 0.303 (0.297).

5.3.5 Oil and Gas- Industry Sectors Pair

Table 5-8: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas, and Industry Sectors

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Industry	Oil and Gas	Industry
Panel A: Mean Equation				
$C_{1,0}$	0.028(0.178)		0.033(0.079)	
$\Phi_{1,1}$	0.031(0.190)		0.027(0.099)	
$\Phi_{1,2}$	0.040(0.055)		0.043(0.013)*	
$C_{2,0}$		0.047(0.014)*		0.054(0.001)*
$\Phi_{2,2}$		0.083(0.000)*		0.073(0.000)*
$\Phi_{2,1}$		0.009(0.633)		0.007(0.549)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.067(0.157)		0.05(0.055)	
$\alpha_{1,1}$	0.143(0.000)*		0.156(0.000)*	
$\alpha_{1,2}$	-0.069(0.003)*		-0.060(0.003)	
$\beta_{1,1}$	0.759(0.000)*		0.783(0.000)*	
$\beta_{1,2}$	0.211(0.098)		0.148(0.080)	
d_1	0.055(0.090)		0.041(0.056)	
$\alpha_{2,0}$		0.232(0.000)*		0.07(0.005)*
$\alpha_{2,2}$		0.164(0.000)*		0.14(0.000)*
$\alpha_{2,1}$		-0.028(0.189)		-0.031(0.096)
$\beta_{2,2}$		0.579(0.000)*		0.771(0.000)*
$\beta_{2,1}$		0.290(0.022)*		0.109(0.037)*
d_2		0.047(0.130)		0.038(0.103)
Panel C: Residuals Diagnostic				
Q-Stat	14.973(0.01)	8.717(0.121)	9.513(0.09)	7.317(0.198)
ARCH Test	0.986(0.425)	0.812(0.541)	2.167(0.055)	1.404(0.219)
LLH	-10975		-12274.99	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimated VAR-AGARCH model results for Oil and Gas/Industry pair have been exhibited in Table 5.8. In the conditional mean of both sectors unadjusted returns, only own lagged variable of Industry sector returns is significant, and its coefficient value is

0.083. No returns spillover is found between these sectors in either direction. On the other hand, for adjusted returns, again the lagged return effect is significant only for Industry sector and its value reduced to 0.073. Looking at the return transmission between these sectors, it is observed that return spillovers (0.043) from Oil and Gas sector become significant to Industry sector for adjusted returns. Likewise, model unable to capture the return spillovers from Oil and Gas sector to Industry sector due to outliers.

The Panel B of Table 5.8 for unadjusted returns model results show that the coefficient associated with own past squared shock and own past volatility in both sector conditional volatilities are statistically significant. The contribution of past squared shock and past volatility is about 0.143 and 0.759 in current volatility of Oil and Gas sector. Alike, past shock and past volatility of Industry sector contributed about 0.164 and 0.579 to its current volatility. The empirical findings show that parameter estimates of past shock is undervalued (overvalued) by the model due to outliers in volatility of Oil and Gas (Industry) sector. The effect of past shock gained from 0.143 to 0.156 and come down to 0.141 from 0.164 in Oil and Gas sector and Industry sector respectively when returns are cleaned for outliers. Similarly, the GARCH effect is underestimated in both sectors conditional variance due to outliers. The GARCH effect has increased from 0.759 to 0.783 in Oil and Gas sector for adjusted returns. And the past volatility coefficient increased (33.2%) to 0.771 from 0.579 for adjusted returns. The leverage effect remains insignificant in case of adjusted returns as well.

The results about shocks and volatility spillovers, shock spillovers from Industry to Oil and Gas sector and volatility spillovers from Oil and Gas sector to Industry sector is found significant. Due to unexpected shocks in Industry Oil and Gas sector returns become less volatility approximately by 0.068 and the transfer of risk is about 0.29

from Oil and Gas to Industry sector. These coefficients of shocks and volatility transmission are still significant for adjusted returns. The coefficient of shock spillovers from Industry to Oil and Gas reduced to -0.060 but volatility spillovers from Oil and Gas to Industry reduced to 0.109 which just 37.6% of the spillovers that observed for unadjusted returns.

5.3.6 Oil and Gas- Consumer Goods Sectors Pair

Table 5-9: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas, and Consumer Goods Sectors

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Consumer Goods	Oil and Gas	Consumer Goo
Panel A: Mean Equation				
$C_{1,0}$	0.022(0.295)		0.034(0.095)	
$\Phi_{1,1}$	0.057(0.009)*		0.048(0.031)*	
$\Phi_{1,2}$	-0.002(0.915)		0.000(0.986)	
$C_{2,0}$		0.037(0.024)*		0.057(0.001)*
$\Phi_{2,2}$		0.129(0.000)*		0.124(0.000)*
$\Phi_{2,1}$		-0.019(0.245)		-0.011(0.537)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.113(0.017)		0.045(0.097)	
$\alpha_{1,1}$	0.118(0.000)*		0.124(0.000)*	
$\alpha_{1,2}$	0.025(0.537)		-0.041(0.082)	
$\beta_{1,1}$	0.81(0.000)*		0.810(0.000)*	
$\beta_{1,2}$	0.034(0.717)		0.123(0.119)	
d_1	0.029(0.302)		0.055(0.007)*	
$\alpha_{2,0}$		0.001(0.552)		0.015(0.154)
$\alpha_{2,2}$		0.115(0.000)*		0.088(0.000)*
$\alpha_{2,1}$		-0.006(0.449)		-0.011(0.257)
$\beta_{2,2}$		0.879(0.000)*		0.911(0.000)*
$\beta_{2,1}$		0.042(0.153)		0.000(0.993)
d_2		-0.001(0.972)		-0.002(0.861)
Panel C: Residuals Diagnostic				
Q-Stat	10.105(0.072)	10.712(0.057)	9.719(0.084)	4.082(0.538)
ARCH Test	1.162(0.326)	0.63(0.677)	2.319(0.041)	1.771(0.115)
LLH	-13201		-12752	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

From Table 5.9, the first conditional moment results of Oil and Gas/Consumer Goods sector show that $\Phi_{1,1}$ =0.057, and $\Phi_{2,2}$=0.129 coefficients are highly significant. The significance of these coefficients points out that the short-run price of sectoral indices of these sectors are forecastable from their respective earlier price. And $\Phi_{1,2}$ and $\Phi_{2,1}$ are insignificant, which reveals that there is no short-run price relationship between sectors. The dynamics of conditional mean of both sectors are approximately same for adjusted returns but coefficients values are slightly less. The coefficient of lagged returns of Oil and Gas reduced to 0.048 and Consumer Goods reduced to 0.124 respectively of adjusted returns.

From Panel B of table above, it is observed that own past squared shocks ($\alpha_{1,1}$ and $\alpha_{2,2}$) and own past volatility ($\beta_{1,1}$and $\beta_{2,2}$) are highly significant in both sector of unadjusted. The Oil and Gas sector volatility is affected by own shock ($\alpha_{1,1}$=0.118) and by past volatility ($\beta_{1,1}$=0.810). On the other hand, past innovations and past volatility of Consumer Goods sector likely to affect its volatility by 0.115 and 0.879. Taking a close look at these coefficients it is observed that past shock effect increased to 0.124 and past volatility effect remain identical for adjusted returns of Oil and Gas sector. Whereas, for adjusted returns, the past shock effect reduced (by 23.5%) to 0.088 and past volatility increased to 0.911 in volatility of Consumer Goods sector. Model did not detect the leverage effect in the Oil and Gas sector due to presence of outliers. The leverage effect (0.055) becomes significant when outliers are cleaned from returns of Oil and Gas sector.

The coefficients of shock and volatility spillovers between these two sectors are statistically insignificant for unadjusted returns and adjusted returns as well.

5.3.7 Oil and Gas- Financial Sectors Pair

Table 5-10: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas, and Financial Sectors

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Finanical	Oil and Gas	Finanical
Panel A: Mean Equation				
$C_{1,0}$	0.040(0.020)*		0.049(0.003)*	
$\Phi_{1,1}$	0.048(0.015)*		0.039(0.100)*	
$\Phi_{1,2}$	0.012(0.595)		0.003(0.886)	
$C_{2,0}$		0.063(0.001)*		0.079(0.000)*
$\Phi_{2,2}$		0.152(0.000)*		0.148(0.000)*
$\Phi_{2,1}$		-0.024(0.245)		-0.026(0.252)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.114(0.019)		0.050(0.015)*	
$\alpha_{1,1}$	0.119(0.000)*		0.136(0.000)*	
$\alpha_{1,2}$	0.015(0.628)		-0.023(0.245)	
$\beta_{1,1}$	0.768(0.000)*		0.753(0.000)*	
$\beta_{1,2}$	0.103(0.452)		0.164(0.060)	
d_1	-0.004(0.880)		0.012(0.563)	
$\alpha_{2,0}$		0.229(0.004)*		0.092(0.000)*
$\alpha_{2,2}$		0.097(0.000)*		0.127(0.000)*
$\alpha_{2,1}$		-0.005(0.835)		-0.037(0.083)
$\beta_{2,2}$		0.683(0.000)*		0.785(0.000)*
$\beta_{2,1}$		0.133(0.220)		0.074(0.454)
d_2		0.089(0.059)		0.061(0.021)*
Panel C: Residuals Diagnostic				
Q-Stat	10.233(0.070)	2.628(0.757)	10.37(0.065)	4.082(0.538)
ARCH Test	1.349(0.24)	1.125(0.345)	1.697(0.002)	1.533(0.176)
LLH	-10975		-12274.99	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

For the Oil and Gas/Financial sector pair, the results have been displayed in Table 5.10. The estimates of conditional mean of Oil and Gas, and Financial sectors shows that coefficients ($\Phi_{1,1}$ and $\Phi_{2,2}$) associate with own lagged returns are significant for unadjusted returns. This shows that the current returns of Oil and Gas sector, and Financial sector effected by own past returns about 0.049% and 0.152%, respectively. When returns are adjusted for outliers, the coefficient of lagged returns of Oil and Gas sector become insignificant and lagged coefficient of Financial sector marginally reduced. On the other hand, there is no return transmission between these two sectors of Pakistan Stock Exchange both for unadjusted and adjusted returns.

Panel B of Table 5.10 reveals that ARCH and GARCH coefficients are significant in both sectors unadjusted returns volatility. The estimated values of these coefficients of Oil and Gas are 0.119 and 0.768 and of Financial sector coefficient values are 0.097 and 0.683 respectively. There is no leverage effect is in both sectors volatilities. The ARCH and GARCH effects are also significant in the volatility of Oil and Gas and Financial sectors for adjusted returns and their estimated values are different to those for unadjusted returns. The ARCH effect in both sectors volatilities is overestimated and the GARCH effect is overestimated (underestimated) of Oil and Gas (Financial) sector volatility. The estimated values of both ARCH and GARCH in Oil and Gas sector volatility are 0.137 (from 0.119) and 0.753 (from 0.768) respectively when returns are adjusted for outliers. Similarly, in Financial sector volatility the estimates of ARCH and GARCH parameter are significantly different for adjusted returns. The ARCH (0.127) parameter is underestimated by 31% and GARCH (0.785) parameter is overestimated by 15%. The asymmetry coefficient (0.061) becomes significant in the volatility of Financial sector which is insignificant for unadjusted returns.

The coefficients of shock and volatility spillovers between these sectors are statistically insignificant for unadjusted and adjusted returns. This implies that neither short-run and nor long-run volatility linkages between Financial sector and Oil and Gas sector.

5.3.8 Industry-Consumer Goods Sectors Pair

Table 5-11: VAR (1)-AGARCH (1,1) Estimates for Industry, and Consumer Goods Sectors

	Unadjusted Returns		Adjusted Returns	
	Industry	Consumer Goods	Industry	Consumer Goods
Panel A: Mean Equation				
$C_{1.0}$	0.041(0.041)*		0.048(0.002)*	
$\Phi_{1,1}$	0.081(0.000)*		0.065(0.000)*	
$\Phi_{1,2}$	0.002(0.911)		0.024(0.147)	
$C_{2.0}$		0.044(0.009)*		0.050(0.029)*
$\Phi_{2,2}$		0.113(0.000)*		0.115(0.000)*
$\Phi_{2,1}$		0.000(0.991)		0.013(0.362)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.199(0.010)*		0.072(0.003)*	
$\alpha_{1,1}$	0.116(0.000)*		0.115(0.000)*	
$\alpha_{1,2}$	-0.018(0.579)*		0.012(0.518)	
$\beta_{1,1}$	0.702(0.000)*		0.805(0.000)*	
$\beta_{1,2}$	0.193(0.207)		0.049(0.513)	
d_1	0.089(0.003)*		0.057(0.005)*	
$\alpha_{2,0}$		0.000(0.876)		0.007(0.566)
$\alpha_{2,2}$		0.112(0.000)*		0.092(0.000)*
$\alpha_{2,1}$		-0.015(0.014)*		-0.012(0.216)
$\beta_{2,2}$		0.871(0.000)*		0.911(0.000)*
$\beta_{2,1}$		0.083(0.020)*		-0.001(0.990)
d_2		0.010(0.641)		0.006(0.672)
Panel C: Residuals Diagnostic				
Q-Stat	10.233(0.069)	11.517(0.042)	7.861(0.164)	10.681(0.058)
ARCH	1.533(0.176)	0.967(0.436)	2.924(0.012)	2.399(0.035)
LLH	-12715		-12162	

Note: 1 symbolizes Industry sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The estimates of conditional mean and conditional variance of Industry and Consumer Goods pair are reported in Table 5.11. Panel A shows that the conditional mean of unadjusted returns is a function of own past returns of both Industry and Consumer Goods sectors. The future returns of these sectors can be forecasted from their present returns approximately by 0.081% and 0.113% respectively. There is no significant return spillover between these sectors. However, when returns are cleaned for outliers, the predictability in Industry sector reduced (19%) to 0.065 and predictability in

Consumer Goods sector approximately remains the same (0.115). Again, return spillovers between these two sectors for adjusted returns as well.

From Panel B, the conditional volatilities of both sectors are sensitive to their own unexpected returns (shocks) and past volatilities. The result of unadjusted returns shows that, the volatility of Industry sector is sensitive to its innovation (0.116) and past volatility (0.702). Similarly, the current volatility of Consumer Goods sector index sensitive to own innovation (0.112) and past volatility (0.0871). The results for adjusted returns reveal that volatility of both sectors remains sensitive to their own past innovations and volatility but values of these coefficients are different from those for unadjusted returns. The estimated values of GARCH coefficient increased by 14.7% but the ARCH effect remains nearly same for Industry sector. On the other hand, the ARCH effect reduced by 17.8% and GARCH effect increased by 5.6% in the volatility of Consumer Goods sectors. The coefficient of asymmetry is significant in the volatility of Industry sector index unadjusted and adjusted returns. When the returns are adjusted of outliers the asymmetry in the volatility reduced (by 36%) from 0.089 to 0.057.

The results of shock and volatility spillovers between these two sectors reveal unidirectional shock and volatility spillovers from Industry to Consumer Goods sector. The Industry sector shocks and volatility affect the volatility of Consumer Goods sector approximately 0.015 (negatively) and 0.83, respectively. When returns are adjusted for outliers, the empirical findings show that the model incorrectly suggests shocks and volatility spillovers from Industry sector to Consumer Goods sector.

5.3.9 Industry-Financial Sectors Pair

Table 5-12: VAR (1)-AGARCH (1,1) Estimates for Industry, and Financial Sectors

	Unadjusted Returns		Adjusted Returns	
	Industry	Financial	Industry	Financial
Panel A: Mean Equation				
$C_{1,0}$	0.048(0.036)*		0.054(0.001)*	
$\Phi_{1,1}$	0.066(0.004)*		0.053(0.005)*	
$\Phi_{1,2}$	0.041(0.030)*		0.039(0.011)*	
$C_{2,0}$		0.054(0.013)*		0.067(0.000)*
$\Phi_{2,2}$		0.120(0.000)*		0.133(0.000)*
$\Phi_{2,1}$		0.024(0.364)		0.016(0.443)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.226(0.002)*		0.069(0.015)	
$\alpha_{1,1}$	0.147(0.000)*		0.145(0.000)*	
$\alpha_{1,2}$	-0.004(0.907)		-0.008(0.607)	
$\beta_{1,1}$	0.484(0.000)*		0.747(0.000)*	
$\beta_{1,2}$	0.481(0.008)*		0.138(0.009)*	
d_1	0.025(0.490)		0.008(0.744)	
$\alpha_{2,0}$		0.147(0.046)*		0.067(0.029)*
$\alpha_{2,2}$		0.119(0.000)*		0.127(0.000)*
$\alpha_{2,1}$		-0.064(0.023)		-0.065(0.009)
$\beta_{2,2}$		0.733(0.000)*		0.801(0.000)*
$\beta_{2,1}$		0.170(0.268)		0.094(0.353)
d_2		0.098(0.018)*		0.083(0.002)*
Panel C: Residuals Diagnostic				
Q-Stat	9.265(0.099)	10.205(0.07)	8.012(0.156)	5.871(0.319)
ARCH Test	1.45(0.203)	0.254(0.938)	3.35(0.005)	1.633(0.148)
LLH	-13319		-12738	

Note: 1 symbolizes Industry sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5%

The VAR (1)-AGARCH (1,1) model estimated for Industry-Financial sector to unfold empirically returns and volatility and both return and spillovers effects with and without outliers. The results have been given in Table 5.12 of both conditional mean and conditional volatilities of both sectors. The results for unadjusted returns indicate that one period lagged returns of both sectors can be used to forecast future returns. 1% increase in own returns of these sectors likely to increase returns by 0.066% and 0.120%, respectively. The returns of Financial sector returns are seen to affect the returns of Industry (0.041) sector significantly. The results for adjusted returns reveal that lagged returns of both sector indices can predict their future value. The prediction from lagged return of both sectors is different for adjusted returns. The lagged return coefficient of Industry sector decreased to 0.053 and lagged return coefficient of Industry sector increased to 0.133 of adjusted returns. However, the return spillovers from Financial sector to Industry sector reduced to 0.011 from 0.030. There is no significant return spillover from Industry to Financial sector. The conditional volatility results have been presented in Panel B of Table 5.12. Both sectors volatilities are sensitive to their own past unexpected news and own past volatility. The volatility results of Industry sector indicate that the sensitively of current volatility to past news is about 0.147 and past volatility is about 0.484. Likewise, the volatility of Financial sector sensitivity to its own past news is about 0.119 and past volatility is about 0.733. From the empirical results it is also observed that negative and positive new in Financial sector have different effect on its volatility. Due to the negative news the Financial sector becomes 0.098 more volatile than a positive news of equal intensity. Contrary to conditional mean results, when outliers are adjusted for outliers the estimates of volatility parameters changed considerably of both sectors. The volatility estimates of Industry show that past shock coefficient approximately unchanged while past volatility increased to 0.748 when outliers adjusted returns are used to estimate model. This shows that GRACH coefficient is undervalued by the model approximately 54.5% due to presence of outliers. Apart from this, model undervalued both ARCH (6.7%) and GARCH (9.3%) coefficients in Financial sector volatility due to outliers. The ARCH and GARCH coefficient increased to 0.127 and 0.801, respectively. The leverage effect is also overestimated by the model due to outliers. The leverage effect coefficient reduced (by 18.1%) to 0.083 from 0.098.

The empirical findings about volatility transmission indicates that shocks spillovers (-0.064) from Industry to Financial sector is f significant and volatility spillovers from Financial sector to Industry sector is significant and its value is about 0.481. The volatility spillover from Financial sector to Industry sector is overvalues by 71.3% and its coefficient reduced to just 0.138 from 0.481 when returns are adjusted for outliers.

5.3.10 Consumer Goods-Financial Sectors Pair

Table 5-13: (1)-AGARCH (1,1) Estimates for Consumer Goods, and Financial Sectors

	Unadjusted Returns		Adjusted Returns	
	Consumer Goods	Financial	Consumer Goods	Financial
Panel A: Mean Equation				
$C_{1,0}$	0.060(0.001)*		0.053(0.002)*	
$\Phi_{1,1}$	0.116(0.000)*		0.115(0.000)*	
$\Phi_{1,2}$	-0.006(0.627)		0.011(0.448)	
$C_{2,0}$		0.044(0.038)		0.059(0.006)*
$\Phi_{2,2}$		0.131(0.000)*		0.145(0.000)*
$\Phi_{2,1}$		0.026(0.269)		0.036(0.097)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.027(0.197)		0.010(0.532)	
$\alpha_{1,1}$	0.093(0.000)*		0.098(0.000)*	
$\alpha_{1,2}$	-0.002(0.897)		-0.016(0.139)	
$\beta_{1,1}$	0.889(0.000)*		0.896(0.000)*	
$\beta_{1,2}$	0.013(0.749)		0.032(0.391)	
d_1	-0.005(0.777)		-0.01(0.339)	
$\alpha_{2,0}$		0.167(0.003)*		0.077(0.011)*
$\alpha_{2,2}$		0.077(0.000)*		0.108(0.000)*
$\alpha_{2,1}$		0.013(0.630)		-0.035(0.149)
$\beta_{2,2}$		0.809(0.000)*		0.779(0.000)*
$\beta_{2,1}$		0.002(0.985)		0.137(0.080)
d_2		0.08(0.015)*		0.106(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	11.007(0.051)	7.357(0.195)	8.197(0.146)	7.442(0.19)
ARCH Test	1.08(0.369)	0.81(0.542)	1.658(0.141)	1.114(0.35)
LLH	-12779		-12451	

Note: 1 symbolizes Consumer Goods sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Finally, the results of bivariate models for Consumer Goods and Financial sectors pair are displayed in Table 5.13. The empirical results for unadjusted returns render that coefficients $\Phi_{1,1}$and $\Phi_{2,2}$ are highly significant. These findings suggest that Consumer Goods sector return is influenced (0.115) by own past returns similarly, the current return of Financial sector influenced (0.145) by own past returns. The coefficients $\Phi_{1,2}$and $\Phi_{2,1}$are insignificant. This confirms that no return spillover exists between Consumer Goods sector and Financial sector. These results for adjusted returns showed that the estimates of lagged coefficients $\Phi_{1,1}$ and $\Phi_{2,2}$ are identical to those for unadjusted returns. There is no significant return spillover between these two sectors of Pakistan Stock Exchange for adjusted returns.

From Panel B, the results for unadjusted returns, shows that both stock sectors volatilities depend on their own past innovations and past volatilities. In the volatility of Consumer Goods sector, the coefficient of past innovation is 0.093 and of past volatility is 0.889 respectively. Similarly, the current volatility sensitivity to own past innovations is 0.078 and past volatility is 0.810. The negative and positive shocks in Financial sector have significantly different effect on its volatility. The negative shock will increase the volatility of Financial sector about 0.078 more than positive shock of equal amount. The model results for adjusted returns demonstrate that current conditional variances of both sector indices are sensitive to their own past innovations and own past conditional variance respectively. The estimates of Consumer Goods sector index volatility are marginally different to those of unadjusted returns. Similarly, in conditional variance of Financial sector the past innovations effect is 0.108 which is 39% more than that for unadjusted returns. Past conditional variance effect on the current volatility of Financial sector index 0.779 which is 3.8% less than that for unadjusted returns.

The estimates of transmission of volatility reveals no significant transmission of innovations and volatility exist between Consumer Goods and Financial sectors unadjusted returns. Likewise, for adjusted returns no volatility spillovers is significant between consumer sector index and Financial sector index.

Table 5-14: Constant Conditional Correlation (CCC) between sectors

		Basic Material	Oil and Gas	Industry	Consumer Goods	Financial
Basic Material	Unadjusted	1				
	Adjusted					
Oil and Gas	Unadjusted	0.613*	1			
	Adjusted	0.565*				
Industry	Unadjusted	0.495*	0.451*	1		
	Adjusted	0.455*	0.398*			
Consumer Goods	Unadjusted	0.481*	0.452*	0.313*	1	
	Adjusted	0.452*	0.412*	0.287*		
Financial	Unadjusted	0.652*	0.624*	0.482*	0.458*	1
	Adjusted	0.611*	0.599*	0.461*	0.431*	

Note: * shows significance at 5% level.

The constant conditional correlation between different sector pairs is also reported in Table 5.14 for unadjusted and adjusted returns. As expected, the constant conditional correlation between sectors is positive, reflecting synchronized progress in the economy. They are all below 0.65 (0.61) showing different advantages and varying roles played by those sectors in the economy. The correlation ranges from 0.31 to 0.65 between Industry-Consumer Goods sectors and between Basic Material -Financial sectors pair respectively. The constant conditional correlation for adjusted returns disclosed that its values in different sectors pair is slightly less that for unadjusted returns, its values varies from 0.29 between Industry-Consumer Goods sector and 0.61 between Basic Material -Financial sector indices. The correlation analysis indicates certain portfolio gain to be expected from assets diversification in this case.

Finally, the residuals based robust tests are performed to check the validity of the above estimated models. The LM-ARCH test for conditional heteroscedasticity and Ljung-Box test of Ljung and Box (1978) for autocorrelation applied to the standardized residuals. The test results have been disseminated in Panel C of Table 5.1 to Table 5.13

for each pair. The Q- statistics values are statistically less than the critical value of the test as the p-value associated with the test are greater than 5% most of the time. This shows that the standardized residuals of the all pair are no more auto correlated. Similarly, the LM test results reveals the same findings about the conditional heteroscedasticity. Therefore, the empirical findings of these estimated models seem to be reliable. There is generally no violation of the assumption of classical regression. In the next section, these results are therefore used to estimate the optimal portfolio weights and hedge ratios for two sectoral portfolio holdings.

5.4 Portfolio Weights and Hedge Ratios

The earlier empirical analysis indicates potential return and volatility spillovers among pair of sectoral stock of Pakistan Stock Exchange. The estimated results of VAR (1)-AGARCH (1,1) are used to estimate the optimal portfolio weights and hedge ratios. In this context, an investor aims at minimizing the risk of his investment without lowering its expected returns in order to hedge exposure to fluctuations in stock prices. The optimal portfolio weights and hedge ratios of two stock portfolio are presented in Table 5.15 for unadjusted and adjusted returns. The results for optimal portfolio weights suggest the weights of different sectors are different when they combined in two sectors portfolio. The variation in the weights of Basic Material sector is higher than any other sector and least variation among the weights is of Consumer Goods sector. This shows that combination of different sectors in two assets portfolio will reduce the invest risk without lowering excepted returns.

The portfolio weights of Basic Material sector ranges from 38% to 59% in Basic Material /Consumer Goods sectors pairs and Basic Material /Oil and Gas sectors pair respectively. These findings suggest that in $100 investment investor may invest $ 59 in Basic Material sector and remaining $ 41 in Oil and Gas sector. The average weight of Basic Material sector in portfolio is just 0.38 when a portfolio comprises of Basic Material and Consumer Goods sectors. On the other hand, the weights of Oil and Gas sector in two sector portfolio ranges from 0.35 to 0.50 for Oil and Gas/Consumer Goods sectors pair and Oil and Gas/Financial sectors pair, respectively. In a two assets portfolio Oil and Gas sector as one asset, the weight of Oil and Gas sector in portfolio is always less than or equal to investment into other sectors in the portfolio. The weights of Industry sector in a portfolio always greater than or equal to 50% except when other sector in the portfolio is Consumer Goods sector. When portfolio consists of Industry/Consumer Goods sectors, in order to minimize risk an investor should invest only 41% of investment in Industry sector and rest of investment in consume goods sectors. The maximum weight of Industry sector in two sectors portfolio is about 57% in Industry/Financial sectors portfolio. Apart from this, the weight of Consumer Goods sector is always greater than other sectors in the portfolio. The weights of Consumer Goods sector ranges from 59% to 67% in Consumer Goods/Industry sectors pair and Consumer Goods/Financial sectors pair. Lastly, the weight of Financial sector is minimum (33%) in Financial/Consumer Goods sectors pair and maximum (50%) in Financial/Oil and Gas sectors pair respectively. In other two pairs (Financial/Oil and Gas pair and Financial/Industry pair) the weights of Financial sector are 40% and 43%, respectively.

Turning to hedge ratio, as can be seen from the Table 5.15 the estimated average values varies across different sector pairs. The minimum value of hedge ratio is for Consumer Goods in Consumer Goods/Industry pair and largest value is for Financial sector in Financial/Basic Material pair. This indicates that most effective hedging strategy to short ($29) Industry sector for long ($100) in Consumer Goods. On the other hand, most expensive hedging strategy to short Basic Material sector for long in Financial sector. For Basic Material sector/other sectors pair portfolio the hedge ratios are 0.58, 0.52, 0.59, and 0.61 which implies that $ 100 long position in Basic Material sector should be shorted by about $58 of Oil and Gas sector or $52 of Industry sector or $59 of Consumer Goods sector or $61 of Financial sector respectively. From the these estimates the most effective strategy for long position in Basic Material sector is to short Industry sector assets.

Similarly, the hedge ratios are 0.68, 0.51, 0.58, and 0.64 when an investor has long position in Oil and Gas sector and short position in Basic Material sector or Industry sector or Consumer Goods sectors or Financial sector. These estimated values suggest that most expensive hedging strategy when an investor has long position Oil and Gas sector to short Basic Material and most effective one is to short Industry sector assets. On the other hand, for long position in Industry sector assets the hedge ratios vary from 0.40 to 0.51 for short position in Consumer Goods and Basic Material sectors respectively. However, one dollar long in Consumer Goods sector the most effective hedging strategy to short Industry sector assets of just 29 cents and worst hedging to short Basic Material sector assets of about 43 cents. Lastly, for long position in Financial sector the average values of hedge ratios range from 0.53 to 0.72 for Financial/Industry sectors portfolio and Financial/Basic Material sectors portfolio respectively suggesting that most effective strategy is to short Industry sector assets instead of Basic Material. For Financial/Industry portfolio $ 100 should short $ 53 of Industry sector assets for $ 100 long in Financial sector. On the other hand, $ 100 long position in Financial sector should be shorted by $ 72 of Basic Material sector.

To sum up the results of optimal portfolio weights and hedge ratios the values of both optimal weights and hedge ratios vary across different sectors pairs. In two sector assets portfolios (10 combinations), the results suggest that investor should invest more (more than 58%) in Consumer Goods sector to minimize his exposure to risk. Contrary to this, the share of investment in Oil and Gas sector in two sectors portfolio should always be less than 45% of the investment excluding Oil and Gas/Financial sectors portfolio (50%). On the other hand, hedge ratio results suggest that most effective hedging strategy is to always short Industry sector assets for long position in any of stock sector. While, for an investor who wants to take long investment position in Industry sector (s) he should short Consumer Goods sector assets.

The results show that the values of optimal weights changed in both ways (increased/decreased) and hedge ratios reduced when the returns are adjusted for possible outliers. For example, the values of optimal portfolio weight of Basic Material in Basic Material /Oil and Gas sectors assets portfolio was 59% of unadjusted returns. When returns are adjusted for outliers its value reduced to 55%. Similarly, in Industry/Consumer Goods sector assets portfolio the share of Industry sector was only 41% of unadjusted returns when returns are adjusted for outliers the share of Industry in the portfolio increased to 46%. Overall results reveal that presence of outliers' model results always biased the estimates of optimal portfolio weights. On the other hand, results regarding hedge ratios of adjusted returns reveals that the correction of outliers have more impact on hedge ratios as compared to the weights. When outliers are present in the returns data results showed that hedge ratios are overestimated most of the time. The change in hedge ratio of adjusted returns from of unadjusted returns ranges from -7% to 2%. The average values of hedge ratios reduced except Financial/ Industry sectors portfolio. Among twenty values of hedge ratios seventeen time the hedge ratio values are overestimated.

Table 5-15: Optimal Portfolio Weights and Hedge Ratios

	Unadjusted Returns		Adjusted Returns	
	Weight	Hedge Ratio	Weight	Hedge Ratio
Basic Material Sector				
Basic Material/Oil and Gas	0.59	0.58	0.55	0.55
Basic Material/Industry	0.50	0.52	0.46	0.50
Basic Material/Consumer	0.38	0.59	0.40	0.55
Basic Material/Financial	0.60	0.61	0.59	0.57
Oil and Gas Sector				
Oil and Gas/ Basic Material	0.41	0.68	0.45	0.61
Oil and Gas/Industry	0.44	0.51	0.43	0.47
Oil and Gas/Consumer Goods	0.35	0.58	0.39	0.51
Oil and Gas/Financial	0.50	0.64	0.53	0.59
Industry Sector				
Industry/ Basic Material	0.50	0.51	0.54	0.45
Industry/Oil and Gas	0.56	0.43	0.57	0.38
Industry/Consumer Goods	0.41	0.40	0.46	0.35
Industry/Financial	0.57	0.45	0.60	0.42
Consumer Goods Sector				
Consumer Goods/Basic	0.62	0.43	0.60	0.41
Consumer Goods/Oil and Gas	0.65	0.36	0.61	0.35
Consumer Goods/Industry	0.59	0.29	0.54	0.29
Consumer Goods/Financial	0.67	0.38	0.65	0.37
Financial Sector				
Financial/Basic Material	0.40	0.72	0.41	0.67
Financial/Oil and Gas	0.50	0.63	0.47	0.63
Financial/Industry	0.43	0.53	0.40	0.55
Financial /Consumer Goods	0.33	0.61	0.35	0.57

Notes: The table reports average optimal weight and hedge ratios of two sector portfolio.

5.5 Summary

This chapter addresses an important research question relating to return and volatility spillovers among five major sectors namely; Basic Material sector, Oil and Gas sector, Industry sector, Consumer Goods sector and Financial sectors of Pakistan Stock Exchange. We estimated bivariate VAR(1)-GARCH(1,1) and VAR(1)-AGARCH(1,1) models proposed by Ling and McAleer (2003) and McAleer et al. (2009) using unadjusted and outliers adjusted data from January 01, 2001 to December 31, 2015. We identify and correct the outliers using non-parametric methods proposed by Charles and Darné (2005) and Laurent et al. (2016). In addition to returns and volatility spillovers between sectors and firms, we also estimate the optimal portfolio weights and hedge ratios. The empirical results suggest that model estimates are approximately insensitive to the outlier detection and correction methods.

The empirical results revealed that estimates of conditional means and conditional variances are sensitive to the paired sectors. The lagged returns coefficients of a sector stock of sectors are sensitive to sectors in bivariate model. Similarly, the coefficients of ARCH and GARCH and leverage effect are also stock sector pair sensitive. The estimates for adjusted returns are significantly different from those for unadjusted returns. Similarly, the estimates of optimal portfolio weights and hedge ratios shows some degree of sensitivity to presence of outliers in the returns. These results are different to those at aggregate level where the estimated values of first and second conditional moments of Pakistan Stock Exchange are nearly insensitive to the other market in the pair.

The estimates of conditional first conditional moment for unadjusted returns of stock sectors reveals that own lagged coefficients are significant except Oil and Gas sector. The lagged coefficient of Oil and Gas sector is insignificant when Oil and Gas sectors is paired with Industry sector. Of Basic Material Basic Material sector own returns spillovers ranges from 0.048 to 0.076 and Oil and Gas sector it lies between 0.043 and 0.057. Similarly, one percent increase in return of Industry sector likely to increase future returns between the 0.066% to 0.083% in different pairs. Also, when Consumer Goods sector is paired with other sectors of Pakistan Stock Exchange the lagged coefficient varied from 0.097 to 0.129. Lastly, past returns of Financial sector to the current is high among all these sectors and it values lies between 0.118 to 0.152 for Financial/Basic Material sectors pair and Financial/Oil and Gas sectors pair, respectively. Predictability in price movement of Financial sector is higher than any other sector followed by Consumer Goods sector and lowest in Oil and Gas sector of Pakistan Stock Exchange. These findings are not inline to those at aggregate level. At aggregate level, the lagged returns coefficient is nearly independent to other market in the pair. On the other hand, the coefficients of conditional volatility; both past shock and past volatility of sectors are specific to sector. The coefficient of past shock in volatility of Industry sector is more sensitive (0.116 to 0.178) to other sector in the pair and Basic Material sector coefficient of past shock is least sensitive (0.139 to 0.158). Whereas, the variation in the GARCH coefficient of Industry sector is larger followed by Financial sector and this variation is least in Consumer Goods sector when these sectors are paired with other sectors. Among sectors, volatility persistence in Consumer Goods sector is higher and lest in Industry sector. This showed that effect of past shock in take long time to fade away in Consumer Goods sector and shock effect in Industry sector die out quickly. The leverage effect is less sensitive to sectors pair. The negative and positive shocks have different effect on the volatility only once out of four pairs of Basic Material and Industry sectors and twice of Financial sector. The asymmetric effect of shock of Basic Material is significant when it is paired with Industry sector and the asymmetric is significant Industry/Consumer Goods pairs in Industry sector. The leverage effect in Financial sector is significant when Financial sector is paired with Industry and Consumer Goods sectors.

Turning to return spillovers between different sector pairs, results showed that no short-run price transmission between these sectors of Pakistan Stock Exchange except price spillovers is significant from Financial sector to Industry sector. The Financial sector transmitted about 0.041 of its past returns to Industry sector. Apart from return spillovers, the shock and volatility spillovers results suggest that in six out of ten pairs of stock sectors there exist significant shock or volatility or both shock and volatility spillovers and results are mixed. The shocks spillovers between Basic Material and Industry sectors is reciprocal whereas, the shock spillovers from Basic Material to Consumer Goods, from Oil and Gas to Industry and from Industry to both Consumer Goods and Financial sectors is statistically significant. Similarly, significant reciprocal volatility transmission exists between Basic Material and Oil and Gas sectors and Basic Material and Consumer Goods. Unidirectional volatility spillover is found significant from Basic Material to Industry, Oil and Gas to Industry, Industry to Consumer Goods and from Financial sector to Industry sectors.

On the hand, when sectoral returns are adjusted for outliers, the coefficients of conditional mean, conditional variance of different sectors are sensitive to other sector in the model and their values are quite different from those of unadjusted returns. Estimated model incorrectly invokes the significance of lagged returns effect in Oil and Gas sector when it is paired with Basic Material and Financial sectors and hide true effect of past returns of Oil and Gas sector whenever it is paired with Industry sector. The presence of outliers always overestimated the Autoregressive coefficient in first conditional moment of Oil and Gas and Industry sectors returns respectively and these findings are consistent with Verhoeven and McAleer (2000). While, the model underestimates the AR coefficient in Basic Material sector in all pairs and for Consumer Goods and Financial sectors AR coefficients is twice overestimated in four pairs. The variation in the lagged coefficients of all sectors reduced of adjusted returns.

From Panel B of Table 5.4 to Table 5.13, it is observed that constant in volatility of all sectors is sensitive to other sector the paired and always overestimated by the model. These findings are in lined with finding of Chapter 4 and consistent with the findings of Carnero et al. (2006). Again, both ARCH and GARCH coefficients are sensitive to sectors pairs but the sensitivity of these estimates is marginally reduced when returns are cleaned of outliers. The ARCH effect is overestimated and GARCH is underestimated by the model in Industry sector volatility due to the presence of consecutive outliers. The findings supported by Carnero et al. (2006), they showed that model overestimate ARCH and undervalued GARCH if outliers are appeared in patches.. on the other hand, the pattern of change in ARCH effect is mixed in other sectors when returns are adjusted of outliers. Also, the GARCH effect is under estimated in Oil and Gas sector, Consumer Goods sector in all pairs when outliers are present in returns. This is consistent with the findings of (Charles and Darné, 2005, 2014; Carnero et al., 2006; Charles, 2008) . Our findings suggest that leverage effect also sensitive to the sector paired and model hide the true asymmetry or unable to capture asymmetry due to outliers. The model did not detect leverage effect in Basic Material sector when Basic Material paired with Oil and Gas and Industry sectors similarly, in Oil and Gas sector when it is paired with Consumer Goods sector due to outliers. The leverage effect is significant in Financial sector in all four pairs but, model detect asymmetry only in two pairs. These findings are consistent with Carnero et al. (2016) which showed that outliers can hide asymmetry or wrongly suggest asymmetry. The estimates of return spillovers showed that model unable to detect return spillovers from Industry sector to Oil and Gas sector due to presence of outliers. The return spillover is significant from Industry to Oil and Gas and from Financial sector to Industry sector only. The Industry sector exported about 0.043 of returns to Oil and Gas sector. The return spillovers from marginally reduced to 0.039 from 0.041 when returns outliers are adjusted from returns. Apart from this, no significant return spillovers between sectors other than this.

The results of adjusted returns revealed that the outliers have serious effect on the estimates of shock and volatility spillovers between sectors of Pakistan Stock

Exchange. In many pairs the model is unable to capture transmission of shock or volatility or both between sectors because of few outliers. For example, both shock and volatility of Basic Material sector have significant effect on the volatility of Financial sector and vice versa model unable to detect due to outliers. Likewise, when outliers are not adjusted only bidirectional spillovers of volatility between Basic Material and Oil and Gas sectors is found significant but when outliers are adjusted the reciprocal shock spillovers also become statistically significant. Apart from this the presence of outliers have significant effect (overvalued or undervalued) on the estimates of parameter of shock and volatility spillovers. The volatility transmission from Oil and Gas sector to Basic Material is undervalued due to outliers. When outliers are adjusted, the coefficient value increased to 0.256 from 0.183. On the other hand, shock spillovers reduced (in absolute) from 0.075 to 0.039 and volatility spillovers reduced to 0.133 from 0.308 from Basic Material to Industry sector when returns are adjusted of outliers. Similarly, the volatility transmission of Financial sector to Industry sector is 0.481 and it reduced to 0.138 only when returns are cleaned of outliers.

The constant conditional correlation (CCC) between different sector of Pakistan Stock Exchange is statistically significant and varies between different sector pairs. The CCC between Industry/Consumer Goods pair is least and strong between Basic Material /Financial sectors. These values of CCC reveal that sectoral investment in Pakistan Stock Exchange provide good opportunity of portfolio diversification and hedge against risk. When the returns are adjusted of outliers the conditional correlation between all sector pair decreased. For example, the correlation between Consumer Goods and Industry is 0.39 of unadjusted returns and it values reduced to 0.31 when returns are adjusted of outliers. Similarly, the CCC between Oil and Gas/Industry pair reduced from 0.451 to 0.398. The value of CCC is less than 50% between different sectors pair most of the time which gave an indication of excellent opportunity of portfolio diversification for an investor who seek investment in different sectors of Pakistan Stock Exchange.

Lastly, the results regrading portfolio weights show that different sectors have different weights in the investment. The investment shares of Basic Material sector in two assets portfolio varies from 0.38 to 0.59 for Basic Material /Consumer Goods pair and Basic Material /Oil and Gas sectors pair. This shows that for an investor who wants to invest in two sector one is Basic Material should investment more in Basic Material sector to minimize his risk without lowering his excepted returns except Consumer Goods sector. When his intention is to distribute his investment into Basic Material and Consumer Goods sectors he should invest only 38% of his investment in Basic Material and rest of amount in Consumer Goods sector. Similarly, optimal weights for Oil and Gas ranges from 0.35 to 0.50. This shows that in two assets portfolio investment, the investment weights in Oil and Gas sectors should be less or equal to 50%. The optimal weights for Consumer Goods sector always between 59% to 67%. This shows that two assets portfolio which is combination of Industry sector and one from other sector the risk exposure is minimum if and only if Industry sector has more weight than other sectors. The hedge ratio results indicate that hedging is cheaper when investor take long position in Consumer Goods sector assets and short position in Industry sector and hedging is costly for long position in Financial sector and short position in Basic Material sector. For an investor who wants to hold Basic Material or Oil and Gas or Consumer Goods or Financial sector he should short Industry sectors to minimize his risk exposure. On other hand, for an investor who hold Industry sector assets should take short position in Consumer Goods sector to minimize his risk exposure.

When outliers adjusted returns are used to estimate optimal portfolio weights results disclose that portfolio weights of all sector pairs change in both ways (increase/decrease). The variation in the weights of optimal portfolio weights ranges from -5 to 5. The weights for Consumer Goods sector reduced and increased for Industry sector for adjusted returns. A part form this, the values of hedge ratios decreased or remains same for all pair except Financial/Industry sectors pair for which its value increased from 0.53 to 0.55 only of adjusted returns. Overall, the correction of outliers has an impact on the portfolio weights and hedge ratios as well.

Chapter 6: Effect of Outliers on Return and Volatility Dynamic Spillovers between Oil and Stock Sectors

6.1 Introduction

Unlike the previous chapters in which the effect of outliers on returns and volatility their spillovers between stock assets has been investigated at market, sectoral level and firm level. This chapter investigates the dynamic linkage between stock returns of selected sectors and Brent oil price of Pakistan stock exchange from two perspectives, return and volatility transmission. The oil price fluctuations potentially influence the stock markets via changes in cash flows and corporate gains. It has gained attention of researchers and practitioners during the last two decades. The effect of oil price changes on stock prices can be expounded through equity evaluation theory. Many researchers (such as Apergis and Miller, 2009; Park and Ratti, 2008; Sadorsky, 1999) has also investigated the influence of oil price changes on macroeconomic aggregates of interest like economic growth, inflation, interest rate etc. It also makes it easy to understand that oil prices are important for corporate gains and discount rates and accordingly for the stock markets. It is also pertinent to note that oil is an important factor of production and any increase in its price leads to rise in cost of production thus negatively influence the corporate gains and real output at macroeconomic level.

Equity price model defines the stock price as the present value of future net earnings. Oil price shocks are reflected in stock prices immediately. According to Huang et al. (1996), oil price increases reduce the expected earnings and leads to decline in stock prices therefore there exists negative correlation between oil prices and stock prices. Another important channel through which oil prices changes are transmitted into stock prices is the interest rate channel. In response to oil price increases, monetary policy makers may increase interest rate to protect economy from inflationary pressures. Due to increase in discount rate, stock prices decline which divert focus of investors toward bonds market hence both of these factors are responsible for stock price decline (Huang et al., 1996). These spillover effects are different for different sectors however literature for Pakistan is silent on this issue. Therefore, this chapter focuses on empirical investigation of return and volatility dynamics in the presence of oil price shocks.

The fuel mix is dominated by thermal resources wherein oil was comprised of 32.1% of total energy supply in 2008-09 which is increasing overtime and is more than 34.5% now. Power sector, transport sector and industrial sectors consumed 42.3%, 49.3% and 5.4% in 2008-09 whereas these percentages were 42.7%, 48.8% and 6.1% respectively. However, it is important to note that more than 85% of the total demand is met through imported oil. This evidence depicts the heavy reliance of Pakistan economy on oil. The rest of Chapter is organized as follows. Graphical and descriptive analysis is presented in Section 6.2. In Section 6.3 discussion about empirical findings of model. The results of portfolio weights and hedge ratio given in Section 6.4, and lastly, summary of chapter in Section 6.5.

6.2 Graphical and Descriptive Analysis

The data for world oil prices is the spot prices of Brent, which is the leading global benchmark of oil prices. The Brent oil price is used to price two thirds of the world's globally traded crude oil supplies. The data for Brent oil price is extracted from DataStream data source. Firms listed at PSX are classified into eight sectors by DataStream data source of Thompson Reuters. The classification of these firms in these eight sectors is based on their business activities. These sectors named as Oil and Gas sector, Industry sector, Healthcare sector, Consumer Goods sector, Utility sector, Basic Material sector, Telecom sector and Financial sector. Time series graph of PSX bench market index (KSE-100 index) and sectoral stock indices with the Brent oil price have been presented in Figure 6.1 to Figure 6.9. The Brent oil price has been symbolized by thin (red) line and stock indices have been symbolized by thick (black) line.

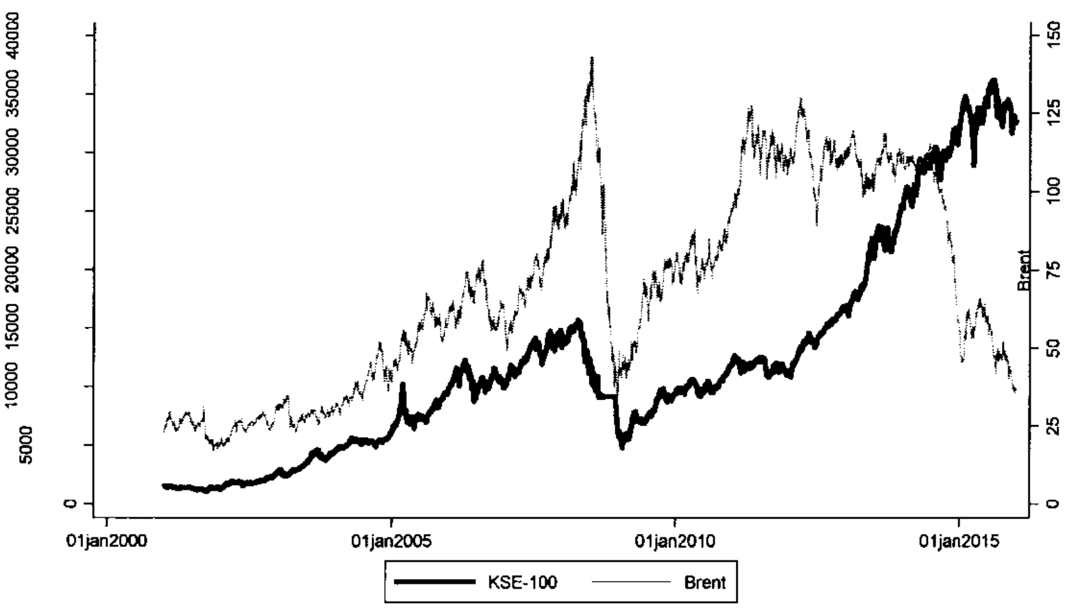

Figure 6-1: KSE-100 Index and Oil Price

Figure 6.1 depict that KSE-100 index and Brent oil price move side by side from the start of the sample to the start of year 2014. Before the start of GFC, the price gap between these two markets is approximately same. In the same direction even in the GFC. During the period of oil price hike, the KSE index move with same pace. After GFC, the price recovery in oil market is very fast than index. After the second quarter of 2011 the oil price is stable and from the year 2014 start declining. But the KSE index price move upward and touches its all-time high of whole sample period during year 2015.

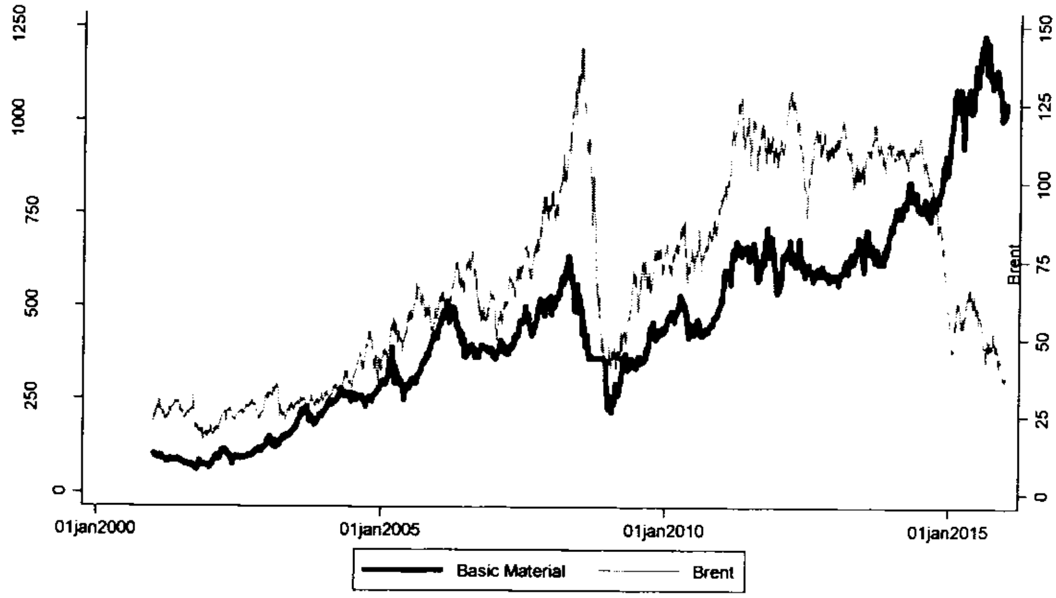

Figure 6-2: Basic Material Sector Index and Oil Price

Figure 6.2 above depicts that both Brent oil prices and Basic Material sector index move side by side. The price increases in Brent oil and Basic Material before the year 2008. There is a sharp decline in price of Brent oil and Basic Material sector of PSX. After the GFC, the oil price increased more quickly than Basic Material sector index price. From the last quarter of 2014, sharp decline in the Brent oil price was observed but the index price of Basic Material sector moves steady upward.

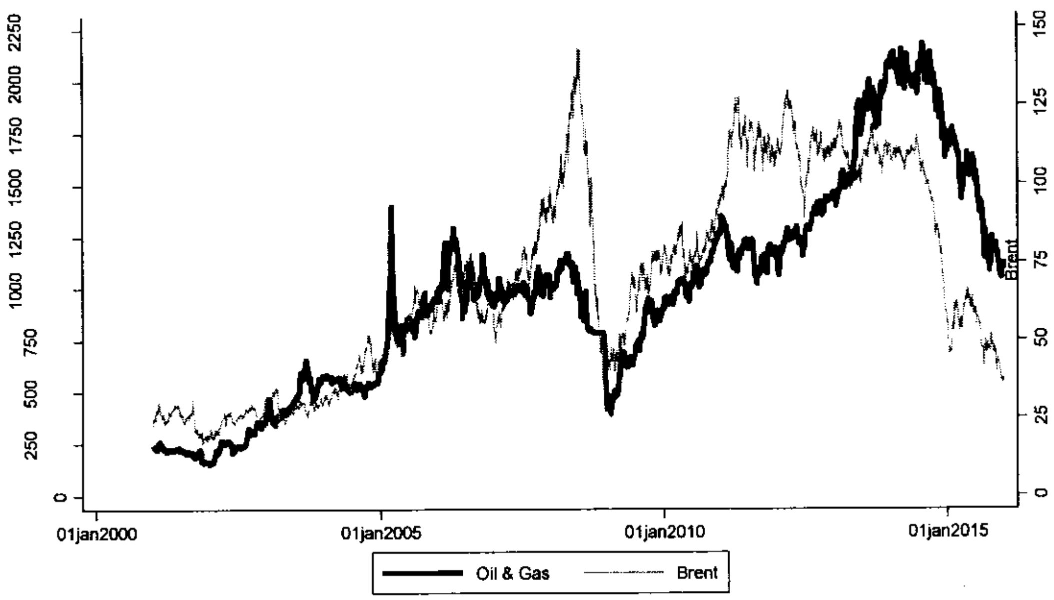

Figure 6-3 Oil and Gas Sector Index and Oil Price

Figure 6.3 shows that shows strong price movement between Brent oil and Oil and Gas sector index of PSX. It can be observed that both Brent oil and index go side by side and follows each other till the mid of year 2007. From the start of third quarter of year 2007, vary sharp increase was observed in oil price and touches its record high before the start of a GFC but the Oil and Gas index move steadily. During GFC, there was a sharp decline in both Brent oil and Oil and Gas sector index whereas their price movement is in the same direction.

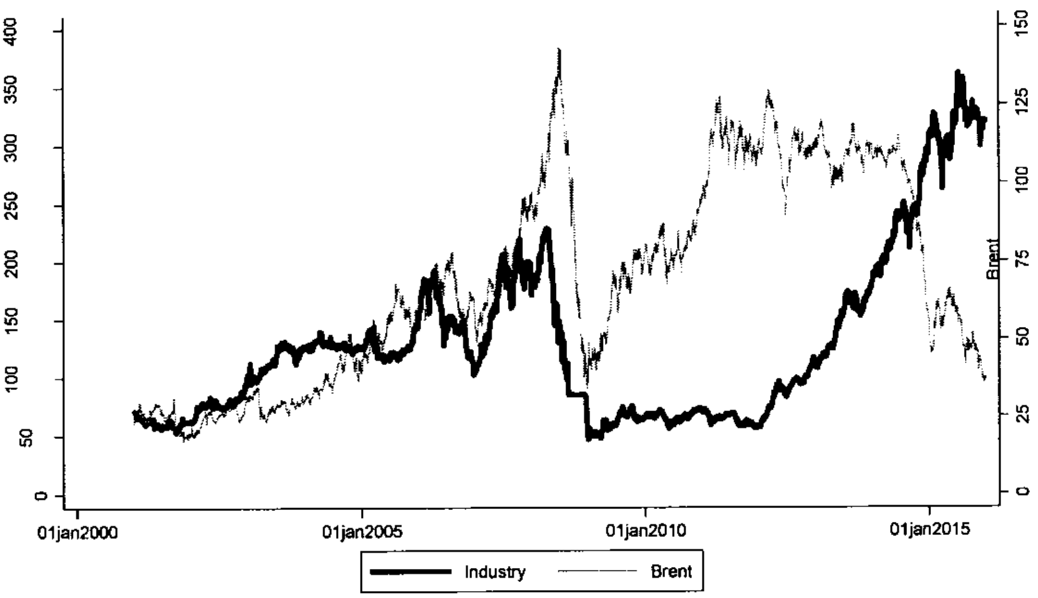

Figure 6-4: Industry Sector Index and Oil Price

The Brent oil and Industry sector index have been drawn in Figure 6.4. The graph portrays that both Industry index price and oil price move in the same direction with similar speed even during GFC. After GFC price recovery in oil is very fast as compared to Industry sector index. From April 2011 to June 2014 the oil prices revolve around 100 and 120. While, the price of Industry sector index is approximately 50 from the start of year 2009 to start of 2013. From the start of year 2013 to mid of year 2015 approximately 300 points added into the index price of Industry sector of Pakistan Stock Exchange.

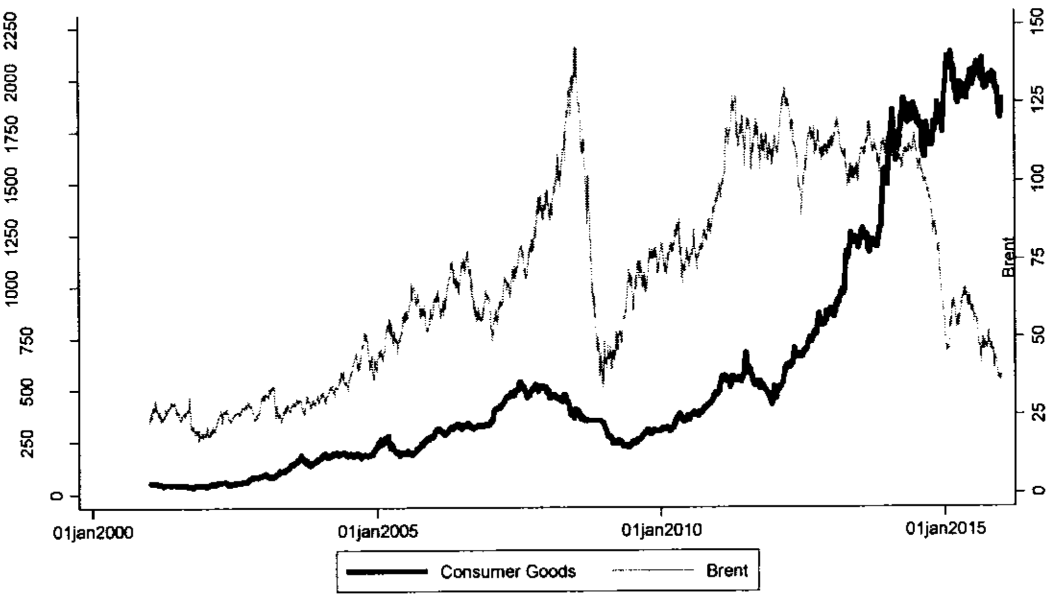

Figure 6-5: Consumer Goods Sector Index and Oil Price

Looking at the Figure 6.5 of Brent oil and Consumer Goods sector of Pakistan Stock Exchange, it has been observed that consumer good index is insensitive to the oil price change. The index price of Consumer Goods sector increased gradually as compared the price of oil which fluctuate very much during the period of investigation. There is no connection between Brent oil price and Consumer Goods index.

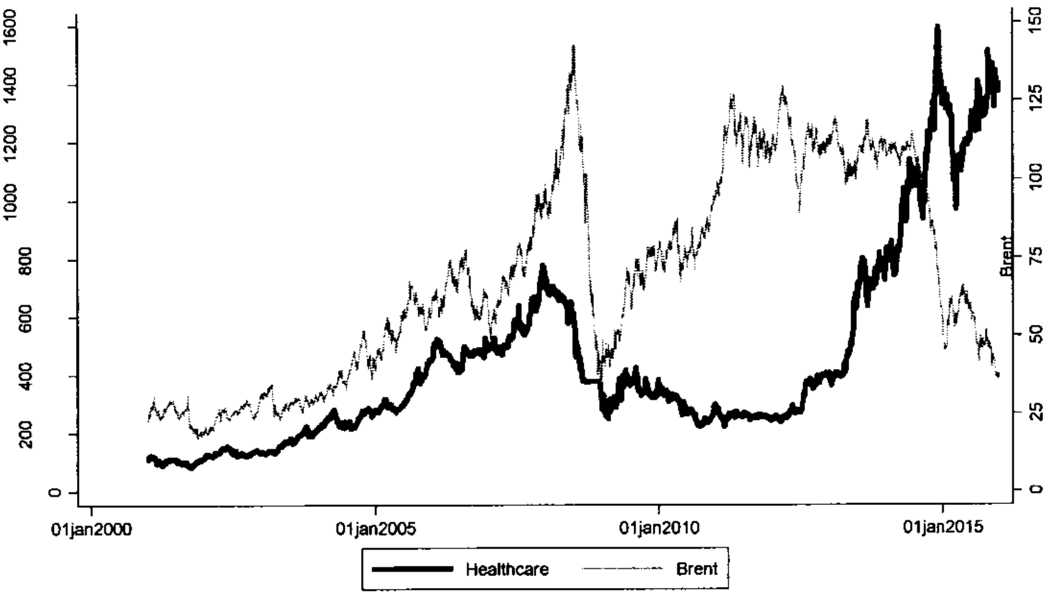

Figure 6-6: Healthcare Sector Index and Oil Price

The price movement in Healthcare sector index relative to the price movement in Brent oil price is nearly identical to the index price of Industry sector relative to Brent oil price. Both Graphs 6.5 and 5.6 nearly identical with each other.

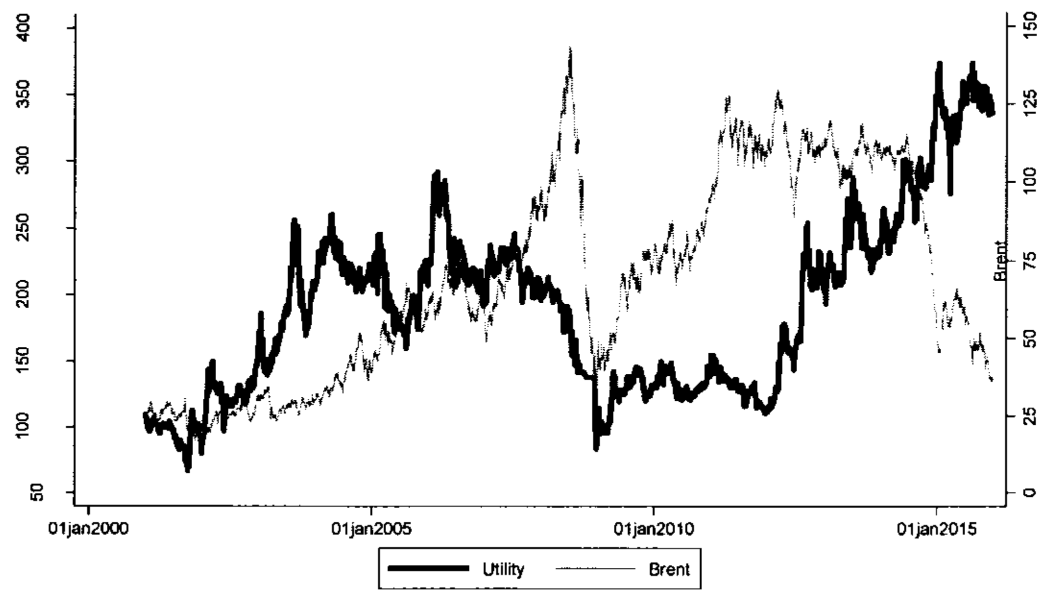

Figure 6-7: Utility Sector Index and Oil Price

Looking at the Figure 6.7, which show the combined price movement of Brent oil and Utility sector of PSX. From the graph the association between Brent price and Utility price index is mixed.

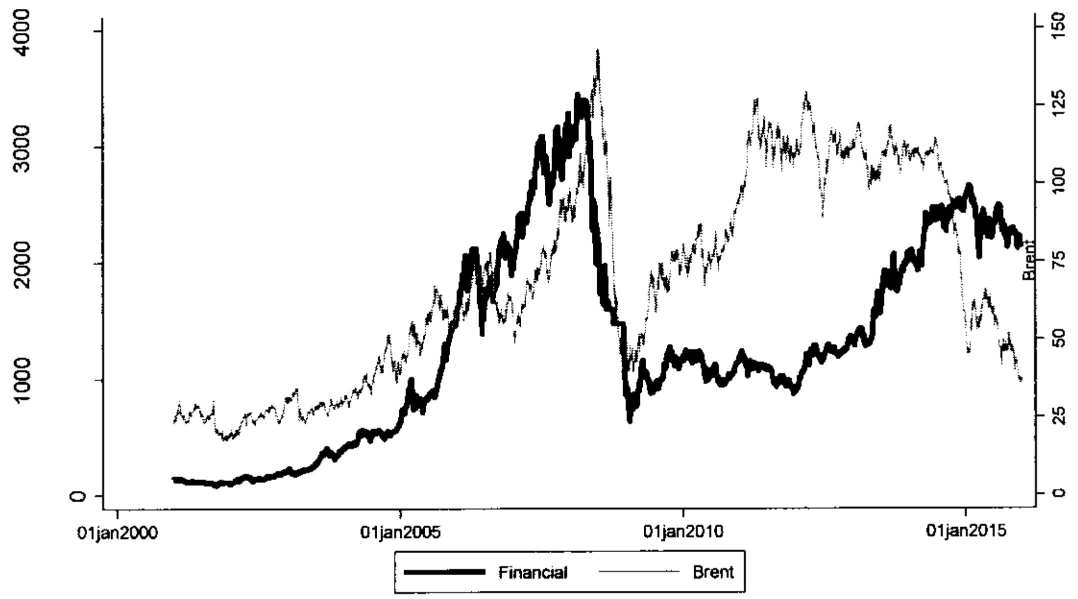

Figure 6-8: Financial Sector Index and Oil Price

Figure 6.8 depicts the price movement of Financial sector index and Brent oil. Till the mid of year 2009 (start of GFC) both oil price and index move side by side with each other. In the first half of this duration the oil price greater than index price but in latter half price of index is greater relative to oil. After GFC, recovery in the oil price but Financial sector index maintains its price level approximately at 1200. From the start of 2009 to last quarter of 2014, Brent oil and Financial sector index move opposite to each other. After the GFC, oil price shows increasing trend, but index maintain it price at certain level after that price of oil maintain a certain price level, but index start. From the last quarter of 2014 till the end of sample the index price again maintains its certain price, but oil price shows a sharp decline. Before the GFC the price movement is positive but from the start of the GFC the pattern of movement in price is mixed.

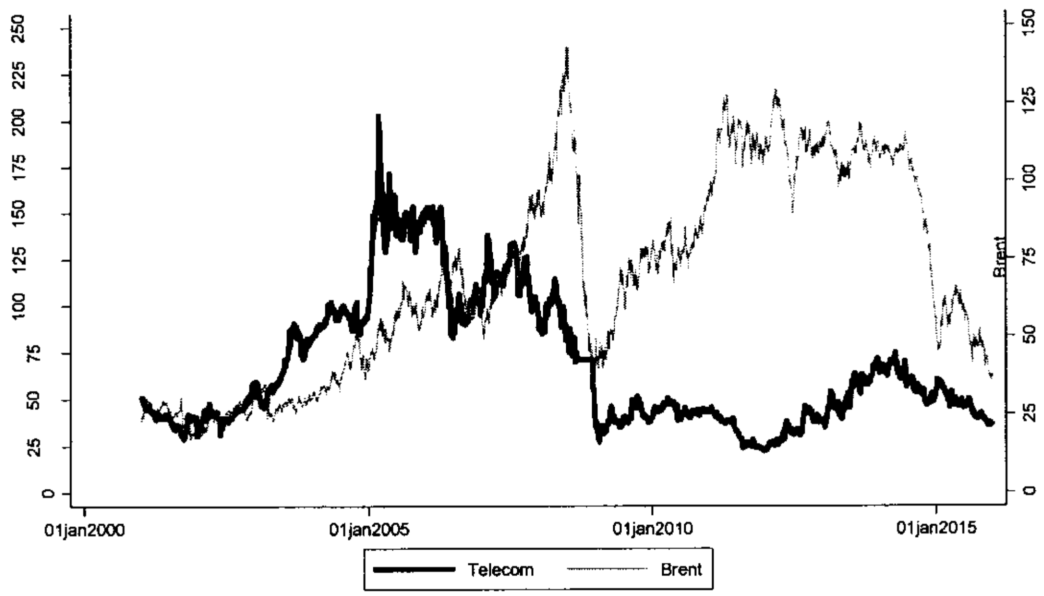

Figure 6-9: Telecom Sector Index and Brent Oil Price

The graph of Brent oil prices and index price of Telecom sector of PSX is given in Figure 6.9. No clear pattern in the price movement of Brent oil and Telecom sector index has been observed. Since the start of sample both oil price and index excel in the same direction, but Telecom sector shows some sharp peaks in its price as compare to oil price which shows steady upward movement. After the GFC, the price of Telecom index remains at same level to the end of the sample period. But, price of oil shows fast recovery with respect to Telecom sector index then maintain a certain level and start downward trend from the mid of year 2014.

From the Figure 6.1 to Figure 6.9, it is observed that sectors of Pakistan Stock Exchange have different level of price sensitively to the oil price movement. Some sectors are very much sensitive to oil prices and their price move along the price of oil and some sectors have no link with oil price. Some sectors have moderate relationship with oil price movement. So, it is interesting to examine empirically the association between oil prices and sectoral stock of PSX both in first and second moment.

Table 6.1 presents the statistical and time series properties of unadjusted and adjusted returns of Brent oil.

Table 6-1: Statistical and time series properties of unadjusted and adjusted Oil price returns

Returns	Mean	SD	Skew	Kurtosis	JB	Q-Stat	ARCH Test	ADF Test
Unadjusted	0.013	2.08	-0.12	5.45*	4844.1*	10.5	39.4*	-25.8**
Adjusted	0.032	2.08	0.09	1.88*	581.0*	5.40	53.4*	-25.7**

Note: * shows significance at 5% level.

From the Table 6.1, the average percentage return of Brent oil is positive of both unadjusted and adjusted returns. When oil market returns are cleaned of outliers the average percentage return increased from 0.013 to 0.032. Standard deviation (unconditional volatility) of both unadjusted and adjusted is about 0.021. The coefficient of skewness is insignificant for both unadjusted and adjusted returns. The values of coefficient of kurtosis is significant for unadjusted and adjusted returns but kurtosis coefficient value well less of adjusted returns. The normality of Brent oil returns is strongly rejected by JB test of unadjusted as well as adjusted returns. But the adjusted returns are more tend toward normality than unadjusted. The Ljung and Box (1978) Q-test used to test empirically the presence of autocorrelation in the Brent oil returns. The value so test for unadjusted and adjusted returns shows that the returns are not autocorrelated. Therefore, no autocorrelation is presence in the Brent oil returns. The future returns of Bent oil cannot be forecast from their present values. In order to test time varying heteroscedasticity (ARCH), the LM-ARCH test of Engle (1982) is used. The test strongly rejects the null of no ARCH in the Brent oil returns. ADF has been utilized to test the stationarity of Bren oil returns and test strongly rejects the unit root at level. From above discussion, the data with such properties the GARCH family models are more suitable than linear models. Unconditional correlation between stock returns and Brent oil returns are calculated and illustrated in Table 6.2 of unadjusted and adjusted returns.

Table 6-2: Unconditional Correlation between Oil and Pakistan stock (Market and Sectors)

	Brent Oil	
	Unadjusted Returns	Adjusted Returns
KSE-100 Index	0.037*	0.039*
Basic Material Sector	0.022	0.023
Oil and Gas Sector	0.068*	0.060*
Industry Sector	0.049*	0.029
Consumer Goods Sector	0.01	0.017
Healthcare Sector	0.019	0.006
Utility Sector	0.025	0.020
Financial	0.033*	0.036*
Telecom Sector	0.022	0.031

Note: * shows significance at 5% level.

The correlation is important not only for a portfolio manager but for transnational investors as well. Correlation analysis between the markets helps them to construct efficient investment portfolios and use hedging strategies in order to get benefit from diversification. It is observed that that the unconditional correlation between Brent oil and stocks is very low and for most of the oil-stock pair it is insignificant. The unconditional correlation between Brent oil and stocks slightly change due to correction of outliers. As expected, the Brent oil has significant and strong correlation with Oil and Gas sector than any other stock of both unadjusted as well as unadjusted returns. The correlation coefficient value between Brent oil and Oil and Gas sector is 0.068 (0.060) for unadjusted and adjusted returns. The correlation of Brent oil with market index, Industry (unadjusted) sector and Financial sector is significant. The correlation of oil with these stock ranges from 0.033 to 0.049.

6.3 Results and Discussion

The estimates of the model of Brent oil and stock pair have been presented in Table 6.3 to Table 6.11 for unadjusted and adjusted returns. The parameter estimates of conditional mean have been represented in Panel A, whereas, parameter estimates of conditional volatility are given in Panel B and in Panel C, diagnostic tests are reported.

Table 6-3: VAR(1)-AGARCH (1,1) Estimates for Oil and Pakistan Stock Exchange

	Unadjusted Returns		Adjusted Returns	
	Oil	PSX	Oil	PSX
Panel A: Mean Equation				
$C_{1.0}$	-0.004(0.912)		0.007(0.821)	
$\Phi_{1,1}$	-0.003(0.834)		-0.009(0.605)	
$\Phi_{1,2}$	0.009(0.717)		-0.026(0.340)	
$C_{2,0}$		0.100(0.000)*		0.117(0.000)*
$\Phi_{2,2}$		0.101(0.000)*		0.097(0.000)*
$\Phi_{2,1}$		0.023(0.007)*		0.022(0.002)*
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.002(0.765)		0.000(0.945)	
$\alpha_{1,1}$	0.017(0.028)		0.016(0.002)*	
$\alpha_{1,2}$	-0.016(0.212)		-0.007(0.508)	
$\beta_{1,1}$	0.958(0.000)*		0.959(0.000)*	
$\beta_{1,2}$	0.607(0.176)		0.463(0.188)	
d_1	0.036(0.000)*		0.037(0.000)*	
$\alpha_{2,0}$		0.057(0.000)*		0.039(0.000)*
$\alpha_{2,2}$		0.081(0.000)*		0.096(0.000)*
$\alpha_{2,1}$		-0.006(0.639)		0.006(0.526)
$\beta_{2,2}$		0.721(0.000)*		0.740(0.000)*
$\beta_{2,1}$		1.581(0.171)		1.156(0.197)
d_2		0.178(0.000)*		0.177(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	3.313(0.652)	11.427(0.044)	1.105(0.954)	11.243(0.047)
ARCH Test	2.017(0.073)	0.943(0.452)	1.137(0.338)	0.568(0.725)
LLH	-14176		-13709	

Note: 1 symbolizes Brent Oil and 2 symbolizes PSX. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Estimates of conditional mean for unadjusted and adjusted returns of oil/market index have been given in Panel A of Table 6.3. For unadjusted returns, it is observed that $\Phi_{2,1} = 0.023$ and $\Phi_{2,2} = 0.101$ coefficients are significant at the 1% level. This shows significant unidirectional causal relationship from Brent oil returns and stock market of Pakistan. Compared to previous research, these findings contradict with the commonly reported findings in the literature relating to negative effects of oil price on stock market prices (Driesprong et al., 2008). These outcomes are consistent with the outcomes of Bouri (2015) who finds a positive causality from oil to stock in a case of Lebanon share market. Similar results were reported by Mohanty et al. (2011) for GCC, Narayan and Narayan (2010) for Vietnam and for India by Nath Sahu et al. (2014). When returns are adjusted for outliers, the values of these coefficients are approximately identical to those for unadjusted returns. The correction of outliers does not have any effect on the estimated values of conditional mean of both Brent oil and Pakistan Stock Exchange. Parameter estimate of lagged returns of Pakistan Stock Exchange is roughly identical to those that we have already observed in Chapter 4.

From Table 6.3, Panel B, the results for unadjusted returns show that coefficients $\alpha_{2,2}$, $\beta_{1,1}$,and $\beta_{2,2}$ are statistically significant at 1% level except $\alpha_{1,1}$ which is significant at 5% significance. This amply shows that the current volatility of Brent oil and Pakistan Stock Exchange can be forecasted from their past squared shocks (ARCH) and past volatility (GARCH). In Brent oil volatility, the ARCH and GARCH coefficients are 0.017 and 0.958. Similarly, the volatility of PSX (market index) affected by past shock (0.081) and past volatility (0.721). Small values of ARCH coefficient imply that the conditional volatility of Brent oil and market does not change very rapidly (Arouri et al., 2011). Asymmetric effect of shocks in oil and stock represented by $d_1$and $d_{,2}$ and they are significant. This infers that own negative shocks likely to increase the volatility of oil (stock) more than the positive shocks of the same size. The negative shocks in Brent oil and PSX will increase their respective volatility about 0.036 and 0.177 more than that of positive shocks of the same intensity. When returns are adjusted for outliers, the estimated values of ARCH, GARCH and leverage coefficients for Brent oil and Pakistan Stock Exchange fare almost identical to those for unadjusted returns. Whereas, the ARCH and GARCH coefficient of volatility are marginally underestimated by the model due to presence of outliers for PSX. When returns are cleaned for outliers, the ARCH coefficient increased from 0.081 to 0.096 and GARCH increased from 0.721 to 0.740, respectively. The leverage effect remains unaffected by the presence of outliers. The second moment results of Pakistan Stock Exchange index returns are not in identical to the results of Chapter 4. The coefficient values of ARCH and GARCH are less and leverage effect is greater than as compared to their values that was observed in Chapter 4. This shows that coefficients that governs the volatility dynamics depends upon the market type with which it is paired. In Chapter 4, the other markets in the pair with PSX were stock markets but here the second market in the pair is oil market.

The empirical results regarding shock and volatility transmission indicates that estimates of $\alpha_{1,2}$, $\alpha_{2,1}$, $\beta_{1,2}$and $\beta_{2,1}$ are insignificant for unadjusted returns. These findings suggest no shock and volatility spillovers between Brent oil and PSX. When returns are adjusted for outliers, these coefficients remain statistically insignificance. This shows that no spillovers of shock and volatility exist between PSX and Brent oil for adjusted returns as well.

Table 6-4: VAR (1)-AGARCH (1,1) Estimates for Oil and Basic Material Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Basic Material	Oil	Basic Material
Panel A: Mean Equation				
$C_{1,0}$	-0.001(0.961)		0.002(0.937)	
$\Phi_{1,1}$	-0.006(0.779)		-0.01(0.543)	
$\Phi_{1,2}$	0.024(0.206)		0.018(0.432)	
$C_{2,0}$		0.069(0.000)*		0.086(0.000)*
$\Phi_{2,2}$		0.079(0.000)*		0.076(0.000)*
$\Phi_{2,1}$		0.020(0.003)*		0.019(0.016)*
Panel B: Variance Equation				
$\alpha_{1,0}$	0.000(0.994)		-0.002(0.622)	
$\alpha_{1,1}$	0.019(0.011)*		0.016(0.003)*	
$\alpha_{1,2}$	-0.009(0.341)		0.006(0.460)	
$\beta_{1,1}$	0.954(0.000)*		0.955(0.000)*	
$\beta_{1,2}$	0.840(0.598)		0.716(0.258)	
d_1	0.039(0.001)*		0.042(0.000)*	
$\alpha_{2,0}$		0.098(0.000)*		0.075 (0.000)*
$\alpha_{2,2}$		0.131(0.000)*		0.129(0.000)*
$\alpha_{2,1}$		0.001(0.973)		-0.002(0.871)
$\beta_{2,2}$		0.761(0.000)*		0.798(0.000)*
$\beta_{2,1}$		1.632(0.629)		0.222(0.734)
d_2		0.080(0.010)*		0.075(0.002)*
Panel C: Residuals Diagnostic				
Q-Stat	3.293(0.655)	4.976(0.419)	0.980(0.964)	4.909(0.427)
ARCH Test	1.502(0.186)	0.305(0.91)	0.878(0.495)	0.503(0.774)
LLH	-15012		-14595	

Note: 1 symbolizes Brent Oil and 2 symbolizes Basic Material. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The maximum likelihood estimates of bivariate VAR-AGARCH model of oil/Basic Material pair have been reported in Table 6.4. First moment dynamics for unadjusted returns shows that the Basic Material sector returns depend upon its past returns and past returns of Brent oil. The coefficients $\Phi_{1,1}$ and $\Phi_{2,1}$of past returns of Basic Material and oil market returns are highly significant. The own return spillover of Basic Material is 0.079 and returns spillovers from Brent oil is 0.020. This is consistent with the findings of Demiralay and Gencer (2014) for Turkey and contradict the findings of Caporale et al. (2015) for China. Clearly, own spillover is greater than the oil returns spillovers effect. First conditional moment for adjusted returns, results shows that their dynamic features are identical to those for unadjusted returns.

The second moment dynamic of oil/Basic Material shows that $\alpha_{1,1} = 0.094, \alpha_{2,2} = 0.131, \beta_{1,1} = 0.954$, and $\beta_{2,2} = 0.761$ are highly significant. The significance of these coefficient shows that volatility of Brent oil and Basic Material sector is perceptive to their respective past shock and past volatility. The coefficient $d_1 = 0.039$ and $d_2 = 0.080$ which represents asymmetric effect of shock are statistically significant both in oil and Basic Material volatility. Negative oil shocks likely to increase volatility (0.039) more than a positive shock of same extent. Similarly, due to negative shocks, Basic Material sector become more volatile about 0.08. Results of Brent oil conditional volatility disclose that estimated values of ARCH, GARCH and asymmetry are identical to those of presented in the Table 6.4. The results for adjusted returns depict that own lagged shock and lagged volatility estimates are statistically significant in both Brent oil and Basic Material. The values of these coefficient estimates are approximately identical to the estimates for unadjusted returns excluding GARCH coefficient of Basic Material sector. The coefficient value increased (by 4.7%) from 0.761 to 0.798 for adjusted returns. This illustrate that due to presence of outliers' model under estimate the volatility persistence of Basic Material sector returns. The values of leverage coefficients nearly same for adjusted returns as well.

The empirical findings on volatility spillovers effect indicate that no significant volatility spillover, neither in short and nor in long run, exist between Brent oil and Basic Material sector for unadjusted returns. Similarly, the volatility spillovers coefficients are again significant of adjusted returns as well. These outcomes contradict the finding of Hamma et al. (2014), who found the shocks and volatility spillovers oil to Basic Material in case of Tunisia.

Table 6-5: VAR (1)-AGARCH (1,1) Estimates for Oil and Oil and Gas Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Oil and Gas	Oil	Oil and Gas
Panel A: Mean Equation				
$C_{1.0}$	0.001(0.967)		0.005(0.823)	
$\Phi_{1,1}$	-0.004(0.816)		-0.01(0.632)	
$\Phi_{1,2}$	-0.018(0.402)		-0.027(0.034)*	
$C_{2,0}$		0.045(0.031)		0.053(0.010)*
$\Phi_{2,2}$		0.058(0.006)*		0.045(0.020)*
$\Phi_{2,1}$		0.053(0.000)*		0.042(0.000)*
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.001(0.916)		0.000(0.990)*	
$\alpha_{1,1}$	0.020(0.028)		0.015(0.003)	
$\alpha_{1,2}$	-0.011(0.289)		-0.003(0.756)	
$\beta_{1,1}$	0.951(0.000)*		0.957(0.000)*	
$\beta_{1,2}$	0.332(0.085)		0.255(0.056)	
d_1	0.037(0.001)*		0.041(0.000)*	
$\alpha_{2,0}$		0.076(0.002)*		0.055(0.000)*
$\alpha_{2,2}$		0.120(0.000)*		0.131(0.000)*
$\alpha_{2,1}$		0.03(0.068)		0.0000(0.972)
$\beta_{2,2}$		0.767(0.000)*		0.804(0.000)*
$\beta_{2,1}$		0.906(0.109)		0.304(0.375)
d_2		0.062(0.043)*		0.065(0.002)*
Panel C: Residuals Diagnostic				
Q-Stat	3.637(0.603)	10.808(0.055)	1.14(0.951)	8.874(0.114)
ARCH Test	2.06(0.067)	1.246(0.285)	0.979(0.429)	1.427(0.211)
LLH	-15272		-14781	

Note: 1 symbolizes Brent Oil and 2 symbolizes Oil and Gas sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The model estimates for Brent oil and Oil and Gas sector pair have been presented in Table 6.5 for unadjusted and adjusted returns. The estimates of conditional mean for unadjusted returns of Brent oil, and Oil and Gas sector have been reported in Panel A. The results reveal that the return of Oil and Gas sector is affected by own lagged return and Brent oil price can be used to predict the index price of Oil and Gas sector in the short run. While, Brent oil price in the short run is unpredictable from its past and no significant price spillover exist from Oil and Gas sector to Brent oil. These results are consistent with findings about Brent oil in Bret oil/market index pair. The coefficient of Oil and Gas own lagged return is $\Phi_{1,1}$= 0.054 and lagged returns of Brent oil is $\Phi_{2,2}$=

0.058. This implies that 1% increases in the return of Oil and Gas sector is expected to increase its future returns by 0.054%. Similarly, Brent oil return has positive effect on the return of Oil and Gas sector (0.058%). Whereas, estimates for outliers adjusted returns of first conditional moment of Brent oil remains same to those for unadjusted returns. Whereas, the results of conditional mean of Oil and Gas shows that model overestimated the both own lagged and lagged return spillovers from oil market marginally in the presence of outliers. The coefficient value of $\Phi_{1,1}$reduced to 0.042 and $\Phi_{2,1}$reduced to 0.045 from 0.054 and 0.058, respectively.

Similarly, conditional variance estimates of Brent oil and Oil and Gas sector are given in Panel B. The results pronounced that the estimates of $\alpha_{1,1}$, $\alpha_{2,2}$, $\beta_{1,1}$, $\beta_{2,2}$,are statistically significant at the 1% level of significance. This suggests that the conditional volatility of Brent oil is function of its past shock, its past volatility. The Negative as well as positive shock have asymmetric effect on its volatility as indicated by d_1. The estimates of innovations, past volatility and leverage are approximately identical to those reported in Table 6.2 and Table 6.4. Likewise, future volatility of Oil and Gas sector forecastable from its past shocks and past volatility about 0.120 and 0.767, respectively. Negative shocks in Oil and Gas sector increase the volatility 0.062 more than the positive shocks of the same intensity. When returns are adjusted for outliers, the estimates of conditional volatility of Brent oil remains the same. Contrary to this, outliers adjusted returns results reveals that the coefficient of innovations and past volatility of the Oil and Gas sector has been underestimated by the model. The values of the coefficients associated with innovations increased to 0.131 from 0.120. The past volatility (GARCH effect) increased (by 4.8%) from 0.767 to 0.804, respectively.

There is no transmission of volatility neither in the short run nor in the long run between oil market and Oil and Gas sector. When returns are cleaned for outliers, the estimated values of shocks and volatility spillovers coefficients remains insignificant. The outliers in the returns have no effect on the volatility transmission

Table 6-6: VAR (1)-AGARCH (1,1) Estimates for Oil and Industry Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Industry	Oil	Industry
Panel A: Mean Equation				
$C_{1.0}$	-0.004(0.893)		0.005(0.861)	
$\Phi_{1,1}$	-0.005(0.771)		-0.011(0.559)	
$\Phi_{1,2}$	-0.005(0.849)		-0.025(0.199)	
$C_{2,0}$		0.06(0.000)*		0.060(0.000)*
$\Phi_{2,2}$		0.079(0.000)*		0.074(0.000)*
$\Phi_{2,1}$		0.010(0.146)		0.009(0.231)
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.015(0.029)*		-0.003(0.469)	
$\alpha_{1,1}$	0.014(0.158)		0.015(0.005)*	
$\alpha_{1,2}$	-0.011(0.305)		-0.012(0.164)	
$\beta_{1,1}$	0.952(0.000)*		0.961(0.000)*	
$\beta_{1,2}$	0.714(0.069)		0.320(0.139)	
d_1	0.04(0.000)*		0.041(0.000)*	
$\alpha_{2,0}$		0.217(0.004)*		0.082(0.000)*
$\alpha_{2,2}$		0.119(0.000)*		0.124(0.000)*
$\alpha_{2,1}$		-0.022(0.336)		-0.014(0.246)
$\beta_{2,2}$		0.691(0.000)*		0.81(0.000)*
$\beta_{2,1}$		0.772(0.309)		-0.133(0.652)
d_2		0.108(0.016)		0.069(0.010)*
Panel C: Residuals Diagnostic				
Q-Stat	3.54(0.617)	8.563(0.128)	0.997(0.963)	7.586(0.181)
ARCH Test	2.781(0.016)	0.315(0.904)	0.972(0.433)	2.508(0.028)
LLH	-14992		-14388	

Note: 1 symbolizes Brent Oil and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

For Brent oil/Industry sector pair, the results have been displayed in Table 6.6. Panel A, B and C contain the estimates of first conditional moment (mean), second conditional moment (volatility) and results of residuals diagnostic tests. From Panel A, for unadjusted returns, all the coefficients associated with the variables in conditional mean equation of Brent oil are insignificant. Alike, in the conditional mean equation of Industry sector only own lagged variable coefficient is significant. For Brent oil, these findings are identical those when Brent is paired with other sectors discussed above. In the Industry sector, the magnitude of lagged effect is just 0.079. The return transmission results reveal no significant causal relationship between the oil market and Industry sector in the short run. The dynamics of both oil market and Industry sector returns remains the same when the outliers are adjusted. This suggests that outliers have no significant effect on the conditional mean of both oil market returns and Industry sector returns.

The parameter estimates of volatility of Brent/Industry pair for unadjusted returns have been reported in Table 6.6, Panel B. Again, the estimates of volatility parameters of Brent oil market are same to those that were presented in Table 6.3 to Table 6.5 except the parameter estimate of innovations. The coefficients of innovations (ARCH) is insignificant in oil/Industry sector pair. While, Industry sector volatility depends upon own past shocks ($\alpha_{2,2}$) and past volatility ($\beta_{2,2}$) In Industry sector persistence of shocks and volatility is 0.119 and 0.691, respectively. In the Industry sector, the coefficient of asymmetry (d_2) is significant and its value is about 0.108. This reveals that Industry sector returns become more volatile than positive shocks about 0.108 more than positive shock of equal intensity.

Correction of outliers made significant impact on the estimates of volatilities of both Brent oil and Industry sector. The ARCH effect becomes significant in the volatility of Brent oil which is insignificant for unadjusted returns. Its value is approximately equal to those in other pairs. Similarly, in the presence of outliers, ARCH and GARCH effects are underestimated and leverage effect is overestimated by the model. The GARCH effect ($\beta_{2,2}$) is underestimated by 17% and leverage effect (d_2) is overestimated about 37%.

The outcomes for adjusted returns also show no transmission linkages between Brent oil and Industry sector volatility neither in the short run nor in the long run. The correction of outliers has no serious effect on the volatility spillovers estimates.

Table 6-7: VAR (1)-AGARCH (1,1) Estimates for Oil and Consumer Goods Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Consumer Goods	Oil	Consumer Good
Panel A: Mean Equation				
$C_{1.0}$	-0.001(0.967)		0.001(0.960)	
$\Phi_{1,1}$	-0.007(0.710)		-0.012(0.496)	
$\Phi_{1,2}$	0.014(0.569)		0.020(0.470)	
$C_{2,0}$		0.055(0.069)		0.055(0.006)
$\Phi_{2,2}$		0.121(0.000)*		0.125(0.000)*
$\Phi_{2,1}$		0.004(0.632)		0.006(0.247)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.004(0.541)		0.000(0.955)	
$\alpha_{1.1}$	0.018(0.018)*		0.016(0.002)*	
$\alpha_{1,2}$	-0.023(0.108)		-0.004(0.756)	
$\beta_{1,1}$	0.959(0.000)*		0.958(0.000)*	
$\beta_{1,2}$	0.543(0.612)		0.474(0.338)	
d_1	0.041(0.000)*		0.043(0.000)*	
$\alpha_{2,0}$		0.007(0.807)		0.008(0.517)
$\alpha_{2,2}$		0.092(0.008)*		0.090(0.000)*
$\alpha_{2,1}$		-0.007(0.342)		-0.005(0.357)
$\beta_{2,2}$		0.904(0.000)*		0.912(0.000)*
$\beta_{2,1}$		0.003(0.996)		-0.119(0.622)
d_2		0.020(0.178)		0.008(0.575)
Panel C: Residuals Diagnostic				
Q-Stat	3.54(0.617)	8.563(0.128)	1.007(0.962)	2.745(0.739)
ARCH Test	2.781(0.016)	0.315(0.904)	0.882(0.492)	1.873(0.096)
LLH	-14389		-14044	

Note: 1 symbolizes Brent Oil and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

From Panel A of Table 6.7 it has been observed that the LLH value of outliers adjusted models is greater than the LLH values of same model for unadjusted return of oil market and Consumer Goods sector. The estimates of both conditional mean and volatility of oil market show insensitivity to sectors included in the model. The model results are identical to previous finding. The coefficient of lagged return in the conditional mean of Consumer Goods sector is highly significant. The future returns of Consumer Goods sector can be forecast from present ($\Phi_{2,2}$= 0.121). While, no return spillover is found significant between oil market and Consumer Goods sector in either direction. Apart from this, Panel A, the results show that the values of the estimated coefficients and their significance remains the same for outliers adjusted returns as well. Yet again, the correction of outliers has no effect on the dynamics of Brent oil returns and Consumer Goods sector returns.

From Panel B of Table 6.7 for unadjusted returns, it is observed that the past shock and the past volatility and leverage effect are significant in conditional volatility of Consumer Goods. The coefficients ($\alpha_{2,2} = 0.092$, and $\beta_{2,2} = 0.904$) are significant at 1% level. The current shock and volatility in the Consumer Goods sector effect the future volatility about 0.092 and 0.904 respectively. Negative news and positive news in Consumer Goods sector have same effect on the volatility because coefficient d_2 is statistically insignificant.

The empirical findings of volatility spillovers suggest that no significant volatility spillovers neither in the short nor log run is found for unadjusted returns and for adjusted returns volatility spillovers coefficients are remains insignificant.

Table 6-8: VAR (1)-AGARCH (1,1) Estimates for Oil and Healthcare Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Healhcare	Oil	Healthcare
Panel A: Mean Equation				
$C_{1.0}$	0.003(0.929)		0.006(0.840)	
$\Phi_{1,1}$	-0.008(0.713)		-0.012(0.579)	
$\Phi_{1,2}$	-0.005(0.811)		-0.006(0.809)	
$C_{2,0}$		0.072(0.002)*		0.065(0.003)*
$\Phi_{2,2}$		0.117(0.000)*		0.106(0.000)*
$\Phi_{2,1}$		0.024(0.014)*		0.021(0.047)*
Panel B: Variance Equation				
$\alpha_{1.0}$	0.000(0.997)		0.008(0.413)	
$\alpha_{1,1}$	0.016(0.024)*		0.017(0.004)*	
$\alpha_{1,2}$	-0.024(0.01)*		-0.003(0.74)	
$\beta_{1,1}$	0.963(0.000)*		0.964(0.000)*	
$\beta_{1,2}$	0.198(0.844)		-0.528(0.683)	
d_1	0.044(0.000)*		0.041(0.000)*	
$\alpha_{2,0}$		0.158(0.000)*		0.096(0.000)*
$\alpha_{2,2}$		0.131(0.000)*		0.134(0.000)*
$\alpha_{2,1}$		-0.004(0.818)		0.002(0.909)
$\beta_{2,2}$		0.804(0.000)*		0.826(0.000)*
$\beta_{2,1}$		-1.005(0.528)		-1.907(0.573)
d_2		0.031(0.193)		0.028(0.227)
Panel C: Residuals Diagnostic				
Q-Stat	3.232(0.664)	4.431(0.489)	1.005(0.962)	8.589(0.127)
ARCH Test	1.457(0.2)	0.293(0.917)	0.882(0.492)	1.748(0.12)
LLH	-15191		-14794	

Note: 1 symbolizes Brent Oil and 2 symbolizes Healthcare sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The bivariate VAR-AGARCH model results for unadjusted and adjusted returns of Bret/Healthcare sector pair are given in Table 6.8. From Panel A, the first moment results of Brent oil for unadjusted and adjusted returns are identical which are discussed above. Regarding Healthcare sector, the correction of outliers has no impact on the approximation of conditional mean for unadjusted and adjusted returns. These variable coefficients ($\Phi_{2,2}$, $\Phi_{2,1}$) are statistically significant at one percent and five percent. This shows that current return of Healthcare sector is a function of its own lagged return and lagged return of Brent oil. Own past return spillover in Healthcare sector is

0.117(0.106) and from Brent oil is 0.024 (0.021) respectively for unadjusted (adjusted) returns.

Panel B of Table 6.8 reveals that volatility estimates of Brent oil are nearly identical for unadjusted and adjusted return excluding shock spillovers from Healthcare sector for unadjusted returns which is surprisingly significant. Whereas, the volatility estimates of Healthcare sector are equivalent for unadjusted and adjusted returns. Volatility of Healthcare sector depends upon its own shocks and past volatility. No significant spillovers from Brent to Healthcare sector. The results reveal that past shock ($\alpha_{2,2}$) shocks effect is 0.132(0.134) and past volatility ($\beta_{2,2}$) effect is 0.804(0.826) in the current volatility of Healthcare.

The volatility spillovers parameter estimates reveal that there exist no transmission of shock and volatility between Brent oil/ Healthcare sector pair both for unadjusted and adjusted returns is found.

Table 6-9: VAR (1)-AGARCH (1,1) Estimates for Oil and Utility Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Utlity	Oil	Utlity
Panel A: Mean Equation				
$C_{1.0}$	-0.003(0.935)		0.003(0.909)	
$\Phi_{1,1}$	-0.003(0.846)		-0.012(0.527)	
$\Phi_{1,2}$	0.019(0.178)		0.014(0.435)	
$C_{2,0}$		0.002(0.945)		0.003(0.865)
$\Phi_{2,2}$		0.004(0.840)		-0.004(0.823)
$\Phi_{2,1}$		0.024(0.131)		0.01(0.239)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.003(0.696)		-0.005(0.453)	
$\alpha_{1,1}$	0.018(0.007)*		0.016(0.002)*	
$\alpha_{1,2}$	-0.016(0.045)*		-0.011(0.103)	
$\beta_{1,1}$	0.960(0.000)*		0.959(0.000)*	
$\beta_{1,2}$	0.315(0.648)		0.521(0.398)	
d_1	0.039(0.001)		0.041(0.000)*	
$\alpha_{2.0}$		0.147(0.010)*		0.145(0.000)*
$\alpha_{2,2}$		0.082(0.000)*		0.125(0.000)*
$\alpha_{2,1}$		0.030(0.187)		0.009(0.608)
$\beta_{2,2}$		0.821(0.000)*		0.793(0.000)*
$\beta_{2,1}$		2.843(0.533)		0.193(0.849)
d_2		0.058(0.018)*		0.063(0.019)*
Panel C: Residuals Diagnostic				
Q-Stat	3.057(0.691)	3.687(0.595)	0.921(0.969)	3.744(0.587)
ARCH Test	1.567(0.166)	0.683(0.636)	1.039(0.393)	0.782(0.563)
LLH	-16010		-15197	

Note: 1 symbolizes Brent Oil and 2 symbolizes Utility sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

When the Brent oil is paired with Utility sector, model results have been reported in Table 6.9 of unadjusted and adjusted returns. From Panel of Table 6.9 conditional mean results disclose that the returns of Brent and Utility sector cannot be predict from their past, the coefficients $\Phi_{1,1}$and $\Phi_{2,2}$are insignificant. No return spillover is found between Brent and Utility sector. These findings hold even when returns are corrected for outliers.

The empirical estimates of conditional volatility of Brent and Utility sector are reported in Table 6.9 Panel B for unadjusted and adjusted returns. Volatility estimates of Brent oil remain are same with those when oil is paired with other sectors for unadjusted and adjusted returns. The Brent oil volatility results are already discussed in detail above. In Utility sector conditional variance (for unadjusted returns), past innovations (ARCH) and past volatility (GARCH) play an import role to determine current conditional variance. The ARCH ($\alpha_{2,2}$) and GARCH ($\beta_{2,2}$) and asymmetry (d_2) coefficients are significant. The share of innovations and past conditional variance is 0.082 and 0.821 in the current conditional variance of Utility sector. The asymmetry suggests that Utility returns become more volatile (0.058) due to negative shocks as compared to positive shocks of equal magnitude. For adjusted returns, all those coefficients which are significant for unadjusted returns are significant for outliers adjusted returns. The significance of these estimate remains same, but the coefficient values are different. The $\alpha_{2,2}$ =0.125 which is 52% greater than the value of coefficient for unadjusted. Similarly, $\beta_{2,2}$ coefficient is overestimated (3.4%) when returns are not adjusted for outliers. Lastly, the coefficient of asymmetry is overestimated about 9.3% when outlying observations are present in the return data.

For unadjusted return, the short-run volatility spillovers from Healthcare sector is surprisingly significant to Brent oil. But when returns are adjusted for outliers the significant of shock spillovers from Healthcare sector become insignificant. This shows that presence of outliers may suggest spillovers effect falsely.

Table 6-10: VAR (1)-AGARCH (1,1) Estimates for Oil and Financial Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Finanical	Oil	Finanical
Panel A: Mean Equation				
$C_{1.0}$	-0.009(0.769)		0.002(0.949)	
$\Phi_{1,1}$	-0.007(0.716)		-0.012(0.494)	
$\Phi_{1,2}$	0.014(0.581)		0.001(0.957)	
$C_{2.0}$		0.067(0.005)*		0.080(0.000)*
$\Phi_{2,2}$		0.143(0.000)*		0.149(0.000)*
$\Phi_{2,1}$		0.039(0.000)*		0.031(0.011)*
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.005(0.391)		-0.001(0.882)	
$\alpha_{1,1}$	0.011(0.078)		0.016(0.002)*	
$\alpha_{1,2}$	-0.028(0.011)*		-0.011(0.236)	
$\beta_{1,1}$	0.961(0.000)*		0.96(0.000)*	
$\beta_{1,2}$	0.718(0.288)		0.278(0.224)	
d_1	0.039(0.000)*		0.04(0.000)*	
$\alpha_{2,0}$		0.106(0.000)*		0.067(0.000)*
$\alpha_{2,2}$		0.084(0.000)*		0.104(0.000)*
$\alpha_{2,1}$		0.016(0.375)		0.015(0.288)
$\beta_{2,2}$		0.748(0.000)*		0.806(0.000)*
$\beta_{2,1}$		2.298(0.344)		0.359(0.541)
d_2		0.132(0.000)*		0.116(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	3.056(0.691)	10.243(0.069)	1.055(0.958)	11.729(0.083)
ARCH Test	1.204(0.304)	0.732(0.599)	1.07(0.375)	0.754(0.583)
LLH	-15278		-14902	

Note: 1 symbolizes Brent Oil and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The empirical findings of first and second moment of VAR-AGARCH for unadjusted and adjusted returns of Brent/Financial have been exhibited in Table 6.10. Of unadjusted returns, Panel A, Table 6.10 exhibits that in the Brent oil returns cannot be predict from its past and no causal relation is observed from Financial sector to Brent oil. Whereas, Financial sector returns are preceptive to its past returns and past oil market returns as well. The coefficients $\Phi_{2,2} = 0.143$ and $\Phi_{2,1} = 0.040$ are statistically highly significant and positive. Own returns spillovers in Financial sector is overriding the return spillovers from oil market. Likewise, Panel A results of adjusted returns are identical to those for unadjusted returns.

Panel B, Table 6.10 contain the estimates of volatility parameters for unadjusted and adjusted returns of Brent oil and Financial sector. The estimated values of parameter of conditional variance of Brent oil remains same for adjusted and unadjusted returns. The volatility for unadjusted returns of Financial sector disclose that the effect of past shock is 0.084 and past volatility is 0.748. The coefficient of asymmetry is found significant and its value is 0.132. There exists a short run volatility transmission (-0.028) from Financial sector to the oil market. The estimated coefficients of volatility are greater than for adjusted Financial sector returns than the coefficient that were observed for unadjusted returns. This shows that volatility of Financial sector was underestimated by the model due to the outliers. The values of these coefficients are 0.104 and 0.806 respectively. The innovation effect about 23% and volatility effect about 7.8% greater than which is observed for unadjusted returns. In contrast, the asymmetric effect reduced by 13.4%.

The estimates of volatility spillovers between oil market and Financial sector analysis reveals that no linkages between the volatilities neither in the short nor long run of adjusted returns. The short run spillover of volatility which was significant from Financial to oil market for unadjusted returns become insignificant when returns are adjusted for outliers. This confirms that model falsely predict spillovers because of outliers.

Table 6-11: VAR (1)-AGARCH (1,1) Estimates for Oil and Telecom Sector

	Unadjusted Returns		Adjusted Returns	
	Oil	Telecom	Oil	Telecom
Panel A: Mean Equation				
$C_{1,0}$	0.002(0.952)		0.006(0.847)	
$\Phi_{1,1}$	-0.006(0.792)		-0.012(0.550)	
$\Phi_{1,2}$	-0.013(0.370)		-0.007(0.666)	
$C_{2,0}$		-0.014(0.651)		0.014(0.653)
$\Phi_{2,2}$		0.051(0.003)*		0.030(0.060)
$\Phi_{2,1}$		0.021(0.144)		0.021(0.194)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.007(0.422)		0.004(0.515)	
$\alpha_{1,1}$	0.020(0.026)		0.018(0.002)*	
$\alpha_{1,2}$	-0.006(0.504)		-0.005(0.483)	
$\beta_{1,1}$	0.960(0.000)*		0.962(0.000)*	
$\beta_{1,2}$	0.014(0.966)		0.022(0.878)	
d_1	0.039(0.002)		0.039(0.000)*	
$\alpha_{2,0}$		0.201(0.020)*		0.165(0.000)*
$\alpha_{2,2}$		0.096(0.000)*		0.107(0.000)*
$\alpha_{2,1}$		0.059(0.026)		0.033(0.106)
$\beta_{2,2}$		0.830(0.000)*		0.836(0.000)*
$\beta_{2,1}$		1.444(0.343)		-0.096(0.888)
d_2		0.008(0.715)		0.040(0.058)
Panel C: Residuals Diagnostic				
Q-Stat	3.699(0.594)	5.112(0.402)	1.114(0.953)	5.738(0.333)
ARCH Test	1.692(0.133)	0.850(0.514)	0.896(0.482)	1.423(0.213)
LLH	-16520		-15956	

Note: 1 symbolizes Brent Oil and 2 symbolizes Telecom sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

The empirical estimates of VAR-AGARCH model for unadjusted and adjusted returns of Brent/Telecom sector are given in Table 6.11. In Panel A, the estimates conditional means are given and in Panel B, the estimates of conditional variance are given. From Panel A and B, the coefficient estimates of conditional mean and volatility of Brent oil returns are approximately same for unadjusted and adjusted returns and we have already discussed these results. From Panel A, the returns of Telecom sector show some dependency on its past for unadjusted returns. No association is found between returns of Brent oil and Telecom sector. The return of Telecom sector influenced by their past returns about 0.051. For adjusted returns, result reveals Telecom sector returns are not influenced by their past. The coefficient $\Phi_{2,2}$ become insignificant for adjusted returns which confirms no return spillover from oil to Telecom sector.

From Panel B, the result reveals that coefficients $\alpha_{2,2}$, and $\beta_{2,2}$, are significant at 1% level. This shows that conditional variance of Telecom sector influenced by own past shocks (0.096) and past conditional variance (0.830). No risk transmission between Brent oil and Telecom sector of PSX. The estimates of conditional variance of Telecom sector are approximately same when model was estimated using outliers filtered returns.

The empirical estimates of volatility transmission between Brent oil and Telecom sector suggest no linkages between Brent oil and Telecom sector

Table 6-12: Conditional Correlation Between Oil and Stocks

	Brent Oil	
	Unadjusted Returns	Adjusted Returns
KSE-100 Index	0.029(0.091)	0.029(0.073)
Basic Material Sector	0.015(0.57)	0.022(0.199)
Oil and Gas Sector	0.051(0.002)*	0.048(0.003)*
Industry Sector	0.038(0.021)*	0.031(0.018)*
Consumer Goods Sector	0.011(0.525)	0.02(0.237)
Healthcare Sector	0.01(0.398)	0.005(0.475)
Utility Sector	0.011()	0.019()
Financial Sector	0.022(0.208)	0.03(0.069)
Telecom Sector	0.019(0.186)	0.026(0.101)

Note: * shows significance at 5% level.

The constant conditional correlation (CCC) between Brent oil returns and stock returns of Pakistan Stock Exchange has been depicted in Table 6.12 for unadjusted and adjusted returns. It is observed that estimates of conditional correlation between Brent oil returns and market index, and Brent oil and sectoral stocks are very low. For unadjusted returns, correlation is positive and significant only between Brent oil/ Oil and Gas and between Brent oil/Industry pairs. The correlation between Brent oil and Oil and Gas sector is 0.051 and between Brent oil and Industry sector is 0.038. only. The results of correlation between Brent prices and stock indices are identical but the estimated values of correlation are lesser for unadjusted returns. The correlation between Brent and Oil and Gas is 0.048. and between Brent and Industry is 0.031, respectively. Whereas, the correlation of Brent with Financial is 0.03 which is greater than of unadjusted returns and become significant at 10% level of significance. The CCC between Brent oil and KSE-100 index is 0.029 and significant at ten percent level of both unadjusted and adjusted returns separately.

Lastly in Panel C of Table 6.4 to 6.11, results of diagnostic tests, based on the standardized residuals, to check the adequacy of the models have been presented. The empirical statistics of the Engle (1982) LM-ARCH test for conditional heteroscedasticity and Ljung and Box (1978) Q-test for autocorrelation are calculated. Panel C, the results illustrate that the standardized residuals are no more heteroscedastic and auto-correlated. Therefore, the empirical findings suggest that estimated models are reliable since there is generally no deviation for standard regression assumptions.

6.4 Portfolio Weights and Hedge Ratios

The optimal weights and hedge ratios results have been depicted in Table 6.13 for both unadjusted and adjusted returns. For unadjusted returns, outcome reveals that optimal average portfolio weight ranges from 0.49 to 0.75 for Telecom sector and market index respectively in stock/Brent oil portfolio. This indicates that on average in $100 investment investor ought to invest $75 in to PSX and $25 in Brent oil to minimize his investment risk without lowering his expected returns. Similarly, the optimal holding of Basic Material is about 66% and of Brent oil is about 34% in Basic Material sector/Brent oil portfolio. On the other hand, to minimize risk of investment investor may invest 64% in Oil and Gas sector and 36% in Brent oil in Oil and Gas sector/Brent oil two assets portfolio. Likewise, the optimal weight of Industry sector is about 66%, Consumer Goods sector is about 71%, Utility sector (55%), Financial sector (64%), Healthcare sector (64%) and the weights of Telecom sector in Telecom sector/Brent oil portfolio is about 49%. Overall these findings pronounced that the investor should hold more stocks than oil if (s)he wants to construct an optimal portfolio which includes stock (market index or sectoral stocks) from Pakistan Stock Exchange and Brent oil except Telecom sector. In case of Telecom sector stock an investor should invest equally in both Telecom sector and Brent oil in order to minimize his risk These results for portfolio weights are consistence with findings of (Arouri et al., 2012; Bouri, 2015; Hamma et al., 2014; Jouini, 2013). Contrasting the portfolio weights the average hedge ratios are very small for long position in Brent oil. For Utility/oil portfolio, the average value of hedge ratio is 0.01 which indicates that one-dollar long position in Brent oil can be shorted by just one cent of Utility stock sector. Similarly, the hedge ratio is about 0.07 for Industry/oil portfolio. This suggests that long position in Brent oil can be shorted by Industry sector stock just about 7 cents.

The correction of outliers does not have significant impact on the estimate portfolio weights and hedge ratios in all Brent/stock portfolios. From Table 6.13, it is observed that the average values of both weights and hedge ratios are approximately identical to those for unadjusted returns. The correction of outliers has no effect on the estimated values of optimal weights except Utility sector/oil and Telecom sector/oil portfolios. For these portfolios the share of stock in the portfolio increased slightly. Whereas, the average values of hedge ratios are approximately identical to those of unadjusted returns. Overall presence or absence of outliers in the returns have no effect on these statistics. These findings are not inline to the findings of Chapter 5 in which a significant effect of outliers was observed on the estimates of portfolio weights and hedge ratios.

Table 6-13: Optimal Weights and Hedge Ratios

	Unadjusted Returns		Adjusted Returns	
	Weights	Hedge Ratio	Weight	Hedge Ratio
KSE-100 Index/Oil	0.75	0.06	0.75	0.06
Basic Material Sector/Oil	0.66	0.02	0.67	0.03
Oil and Gas Sector /Oil	0.64	0.07	0.65	0.07
Industry Sector /Oil	0.66	0.06	0.68	0.05
Consumer Goods Sector /Oil	0.71	0.02	0.71	0.04
Health Care Sector /Oil	0.64	0.01	0.64	0.01
Utility Sector /Oil	0.55	0.01	**0.60**	0.03
Financial Sector /Oil	0.64	0.03	0.63	0.04
Telecom Sector /Oil	0.49	0.02	**0.52**	0.03

Note: The table reports average optimal weight and hedge ratios for oil-stock portfolio.

In short, the results reveal that by adding oil in the portfolio along with stock, the risk adjusted performance of portfolio can be increased. These results also point out the fact that there is difference in optimal weights and hedge ratio. This is an indication of dissimilarities in the characteristics of stock sectors such as firm's business, no of firms and liquidity.

6.5 Summary

This chapter has thoroughly analyzed the return and volatility and their linkages between Pakistan Stock Exchange (market and sectoral level) and Brent oil, taking into account the outliers. The world oil price has been proxied by the Brent oil price. The daily data has been used in this analysis which is retrieved from DataStream of Thompson Reuters from 1stJanuary 2001 to 31st December 2015. The effect of outliers on the portfolio weights and hedge ratios has also been analyzed.

The estimates of bivariate VAR-AGARCH model has been presented in Table 6.2 to 6.11. The estimates of mean and variance of Brent oil returns are not stock specific. The estimated values of parameters of first and second conditional moments of Brent oil are approximately identical in all pairs of Brent oil/stock. The findings confirm our findings in Chapter 4; that at market level both mean, and volatility estimates are approximately insensitive to other market. These findings are aligned with Demiralay and Gencer (2014); for emerging market sectors using weekly data and estimated the same model. On the other hand, these findings are not in line with Jouini (2013) in case of Saudi Arabia and of Arouri et al. (2012) in case of Europe. Whereas, the estimates of conditional mean and conditional variance varies across stock indices (market and sectoral stock indices). These findings are aligned with findings of Chapter 4 and Chapter 5. The findings are consistent with Bouri et al. (2016), Jouini (2013) and Arouri et al. (2012) .

The future return of Brent oil cannot be forecast from their current return in all pairs of oil/stock and no significant return spillovers is found from stock to Brent oil. These empirical findings are supported by Hamma et al. (2014) in case of Tunisia. And against the findings of Demiralay and Gencer (2014) for emerging sectors, Jouini (2013) in case of Saudi Arabia, Arouri, Lahiani, et al. (2011) for Bahrain and Qatar, and Arouri et al. (2011) for Europe and the US. Apart from this, index price (market index and sectoral indices) can be forecast from present index except Utility sector index in the short run. Same conclusion was drawn about KSE-100 index in Chapter 4 and some of the selected stock sector indices in Chapter 5 as well.

The results regarding returns spillovers show that return spillovers from Brent oil is significant for market index as well as sectoral stock (four out of eight sectors) indices of Pakistan Stock Exchange. These findings are not consistent with the outcomes of Jouini (2013) who did not found any spillovers between oil price and stock in case of KSA and consistent with the findings of Bouri (2015). The Oil and Gas sector is more sensitive to past return followed by market index. The return spillovers effects from

Brent oil to stocks are very weak. When returns are corrected for outliers the lagged return coefficient of Telecom sector become insignificant which is significant for unadjusted returns. Overall, the return dynamics of oil and stock (aggregate and disaggregate) and returns linkages across oil and stock remains the same. No significant change in the estimates of conditional means of both oil and stocks. This shows that the correction of outliers has no impact on the dynamics of conditional mean of both Brent oil and stock. The second conditional moment (volatility) of Brent oil is relatively stable and volatility persistence is very high. The volatility of Brent oil revolves around its past. Whereas, the Pakistani stocks are jumpy because of large ARCH coefficients. Among sector stock indices, Consumer Goods sector index is more volatile followed by Telecom sector. No evidence of significant shock and volatility transmission from Brent oil to Pakistani stock market as well as stock sectors of Pakistan Stock Exchange. Surprisingly shock spillovers is significant and negative from Healthcare, Utility and Financial sector to Brent oil. The constant conditional correlation between Brent and stock is very low, even insignificant for many cases.

The conditional variance estimates of Brent oil for outliers adjusted returns are approximately identical to those for unadjusted returns. This reveals that the presence of outliers in returns of Brent oil price have no effect on the estimates of its conditional variance. The constant in the conditional volatility of sectoral stock indices is less than the conditional variance of unadjusted returns. This is consistent with findings of Carnero et al. (2006) who showed that model always overestimate the constant of conditional variance. The empirical finding shows that six out of nine, the effect of both innovations and past volatility is greater than of adjusted returns than of unadjusted returns. This suggests that the presence of isolated outliers in the returns Carnero et al. (2006). In one case the innovation effect reduced and past volatility effect increased this suggest the presence of consecutive outliers in the data Carnero et al. (2006). The asymmetry in the volatility is significant for PSX, the Basic Material index, Oil and Gas sector, Industry sector, Healthcare sector and Financial sector. These coefficients are biased upward as the estimated coefficient values are reduced for adjusted returns. The outcomes are consistent with Carnero et al. (2016) which pointed out true asymmetry in the volatility may be hidden by the outliers. The results show that the strength of relationship between Brent and stock remains the same for unadjusted and adjusted returns.

The results for the optimal portfolio weights and hedge ratios suggests making oil part of a diversified portfolio of stocks increase its risk-adjusted performance and have more stocks than Brent oil. It is also observed that optimal weights and hedge ratios differ across stock sectors, due to the difference in their characteristics. These outcomes are robust to the outliers in the returns.

Chapter 7: Conclusions and Recommendations

7.1 Introduction

The existing literature on Pakistan Stock Exchange (PSX) is focused on examining relationship between first moment of PSX with other financial markets. The classic studies either employed VAR or cointegration for estimating intermarket relationship. Some studies take exceptions by examining the volatility spillovers between Pakistan Stock Exchange and other financial markets using augmented GARCH family models in univariate framework. It is an established fact in the available empirical literature that presence of outliers has adverse effects on the estimates and properties of univariate GARCH models. The effects of outliers on the return and volatility and their spillovers have rarely been studied using multivariate GARCH models. This study bridges the gap in the existing literature by probing in to the effects of outliers on the estimates of return and volatility and their spillovers using bivariate GARCH model.

This study has examined the effect of outliers on the return and volatility, and their spillovers between Pakistan Stock Exchange and selected stock markets of different countries, between selected sectors of stock market of Pakistan and then between Pakistan Stock Exchange and Brent oil. Impact of outliers on the estimates of optimal portfolio weights and hedge ratios have also been analyzed. This thesis used daily data from 01-01-2001 to 31-12-2015 taken from DataStream of Thompson Reuters

This study employed recently proposed Laurent et al. (2016) and Charles and Darné (2005) methods for simultaneous detection and correction of outliers. To explore the effect of outliers on the return and volatility and their spillovers, this study estimated the VAR(1)-GARCH(1,1) model of Ling and McAleer (2003) and VAR(1)-AGARCH(1,1) model of McAleer et al. (2009) for both outliers unadjusted and adjusted returns. These models are being capable of capturing both returns and volatility dynamics, and their spillovers simultaneously (for detail see section 3.2). The estimates from these models are then used to construct the optimal portfolio weights and hedge ratios for both unadjusted and adjusted returns. The discussion below is based on the finding of VAR-AGARCH model.

7.2 Conclusions

The dynamic structure of conditional mean and conditional variance of Pakistan Stock Exchange is approximately neutral to other markets in bivariate model as found in Chapter 4. The difference in the estimated values of first and second moment coefficients is small when PSX was paired with world selected stock markets except the volatility intercept. The autoregressive term in return of PSX is significant in all pairs of PSX with world selected stock markets, providing an evidence of return predictability in PSX. The volatility of stock market of Pakistan is sensitive to past market socks and past volatility; these coefficients are significant in all pairs. The negative and positive shocks in Pakistan Stock Exchange have significantly different effect on its volatility. The negative shocks likely to increase its volatility (0.124 to 0.148) in all pairs more than a positive shock of the same intensity. The results of mean equation of PSX indicate that the current returns are significantly affected by the past returns of the US (0.06), UK (0.065), Euro (0.053) and Indian (0.036) stock markets. This indicates the presence of positive returns spillovers from these markets to PSX. The volatility of PSX is sensitive to unexpected shocks that effect the dynamics of returns of the US, UK and Euro markets. Pakistan Stock Exchange shocks have significant negative effect (-0.033) on the volatility of Chinese stock market and both shocks (0.03) and volatility (0.452) spillovers is found significant from PSX to Indian stock market.

When returns are adjusted for outliers and model was re-estimated, results illustrate that the estimates of conditional mean and variance of PSX become more stable, as the disparity in these estimates reduced considerably in all pairs of PSX/other. For example, ARCH effect maximum variation in different pairs reduced to 6.8% from 20.2% and leverage effect reduced to 6.1% from 19.3%. Similarly, parameters of mean and variance equations are underestimated (overestimated) and in some pairs they are incorrectly shown to be significant (insignificant). The volatility constant of PSX is overestimated (80.5% in Pakistan/Japan pair) in all pairs and its value reduced to 0.047 to 0.085 when returns are cleaned for outliers. The leverage effect is significant but underestimated in all pairs due to presence of outliers. The return spillovers from the US, the UK, Euro region and India were overvalued (overestimated) and return spillover from Japan was found insignificant towards PSX which become significant at 1% level when returns are adjusted for outliers. In presence of outliers, the model wrongly confirmed shock spillovers from the UK to PSX. The shock spillovers from the Euro to Pakistan Stock Exchange and volatility spillovers from PSX to Indian stock market are overestimated by the model.

The coefficients of CCC between Pakistan Stock Exchange and selected stock markets of the world was very low. The correction of outliers from returns of PSX and selected stock markets of the world showed that linear relationship is slightly overestimated by the models due to the presence of outliers. The correlation between PSX and world selected stock markets is very weak but significant (the US and Sri Lanka) at 1% for both unadjusted and adjusted returns. The average values of optimal portfolio weights and hedge ratios showed that in two assets portfolio, the average weights and hedge ratios vary across pairs of markets and the correction of outliers have no significant effect on these statistics.

From the perspective of investment, results of optimal portfolio weights suggest that proportion of investment in Pakistan Stock Exchange is different for other market in the portfolio. Portfolio weights suggest that investor may invest more than 50% of his investment in Pakistan Stock Exchange in four out of seven pairs of PSX with selected stock markets of the world to reduce his risk without lowering his expected returns. The hedge ratios are very low which provide hedging opportunity that minimize the risk exposure of investment. The correction of outliers from stock returns have a very minor effect on the estimates of both portfolio weights and hedge ratios.

The returns and volatility spillovers between sectors of Pakistan Stock Exchange and effect of outliers on the estimates have been studied in Chapter 5. The parameter estimates of conditional mean and conditional variance of a sector are sensitive to other sectors in the pair. These results are not in line with the at market level (Chapter 4) findings in which parameter estimates of PSX are insensitive to other stock market in model.

The results show that the estimates of conditional mean are more sensitive to other sector than the estimates of conditional variance. The autoregressive term in mean equation of Oil and Gas sector was more sensitive to other sector and become insignificant in Oil and Gas sector/Industry sector pair. The leverage effect was significant in three out of four pairs in Financial sector and only once in four pairs in Basic Material sector and Industry sector. There is no interdependence between the sector returns of PSX excluding Industry sector and Financial sector. The Financial sector lagged returns affect the Industry sector about 0.066. Contrary to this, volatilities of these sectors were more or less sensitive to other sector activities. Unidirectional shock spillovers were found significant from Industry sector to Oil and Gas sector (-

0.069), Financial sector (-0.065) and Consumer Goods sector (-0.015). But bidirectional shock spillover was found significant between Basic Material sector and Industry sector of PSX. The shocks effect of Basic Material (Industry) sector to Industry (Basic Material) sector is -0.048 (0.075). Whereas, past volatility of Basic Material sector, Oil and Gas sector and Financial sector had significant effect on the volatility of Industry sector and Industry sector transmit its volatility to Consumer Goods sector only. Long run volatility spillovers from Basic Material sector (0.481), Oil and Gas sector (0.308) and Financial sector (0.29) to Industry sector were very high. In addition, volatility spillover from Industry sector to Consumer Goods sector was 0.083. While, bidirectional volatility spillovers only exist between Basic Material sector and Oil and Gas sector. Volatility transmission from Basic Material to Oil and Gas sector was 0.261 whereas, transmission of volatility from Oil and Gas to Basic Material was 0.183.

The model has been re-estimated for all sectoral stock pairs for outliers adjusted returns. The empirical finding reveals that the coefficient estimates of mean and volatility are sensitive to the outliers. The estimates of mean and variance equation of sectoral stock returns are overvalued (undervalued) by the model due to presence of outliers. The findings are not inline with the results at aggregate level (Chapter 4). The return and volatility spillover effects are also affected by outliers and in some pairs, model fallaciously postulate (hide) spillovers of return and volatility between sectors. The lagged returns coefficient variation due to change of other sectors in the pair increased for all sector (except Financial sector). This shows that model does not detect exact predictability of a sector returns when it is paired with other sectors because of outlier's presence. The variation in the values of ARCH effect of Basic Material sector, Oil and Gas sector, Industry sector and Financial sector and reduced but increased in Consumer Goods sector in different pairs when return is adjusted for outliers. When a sector is paired with other sectors then for all sectors the variation in GARCH coefficient is reduced except the Basic Material sector for outliers adjusted returns. In presence of outliers, leverage effect is overestimated (underestimated) and its significance in Industry sector is wrongly suggested by the model.

The return spillovers from Financial sector to Industry sector is overvalued (24.5%) by the model and significant return spillovers (0.043) from Industry to Oil and Gas wiped out due to the outliers. The effect of outliers on the volatility spillovers is stronger as compare to shock spillovers. The model is unable to capture the reciprocal shock transmission between Basic Material sector and Oil and Gas sector. Furthermore, the model fails to account for bidirectional shock and volatility spillovers between Basic Material sector and Financial sector of PSX. Contrary to the results of Chapter 4, the presence of outliers affects the coefficient of conditional correlation, optimal portfolio weights and hedge ratio of sector of PSX. The constant conditional correlation between sectors of PSX has been overestimated by the model, in all pair of sectors, because of outliers.

In bivariate model of oil and stock, the estimates of Brent oil first and second conditional moments were insensitive to stock in the pair (see chapter 6). Estimates of return and volatility of Pakistan Stock Exchange at aggregate level were consistent with the findings of chapter 4 when paired with world oil market. Whereas, the estimates of conditional mean and volatility of different stock sectors were different when they were paired with Brent oil. The Brent oil future price cannot be forecasted from its current price (autoregressive coefficient is insignificant). Whereas, current stock returns seem to influence future returns except the Utility sector. The second conditional moment (volatility) of Brent oil is relatively stable (ARCH coefficient is between 0.011 to 0.020) and volatility persistence (GARCH effect) is very high (ranges from 0.951 to 0.963).

This shows that volatility of Brent oil revolves around its past volatility. Whereas, the Pakistani stocks are jumpy because of large coefficient of ARCH effect (varies from 0.081 to 0.131). Among stock sectors, volatility persistence (GARCH) is high (low) in Consumer Goods (Industry) sector. The volatility of stock market (aggregate and sectoral level) is more sensitive to negative shocks as compare to the oil market. The Brent oil returns looks to affect the market returns and four out of eight sector's returns, the return spillovers coefficient from Brent oil to stock is significant in these pairs. Whereas, no reciprocal return spillover is significant from stock to oil market returns. The Oil and Gas sector was more perceptive to oil price fluctuation in the short run. The unexpected shocks in world oil market have insignificant effect on the stock market (aggregate and sectoral) of Pakistan. Similarly, no risk (volatility) transmission from Brent oil to Pakistan Stock Exchange (aggregate and sectoral) was observed. Surprisingly shock spillovers is found significant from three sectors (Healthcare, Utility and Financial) to Brent oil.

The presence of outliers has no significant effect on the estimates of lagged returns coefficient of Brent oil in all pairs of oil-stock. The estimated coefficient of lagged returns of Brent oil is insignificant for adjusted returns as well in all pair. While, in the stock (market and sector), model overestimated the lagged returns effect except Consumer Goods sector and wrongly suggest its significance in Telecom sector due to presence of outliers. However, outliers adjusted returns model estimates reveal that conditional variance coefficient of Brent oil remain almost similar to the unadjusted returns. While, the outliers significantly affect the conditional variance of stock (market and sector) returns. These findings are consistent with Chapter 4 and 5. Both ARCH and GARCH effects are underestimated in six out of nine oil/stock pair due the presence of outliers. Constant in the volatility of stock returns is overestimated in all pairs of oil and stock. The effect of outliers on the estimate of leverage effect is not clear Presence of outliers does not change the spillovers effect from the Brent oil to stock both in mean and variance equations. The spillover coefficients remain insignificant for adjusted returns as well. However, the shock spillovers from Healthcare, Utility and Financial sectors which were significant for unadjusted return become insignificant when returns are cleaned for outliers. This leads to the conclusion that model may suggest significant spillovers, which are actually not present, just because of few outliers.

The constant conditional correlation between Brent oil and stock is very low, even insignificant for many cases. Similarly, the outliers have no effect on the estimated values of optimal weights and hedge ratio. The average value of weight and hedge ratios are almost same for unadjusted and adjusted returns. To minimize the investment risk, on average the investor may hold more stock than oil in case of investment in stock assets from Pakistan and Brent oil. It is also observed that optimal weights and hedge ratios differ across stock sectors due to the difference in their characteristics. These findings are robust to the outliers in the returns.

7.3 Recommendations

The presence of outliers has a significant effect on estimates of GARCH family of models in univariate framework. It has been observed that outliers have significant effect on the estimates of return and volatility spillover in bivariate GARCH models. In the light of these findings, it is recommended that outliers may be detected and corrected when dealing with high frequency financial data to get reliable estimates. This study revealed that the effect of outliers is more visible at disaggregated level than aggregate level. It is therefore recommended that investor who wants to diversify his investment portfolio, may take care of unexpected events (outliers).

From investor's point of view, who wants to diversify his investment by simultaneously investing in Pakistan Stock Exchange and international stock markets, it is recommended that investor may consider the sensitivity of PSX with other international stock markets. The optimal portfolio weights suggest that investor may adjust his investment in PSX according to other stock market in the pair. If an investor is investing in PSX only, he may not take investment decision by only looking at the overall market performance but may also consider the performance of different sectors.

If an investor is investing in oil market and wants to diversify his investment by investing in PSX, he may not consider only the overall performance of PSX rather he may also consider the performance of different sectors of PSX. It is suggested that in order to minimize his investment risk without lowering his expected returns, his share of investment should be greater in PSX than oil.

7.4 Direction for Future Research

First, this thesis employs daily data to explore the return and volatility spillovers and effect of outliers on these estimates. It is quite interesting to re-examine the same issue using intraday data. This might give more visible picture regarding the effect of outliers on the estimates of returns and volatility. Second, this thesis investigated the return and risk linkages between Pakistan Stock Exchange and selected stock markets of the world by considering the presence of outliers. One can also explore the returns and volatility spillovers between stock market of Pakistan and world stock markets at sector level. Third, it is interesting to study the effect of outliers on returns and volatility spillovers between leading firms listed at stock market of Pakistan. Fourth, this thesis estimated model with constant conditional correlation one may apply models which are capable to capture the dynamics of conditional correlation between different assets in the model. Fifth, this study is restricted to stock market and oil market only, researcher may consider other financial markets like forex market, bond market, grain market to investigate relationship with stock market.

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Appendix 1

Table A-1-1 to Table A-1-7 represent the model estimates of both unadjusted and adjusted returns of Pakistan Stock Exchange and world selected stock markets when returns are adjusted for outliers using Charles and Darné (2005) method.

Table A-1-1: Bivariate VAR (1)-AGARCH (1,1) Model for Pakistan and the USA

	Unadjusted Returns		Adjusted Returns	
	Pakistan	US	Pakistan	US
Panel A: Mean Equation				
$C_{1,0}$	0.095(0.000)*		0.097(0.000)*	
$\Phi_{1,1}$	0.097(0.000)*		0.105(0.000)*	
$\Phi_{1,2}$	0.060(0.000)*		0.080(0.000)*	
$C_{2,0}$		0.01(0.449)		0.010(0.521)
$\Phi_{2,2}$		-0.052(0.002)*		-0.050(0.003)*
$\Phi_{2,1}$		0.002(0.812)		-0.001(0.96)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.077(0.000)*		0.067(0.000)*	
$\alpha_{1,1}$	0.101(0.000)*		0.096(0.000)*	
$\alpha_{1,2}$	0.054(0.040)*		0.057(0.011)*	
$\beta_{1,1}$	0.775(0.000)*		0.78(0.000)*	
$\beta_{1,2}$	0.581(0.522)		0.985(0.498)	
d_1	0.135(0.000)*		0.129(0.000)*	
$\alpha_{2,0}$		0.016(0.000)*		0.015(0.000)*
$\alpha_{2,2}$		-0.024(0.000)*		-0.025(0.000)*
$\alpha_{2,1}$		-0.006(0.369)		-0.007(0.271)
$\beta_{2,2}$		0.934(0.000)*		0.942(0.000)*
$\beta_{2,1}$		-0.21(0.287)		-0.252(0.276)
d_2		0.159(0.000)*		0.146(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	11.894(0.036)	5.639(0.343)	10.603(0.06)	5.704(0.336)
ARCH Test	0.505(0.772)	2.609(0.023)	1.009(0.41)	2.123(0.06)
LLH	-11281		-11163	

Note: 1 symbolizes Pakistan tor and 2 symbolizes US. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-2: VAR (1)-AGARCH (1,1) Estimates for Pakistan and the UK

	Unadjusted Returns		Adjusted Returns	
	Pakistan	UK	Pakistan	UK
Panel A: Mean Equation				
$C_{1,0}$	0.098(0.000)*		0.098(0.000)*	
$\Phi_{1,1}$	0.093(0.000)*		0.099(0.000)*	
$\Phi_{1,2}$	0.065(0.007)		0.083(0.000)*	
$C_{2,0}$		-0.001(0.929)		0.000(0.98)
$\Phi_{2,2}$		-0.041(0.012)*		-0.039(0.005)*
$\Phi_{2,1}$		-0.012(0.269)		-0.011(0.277)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.079(0.000)*		0.066(0.000)*	
$\alpha_{1,1}$	0.101(0.000)*		0.095(0.000)*	
$\alpha_{1,2}$	0.061(0.049)*		0.044(0.031)*	
$\beta_{1,1}$	0.786(0.000)*		0.788(0.000)*	
$\beta_{1,2}$	0.011(0.978)		0.258(0.534)	
d_1	0.127(0.000)*		0.121(0.000)*	
$\alpha_{2,0}$		0.019(0.000)*		0.017(0.000)*
$\alpha_{2,2}$		-0.012(0.086)		-0.009(0.266)
$\alpha_{2,1}$		-0.006(0.557)		-0.005(0.574)
$\beta_{2,2}$		0.907(0.000)*		0.915(0.000)*
$\beta_{2,1}$		0.0000(0.997)		-0.02(0.793)
d_2		0.175(0.000)*		0.156(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	12.816(0.025)	4.492(0.481)	11.352(0.045)	5.235(0.388)
ARCH Test	0.482(0.79)	1.284(0.268)	0.872(0.499)	1.228(0.293)
LLH	-11290		-11177	

Note: 1 symbolizes Pakistan tor and 2 symbolizes UK. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-3: Bivariate VAR (1)-AGARCH (1,1) Model for Pakistan and Euro Region

	Unadjusted Returns		Adjusted Returns	
	Pakistan	Euro	Pakistan	Euro
Panel A: Mean Equation				
$C_{1.0}$	0.096(0.000)*		0.097(0.000)*	
$\Phi_{1,1}$	0.094(0.000)*		0.100(0.000)*	
$\Phi_{1,2}$	0.053(0.000)*		0.062(0.000)*	
$C_{2,0}$		0.005(0.758)		0.006(0.697)
$\Phi_{2,2}$		-0.02(0.232)		-0.016(0.385)
$\Phi_{2,1}$		-0.001(0.957)		-0.004(0.763)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.078(0.000)*		0.070(0.000)*	
$\alpha_{1,1}$	0.099(0.000)*		0.093(0.000)*	
$\alpha_{1,2}$	0.053(0.014)*		0.045(0.017)*	
$\beta_{1,1}$	0.786(0.000)*		0.791(0.000)*	
$\beta_{1,2}$	0.044(0.901)		0.142(0.723)	
d_1	0.131(0.000)*		0.125(0.000)*	
$\alpha_{2,0}$		0.023(0.000)*		0.021(0.000)*
$\alpha_{2,2}$		-0.029(0.000)*		-0.027(0.000)*
$\alpha_{2,1}$		-0.015(0.162)		-0.016(0.054)
$\beta_{2,2}$		0.928(0.000)*		0.937(0.000)*
$\beta_{2,1}$		-0.042(0.591)		-0.076(0.392)
d_2		0.178(0.000)*		0.158(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	12.093(0.034)	14.349(0.014)	10.686(0.058)	14.347(0.014)
ARCH Test	0.459(0.807)	3.705(0.002)	0.833(0.526)	2.78(0.016)
LLH	-12033		-11919	

Note: 1 symbolizes Pakistan tor and 2 symbolizes Euro Region. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-4: Bivariate VAR (1)-AGARCH (1,1) Model for Pakistan and Japan

	Unadjusted Returns		Adjusted Returns	
	Pakistan	Japan	Pakistan	Japan
Panel A: Mean Equation				
$C_{1,0}$	0.094(0.000)*		0.095(0.000)*	
$\Phi_{1,1}$	0.092(0.000)*		0.100(0.000)*	
$\Phi_{1,2}$	0.029(0.053)		0.041(0.007)*	
$C_{2,0}$		0.019(0.346)		0.024(0.259)
$\Phi_{2,2}$		-0.019(0.310)		-0.018(0.309)
$\Phi_{2,1}$		0.014(0.435)		0.013(0.479)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.085(0.000)*		0.066(0.002)*	
$\alpha_{1,1}$	0.100(0.000)*		0.095(0.000)*	
$\alpha_{1,2}$	-0.022(0.210)		-0.015(0.521)	
$\beta_{1,1}$	0.784(0.000)*		0.781(0.000)*	
$\beta_{1,2}$	-0.002(0.996)		0.184(0.569)	
d_1	0.139(0.000)*		0.133(0.001)*	
$\alpha_{2,0}$		0.044(0.000)*		0.033(0.001)*
$\alpha_{2,2}$		0.04(0.001)*		0.03(0.000)*
$\alpha_{2,1}$		0.004(0.818)		-0.004(0.751)
$\beta_{2,2}$		0.885(0.000)*		0.908(0.000)*
$\beta_{2,1}$		0.053(0.501)		0.018(0.814)
d_2		0.097(0.000)*		0.088(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	14.72(0.012)	1.87(0.867)	13.127(0.022)	1.088(0.955)
ARCH Test	0.36(0.876)	0.764(0.576)	0.727(0.603)	2.177(0.054)
LLH	-12550		-12397	

Note: 1 symbolizes Pakistan tor and 2 symbolizes Japan. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-5: VAR (1)-AGARCH (1,1) Estimates for Pakistan and China

	Unadjusted Returns		Adjusted Returns	
	Pakistan	China	Pakistan	China
Panel A: Mean Equation				
$C_{1.0}$	0.093(0.000)*		0.095(0.000)*	
$\Phi_{1,1}$	0.094(0.000)*		0.103(0.000)*	
$\Phi_{1,2}$	0.017(0.098)		0.019(0.14)	
$C_{2,0}$		0.001(0.972)		0.004(0.887)
$\Phi_{2,2}$		0.011(0.492)		0.008(0.666)
$\Phi_{2,1}$		0.011(0.461)		0.007(0.733)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.081(0.000)*		0.067(0.000)*	
$\alpha_{1,1}$	0.098(0.000)*		0.093(0.000)*	
$\alpha_{1,2}$	-0.011(0.479)		-0.009(0.612)	
$\beta_{1,1}$	0.791(0.000)*		0.786(0.000)*	
$\beta_{1,2}$	0.001(0.998)		0.278(0.551)	
d_1	0.128(0.000)*		0.128(0.000)*	
$\alpha_{2,0}$		0.021(0.033)		0.022(0.006)*
$\alpha_{2,2}$		0.053(0.000)*		0.053(0.000)*
$\alpha_{2,1}$		-0.033(0.015)*		-0.021(0.153)
$\beta_{2,2}$		0.912(0.000)*		0.926(0.000)*
$\beta_{2,1}$		0.335(0.081)		0.137(0.405)
d_2		0.030(0.022)*		0.014(0.244)
Panel C: Residuals Diagnostic				
Q-Stat	14.762(0.011)	12.664(0.027)	12.777(0.026)	12.029(0.034)
ARCH	0.367(0.872)	0.309(0.908)	0.709(0.616)	0.706(0.619)
LLH	-12863		-12657	

Note: 1 symbolizes Pakistan tor and 2 symbolizes China. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-6: VAR (1)-AGARCH (1,1) Estimates for Pakistan and India

	Unadjusted Returns		Adjusted Returns	
	Pakistan	India	Pakistan	India
Panel A: Mean Equation				
$C_{1.0}$	0.097(0.000)*		0.097(0.000)*	
$\Phi_{1,1}$	0.092(0.000)*		0.100(0.000)*	
$\Phi_{1,2}$	0.036(0.006)*		0.041(0.002*)	
$C_{2,0}$		0.05(0.019)*		0.051(0.014)*
$\Phi_{2,2}$		0.117(0.000)*		0.101(0.000)*
$\Phi_{2,1}$		0.010(0.306)		0.008(0.644)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.072(0.000)*		0.062(0.001)	
$\alpha_{1,1}$	0.100(0.000)*		0.097(0.000)*	
$\alpha_{1,2}$	-0.017(0.421)		-0.003(0.859)	
$\beta_{1,1}$	0.778(0.000)*		0.772(0.000)*	
$\beta_{1,2}$	0.229(0.448)		0.395(0.377)	
d_1	0.124(0.000)*		0.121(0.000)*	
$\alpha_{2,0}$		0.038(0.01)*		0.036(0.001)*
$\alpha_{2,2}$		0.050(0.000)*		0.039(0.000)*
$\alpha_{2,1}$		0.03(0.043)*		0.022(0.061)
$\beta_{2,2}$		0.837(0.000)*		0.865(0.000)*
$\beta_{2,1}$		0.452(0.028)*		0.299(0.042)*
d_2		0.117(0.000)*		0.099(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	12.923(0.024)	8.014(0.155)	11.741(0.039)	6.498(0.261)
ARCH Test	0.391(0.855)	0.199(0.963)	0.75(0.586)	0.877(0.495)
LLH	-12243		-12056	

Note: 1 symbolizes Pakistan tor and 2 symbolizes India. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-1-7: VAR (1)-AGARCH (1,1) Estimates for Pakistan and Sri Lanka

	Unadjusted Returns		Adjusted Returns	
	Pakistan	Sri Lanka	Pakistan	Sri Lanka
Panel A: Mean Equation				
$C_{1,0}$	0.094(0.000)*		0.096(0.000)*	
$\Phi_{1,1}$	0.105(0.000)*		0.107(0.000)*	
$\Phi_{1,2}$	0.015(0.29)		0.015(0.298)	
$C_{2,0}$		0.037(0.015)*		0.043(0.000)*
$\Phi_{2,2}$		0.234(0.000)*		0.217(0.000)*
$\Phi_{2,1}$		0.02(0.115)		0.012(0.22)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.059(0.000)*		0.061(0.001)*	
$\alpha_{1,1}$	0.084(0.000)*		0.088(0.000)*	
$\alpha_{1,2}$	-0.019(0.566)		-0.024(0.425)	
$\beta_{1,1}$	0.782(0.000)*		0.783(0.000)*	
$\beta_{1,2}$	0.689(0.086)		0.695(0.177)	
d_1	0.148(0.000)*		0.135(0.000)*	
$\alpha_{2,0}$		0.019(0.105)		0.027(0.004)*
$\alpha_{2,2}$		0.259(0.000)*		0.145(0.000)*
$\alpha_{2,1}$		-0.016(0.502)		-0.005(0.693)
$\beta_{2,2}$		0.758(0.000)*		0.786(0.000)*
$\beta_{2,1}$		0.445(0.19)		0.278(0.254)
d_2		-0.006(0.901)		0.058(0.022)*
Panel C: Residuals Diagnostic				
Q-Stat	13.281(0.021)	25.46(0)	12.479(0.029)	38.708(0)
ARCH Test	1.045(0.389)	0.342(0.888)	0.959(0.442)	0.507(0.771)
LLH	-10975		-10508	

Note: 1 symbolizes Pakistan tor and 2 symbolizes Sri Lanka. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Appendix 2

Table A-2-1 to Table A-2-10 represent the model estimates of both unadjusted and adjusted returns of sectors of Pakistan Stock Exchange when returns are adjusted for outliers using Charles and Darné (2005) method.

Table A-2-1: VAR (1)-AGARCH (1,1) Estimates for Basic Material and Oil and Gas

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Oil and Gas	Basic Material	Oil and Gas
Panel A: Mean Equation				
$C_{1.0}$	0.058(0.002)*		0.061(0.001)*	
$\Phi_{1,1}$	0.074(0.001)*		0.075(0.001)*	
$\Phi_{1,2}$	-0.006(0.726)		-0.012(0.526)	
$C_{2,0}$		0.035(0.061)		0.040(0.042)*
$\Phi_{2,2}$		0.043(0.042)*		0.043(0.062)
$\Phi_{2,1}$		0.014(0.51)		0.003(0.879)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.122(0.000)*		0.106(0.000)*	
$\alpha_{1.1}$	0.141(0.000)*		0.132(0.000)*	
$\alpha_{1,2}$	0.002(0.949)		-0.016(0.376)	
$\beta_{1,1}$	0.667(0.000)*		0.641(0.000)*	
$\beta_{1,2}$	0.183(0.018)*		0.252(0.002)*	
d_1	0.036(0.248)		0.039(0.092)	
$\alpha_{2,0}$		0.108(0.058)		0.117(0.015)*
$\alpha_{2,2}$		0.179(0.000)*		0.173(0.000)*
$\alpha_{2,1}$		-0.062(0.068)		-0.060(0.013)*
$\beta_{2,2}$		0.671(0.000)*		0.680(0.000)*
$\beta_{2,1}$		0.261(0.042)*		0.246(0.030)*
d_2		0.007(0.800)		-0.005(0.823)
Panel C: Residuals Diagnostic				
Q-Stat	5.863(0.32)	10.794(0.056)	6.787(0.237)	13.758(0.017)
ARCH Test	1.239(0.288)	1.121(0.347)	0.743(0.591)	1.726(0.125)
LLH	-12929		-12775	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Oil and Gas sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-2: VAR (1)-AGARCH (1,1) Estimates for Basic Material and Industry

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Industry	Basic Material	Industry
Panel A: Mean Equation				
$C_{1.0}$	0.061(0.001)*		0.064(0.001)*	
$\Phi_{1,1}$	0.048(0.032)*		0.048(0.029)*	
$\Phi_{1,2}$	0.039(0.054)		0.034(0.071)	
$C_{2,0}$		0.050(0.020)*		0.054(0.009)*
$\Phi_{2,2}$		0.071(0.007)*		0.059(0.004)*
$\Phi_{2,1}$		0.034(0.167)		0.040(0.032)*
Panel B: Variance Equation				
$\alpha_{1.0}$	0.076(0.024)*		0.087(0.008)*	
$\alpha_{1,1}$	0.158(0.000)*		0.15(0.000)*	
$\alpha_{1,2}$	-0.048(0.014)*		-0.053(0.003)*	
$\beta_{1,1}$	0.754(0.000)*		0.793(0.000)*	
$\beta_{1,2}$	0.138(0.240)		0.063(0.519)	
d_1	0.043(0.101)		0.037(0.097)	
$\alpha_{2,0}$		0.220(0.000)*		0.204(0.000)*
$\alpha_{2,2}$		0.178(0.000)*		0.147(0.000)*
$\alpha_{2,1}$		-0.074(0.003)*		-0.024(0.433)
$\beta_{2,2}$		0.584(0.000)*		0.672(0.000)*
$\beta_{2,1}$		0.308(0.005)*		0.16(0.087)
d_2		0.043(0.090)		0.02(0.426)
Panel C: Residuals Diagnostic				
Q-Stat	5.457(0.363)	9.794(0.081)	6.445(0.265)	6.599(0.252)
ARCH Test	0.95(0.448)	0.55(0.738)	0.965(0.438)	0.462(0.805)
LLH	-12999		-12833	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-3: VAR (1)-AGARCH (1,1) Estimates for Basic Material and Consumer Goods

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Consumer Goods	Basic Material	Consumer Good
Panel A: Mean Equation				
$C_{1.0}$	0.045(0.032)*		0.045(0.021)*	
$\Phi_{1,1}$	0.076(0.000)*		0.077(0.000)*	
$\Phi_{1,2}$	-0.002(0.942)		0.009(0.629)	
$C_{2,0}$		0.047(0.006)*		0.050(0.000)*
$\Phi_{2,2}$		0.097(0.000)*		0.097(0.000)*
$\Phi_{2,1}$		0.015(0.386)		0.014(0.305)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.109(0.002)*		0.089(0.002)*	
$\alpha_{1,1}$	0.139(0.000)*		0.144(0.000)*	
$\alpha_{1,2}$	-0.030(0.285)		-0.058(0.019)*	
$\beta_{1,1}$	0.690(0.000)*		0.681(0.000)*	
$\beta_{1,2}$	0.257(0.013)*		0.322(0.004)*	
d_1	0.069(0.009)*		0.059(0.022)*	
$\alpha_{2,0}$		-0.002(0.614)		-0.001(0.754)
$\alpha_{2,2}$		0.118(0.000)*		0.117(0.000)*
$\alpha_{2,1}$		-0.026(0.001)*		-0.025(0.001)*
$\beta_{2,2}$		0.845(0.000)*		0.849(0.000)*
$\beta_{2,1}$		0.119(0.007)*		0.123(0.014)*
d_2		-0.006(0.795)		-0.025(0.062)
Panel C: Residuals Diagnostic				
Q-Stat	5.418(0.367)	8.035(0.154)	4.974(0.419)	7.27(0.201)
ARCH Test	0.822(0.533)	0.814(0.54)	0.65(0.662)	0.519(0.762)
LLH	-12417		-12256	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-4: VAR (1)-AGARCH (1,1) Estimates for Basic Material and Financial

	Unadjusted Returns		Adjusted Returns	
	Basic Material	Financial	Basic Material	Financial
Panel A: Mean Equation				
$C_{1.0}$	0.054(0.002)*		0.052(0.005)*	
$\Phi_{1,1}$	0.064(0.006)*		0.054(0.012)*	
$\Phi_{1,2}$	0.015(0.406)		0.025(0.158)	
$C_{2,0}$		0.056(0.016)*		0.054(0.007)*
$\Phi_{2,2}$		0.118(0.000)*		0.128(0.000)*
$\Phi_{2,1}$		0.031(0.215)		0.012(0.617)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.115(0.000)*		0.093(0.004)*	
$\alpha_{1,1}$	0.151(0.000)*		0.148(0.000)*	
$\alpha_{1,2}$	-0.033(0.12)		-0.038(0.086)	
$\beta_{1,1}$	0.698(0.000)*		0.605(0.000)*	
$\beta_{1,2}$	0.161(0.08)		0.314(0.015)*	
d_1	0.023(0.459)		0.021(0.287)	
$\alpha_{2,0}$		0.19(0.007)*		0.096(0.043)*
$\alpha_{2,2}$		0.122(0.000)*		0.132(0.000)*
$\alpha_{2,1}$		-0.031(0.255)		-0.063(0.019)*
$\beta_{2,2}$		0.75(0.000)*		0.749(0.000)*
$\beta_{2,1}$		0.078(0.387)		0.171(0.163)
d_2		0.042(0.093)		0.032(0.119)
Panel C: Residuals Diagnostic				
Q-Stat	4.784(0.443)	4.5(0.48)	5.125(0.401)	4.862(0.433)
ARCH Test	2.178(0.054)	0.611(0.692)	1.787(0.112)	1.394(0.223)
LLH	-12802		-12634	

Note: 1 symbolizes Basic Material sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-5: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas and Industry

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Industry	Oil and Gas	Industry
Panel A: Mean Equation				
$C_{1,0}$	0.028(0.178)		0.027(0.169)	
$\Phi_{1,1}$	0.031(0.19)		0.032(0.101)	
$\Phi_{1,2}$	0.040(0.055)		0.034(0.072)	
$C_{2,0}$		0.047(0.014)*		0.048(0.013)*
$\Phi_{2,2}$		0.083(0.000)*		0.073(0.000)*
$\Phi_{2,1}$		0.009(0.633)		0.010(0.539)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.067(0.157)		0.07(0.100)	
$\alpha_{1,1}$	0.143(0.000)*		0.127(0.000)*	
$\alpha_{1,2}$	-0.069(0.003)*		-0.058(0.002)*	
$\beta_{1,1}$	0.759(0.000)*		0.796(0.000)*	
$\beta_{1,2}$	0.211(0.098)		0.148(0.154)	
d_1	0.055(0.090)		0.033(0.072)	
$\alpha_{2,0}$		0.232(0.000)*		0.159(0.002)*
$\alpha_{2,2}$		0.164(0.000)*		0.151(0.000)*
$\alpha_{2,1}$		-0.028(0.189)		-0.042(0.108)
$\beta_{2,2}$		0.579(0.000)*		0.677(0.000)*
$\beta_{2,1}$		0.29(0.022)*		0.199(0.007)*
d_2		0.047(0.130)		0.036(0.197)
Panel C: Residuals Diagnostic				
Q-Stat	14.973(0.01)	8.717(0.121)	16.163(0.006)	6.01(0.305)
ARCH Test	0.986(0.425)	0.812(0.541)	2.291(0.043)	0.745(0.589)
LLH	-13398		-13226	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-6: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas and Consumer Goods

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Consumer Good	Oil and Gas	Consumer Good
Panel A: Mean Equation				
$C_{1,0}$	0.022(0.295)		0.022(0.343)	
$\Phi_{1,1}$	0.057(0.009)*		0.051(0.030)*	
$\Phi_{1,2}$	-0.002(0.915)		-0.005(0.822)	
$C_{2,0}$		0.037(0.024)*		0.041(0.023)*
$\Phi_{2,2}$		0.129(0.000)*		0.130(0.000)*
$\Phi_{2,1}$		-0.019(0.245)		-0.025(0.204)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.113(0.017)*		0.104(0.01)*	
$\alpha_{1,1}$	0.118(0.000)*		0.111(0.000)*	
$\alpha_{1,2}$	0.025(0.537)		-0.006(0.838)	
$\beta_{1,1}$	0.810(0.000)*		0.829(0.000)*	
$\beta_{1,2}$	0.034(0.717)		0.025(0.764)	
d_1	0.029(0.302)		0.024(0.235)	
$\alpha_{2,0}$		0.001(0.552)		0.001(0.586)
$\alpha_{2,2}$		0.115(0.000)*		0.108(0.000)*
$\alpha_{2,1}$		-0.006(0.449)		0.000(0.991)
$\beta_{2,2}$		0.879(0.000)*		0.892(0.000)*
$\beta_{2,1}$		0.042(0.153)		0.034(0.194)
d_2		-0.001(0.972)		-0.02(0.128)
Panel C: Residuals Diagnostic				
Q-Stat	14.105(0.015)	10.712(0.057)	16.849(0.005)	8.637(0.124)
ARCH Test	1.162(0.326)	0.63(0.677)	2.305(0.042)	0.657(0.656)
LLH			-12702	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-7: VAR (1)-AGARCH (1,1) Estimates for Oil and Gas and Financial

	Unadjusted Returns		Adjusted Returns	
	Oil and Gas	Finanical	Oil and Gas	Finanical
Panel A: Mean Equation				
$C_{1.0}$	0.040(0.020)*		0.039(0.036)*	
$\Phi_{1,1}$	0.048(0.015)*		0.044(0.058)	
$\Phi_{1,2}$	0.012(0.595)		0.009(0.700)	
$C_{2,0}$		0.063(0.001)*		0.062(0.001)*
$\Phi_{2,2}$		0.152(0.000)*		0.155(0.000)*
$\Phi_{2,1}$		-0.024(0.245)		-0.036(0.143)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.114(0.019)*		0.112(0.008)*	
$\alpha_{1,1}$	0.119(0.000)*		0.122(0.000)*	
$\alpha_{1,2}$	0.015(0.628)		-0.011(0.655)	
$\beta_{1,1}$	0.768(0.000)*		0.758(0.000)*	
$\beta_{1,2}$	0.103(0.452)		0.13(0.261)	
d_1	-0.004(0.880)		-0.005(0.811)	
$\alpha_{2,0}$		0.229(0.004)*		0.122(0.001)*
$\alpha_{2,2}$		0.097(0.000)*		0.101(0.000)*
$\alpha_{2,1}$		-0.005(0.835)		-0.015(0.494)
$\beta_{2,2}$		0.683(0.000)*		0.759(0.000)*
$\beta_{2,1}$		0.133(0.220)		0.111(0.33)
d_2		0.089(0.059)		0.057(0.028)*
Panel C: Residuals Diagnostic				
Q-Stat	12.911(0.024)	2.628(0.757)	15.44(0.009)	2.151(0.828)
ARCH Test	1.349(0.24)	1.125(0.345)	3.069(0.009)	5.935(0)
LLH	-13201		-13016	

Note: 1 symbolizes Oil and Gas sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-8: VAR (1)-AGARCH (1,1) Estimates for Industry and Consumer Goods

	Unadjusted Returns		Adjusted Returns	
	Industry	Consumer Good	Oil and Gas	Consumer Good
Panel A: Mean Equation				
$C_{1.0}$	0.041(0.041)*		0.045(0.037)*	
$\Phi_{1,1}$	0.081(0.000)*		0.069(0.001)*	
$\Phi_{1,2}$	0.002(0.911)		0.009(0.661)	
$C_{2.0}$		0.044(0.009)*		0.047(0.016)*
$\Phi_{2,2}$		0.113(0.000)*		0.118(0.000)*
$\Phi_{2,1}$		0.000(0.991)		-0.008(0.664)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.199(0.010)*		0.152(0.002)*	
$\alpha_{1,1}$	0.116(0.000)*		0.109(0.000)*	
$\alpha_{1,2}$	-0.018(0.579)		-0.012(0.669)	
$\beta_{1,1}$	0.702(0.000)*		0.757(0.000)*	
$\beta_{1,2}$	0.193(0.207)		0.127(0.227)	
d_1	0.089(0.003)*		0.056(0.025)*	
$\alpha_{2,0}$		0.000(0.876)		0.002(0.63)
$\alpha_{2,2}$		0.112(0.000)*		0.104(0.000)*
$\alpha_{2,1}$		-0.015(0.014)*		-0.007(0.345)
$\beta_{2,2}$		0.871(0.000)*		0.894(0.000)*
$\beta_{2,1}$		0.083(0.020)*		0.043(0.338)
d_2		0.010(0.641)		-0.006(0.704)
Panel C: Residuals Diagnostic				
Q-Stat	10.233(0.069)	11.517(0.042)	7.955(0.159)	10.704(0.058)
ARCH	1.533(0.176)	0.967(0.436)	0.363(0.874)	0.984(0.426)
LLH	-12715		-12547	

Note: 1 symbolizes Industry sector and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-9: VAR (1)-AGARCH (1,1) Estimates for Industry and Financial

	Unadjusted Returns		Adjusted Returns	
	Industry	Finanical	Industry	Finanical
Panel A: Mean Equation				
$C_{1.0}$	0.048(0.036)*		0.049(0.008)*	
$\Phi_{1.1}$	0.066(0.004)*		0.055(0.008)*	
$\Phi_{1.2}$	0.041(0.030)*		0.050(0.001)*	
$C_{2.0}$		0.054(0.013)*		0.048(0.010)*
$\Phi_{2.2}$		0.120(0.000)*		0.126(0.000)*
$\Phi_{2.1}$		0.024(0.364)		0.016(0.479)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.226(0.002)*		0.203(0.000)*	
$\alpha_{1.1}$	0.147(0.000)*		0.129(0.000)*	
$\alpha_{1.2}$	-0.004(0.907)		0.02(0.513)	
$\beta_{1.1}$	0.484(0.000)*		0.579(0.000)*	
$\beta_{1.2}$	0.481(0.008)*		0.332(0.004)*	
d_1	0.025(0.490)		-0.002(0.946)	
$\alpha_{2.0}$		0.147(0.046)*		0.053(0.272)
$\alpha_{2.2}$		0.119(0.000)*		0.115(0.000)*
$\alpha_{2.1}$		-0.064(0.023)*		-0.064(0.014)*
$\beta_{2.2}$		0.733(0.000)*		0.784(0.000)*
$\beta_{2.1}$		0.170(0.268)		0.182(0.311)
d_2		0.098(0.018)*		0.075(0.005)*
Panel C: Residuals Diagnostic				
Q-Stat	9.265(0.099)	10.205(0.07)	6.658(0.247)	12.446(0.029)
ARCH Test	1.45(0.203)	0.254(0.938)	0.809(0.543)	1.344(0.242)
LLH	-13319		-13130	

Note: 1 symbolizes Industry sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-2-10: VAR (1)-AGARCH (1,1) Estimates for Consumer Goods and Financial

	Unadjusted Returns		Adjusted Returns	
	Consumer Goo	Finanical	Consumer Good:	Finanical
Panel A: Mean Equation				
$C_{1.0}$	0.06(0.001)*		0.042(0.041)*	
$\Phi_{1,1}$	0.116(0.000)*		0.115(0.000)*	
$\Phi_{1,2}$	-0.006(0.627)		-0.001(0.960)	
$C_{2,0}$		0.044(0.038)*		0.033(0.121)
$\Phi_{2,2}$		0.131(0.000)*		0.140(0.000)*
$\Phi_{2,1}$		0.026(0.269)		0.030(0.146)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.027(0.197)		0.002(0.701)	
$\alpha_{1,1}$	0.093(0.000)*		0.109(0.000)*	
$\alpha_{1,2}$	-0.002(0.897)		-0.015(0.043)*	
$\beta_{1,1}$	0.889(0.000)*		0.878(0.000)*	
$\beta_{1,2}$	0.013(0.749)		0.068(0.073)	
d_1	-0.005(0.777)		-0.022(0.179)	
$\alpha_{2,0}$		0.167(0.003)*		0.063(0.062)
$\alpha_{2,2}$		0.077(0.000)*		0.093(0.000)*
$\alpha_{2,1}$		0.013(0.630)		-0.03(0.255)
$\beta_{2,2}$		0.809(0.000)*		0.788(0.000)*
$\beta_{2,1}$		0.002(0.985)		0.191(0.025)*
d_2		0.080(0.015)*		0.082(0.002)*
Panel C: Residuals Diagnostic				
Q-Stat	21.377(0.001)	7.357(0.195)	20.16(0.001)	7.105(0.213)
ARCH Test	1.08(0.369)	0.81(0.542)	0.866(0.503)	1.551(0.171)
LLH	-12719		-12603	

Note: 1 symbolizes Consumer Goods sector and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level

Appendix 3

Table A-3-1 to Table A-3-9 represent the model estimates of both unadjusted and adjusted returns of Pakistan Stock Exchange and Brent oil market when returns are adjusted for outliers using Charles and Darné (2005) method.

Table A-3-1: VAR (1)-AGARCH (1,1) Estimates for Oil and PSX

	Unadjusted Returns		Adjusted Returns	
	Oil	PSX	Oil	PSX
Panel A: Mean Equation				
$C_{1.0}$	-0.004(0.912)		-0.008(0.795)	
$\Phi_{1,1}$	-0.003(0.834)		0.004(0.827)	
$\Phi_{1,2}$	0.009(0.717)		0.015(0.583)	
$C_{2,0}$		0.100(0.000)*		0.099(0.000)*
$\Phi_{2,2}$		0.101(0.000)*		0.106(0.000)*
$\Phi_{2,1}$		0.023(0.007)*		0.023(0.007)*
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.002(0.765)		-0.004(0.376)	
$\alpha_{1,1}$	0.017(0.028)*		0.011(0.043)	
$\alpha_{1,2}$	-0.016(0.212)		-0.009(0.395)	
$\beta_{1,1}$	0.958(0.000)*		0.963(0.000)*	
$\beta_{1,2}$	0.607(0.176)		0.592(0.143)	
d_1	0.036(0.000)*		0.035(0.000)*	
$\alpha_{2,0}$		0.057(0.000)*		0.057(0.001)*
$\alpha_{2,2}$		0.081(0.000)*		0.084(0.000)*
$\alpha_{2,1}$		-0.006(0.639)		-0.01(0.411)
$\beta_{2,2}$		0.721(0.000)*		0.74(0.000)*
$\beta_{2,1}$		1.581(0.171)		1.220(0.243)
d_2		0.178(0.000)*		0.159(0.000)*
Panel C: Residuals Diagnostic				
Q-Stat	3.313(0.652)	11.427(0.044)	1.866(0.867)	11.222(0.047)
ARCH Test	2.017(0.073)	0.943(0.452)	0.984(0.426)	1.034(0.396)
LLH	-14176		-138989	

Note: 1 symbolizes Oil and 2 symbolizes PSX sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-2: VAR (1)-AGARCH (1,1) Estimates for Oil and Basic Material

	Unadjusted Returns		Adjusted Returns	
	Oil	Basic Material	Oil	Basic Material
Panel A: Mean Equation				
$C_{1,0}$	-0.001(0.961)		-0.007(0.816)	
$\Phi_{1,1}$	-0.006(0.779)		0.002(0.908)	
$\Phi_{1,2}$	0.024(0.206)		0.027(0.107)	
$C_{2,0}$		0.069(0.000)*		0.071(0.000)*
$\Phi_{2,2}$		0.079(0.000)*		0.079(0.000)*
$\Phi_{2,1}$		0.02(0.003)*		0.023(0.024)*
Panel B: Variance Equation				
$\alpha_{1,0}$	0.000(0.994)		-0.005(0.330)	
$\alpha_{1,1}$	0.019(0.011)*		0.013(0.008)*	
$\alpha_{1,2}$	-0.009(0.341)		0.003(0.699)	
$\beta_{1,1}$	0.954(0.000)*		0.957(0.000)*	
$\beta_{1,2}$	0.84(0.598)		-3.173(0.054)	
d_1	0.039(0.001)*		0.0390(0.000)	
$\alpha_{2,0}$		0.098(0.000)*		0.094(0.000)*
$\alpha_{2,2}$		0.131(0.000)*		0.125(0.000)*
$\alpha_{2,1}$		0.001(0.973)		0.006(0.664)
$\beta_{2,2}$		0.761(0.000)*		0.792(0.000)*
$\beta_{2,1}$		1.632(0.629)		-2.028(0.441)
d_2		0.08(0.010)*		0.057(0.015)*
Panel C: Residuals Diagnostic				
Q-Stat	3.293(0.655)	4.976(0.419)	1.831(0.872)	5.309(0.379)
ARCH Test	1.502(0.186)	0.305(0.91)	0.818(0.537)	0.233(0.948)
LLH	-15012		-14805	

Note: 1 symbolizes Oil and 2 symbolizes Basic Material sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-3: VAR (1)-AGARCH (1,1) Estimates for Oil and Oil and Gas

	Unadjusted Returns		Adjusted Returns	
	Oil	Oil and Gas	Oil	Oil and Gas
Panel A: Mean Equation				
$C_{1.0}$	0.001(0.967)		-0.003(0.917)	
$\Phi_{1.1}$	-0.004(0.816)		0.003(0.889)	
$\Phi_{1.2}$	-0.018(0.402)		-0.015(0.51)	
$C_{2.0}$		0.045(0.031)*		0.045(0.047)*
$\Phi_{2.2}$		0.058(0.006)*		0.054(0.005)*
$\Phi_{2.1}$		0.053(0.000)*		0.052(0.000)*
Panel B: Variance Equation				
$\alpha_{1.0}$	-0.001(0.916)		-0.003(0.532)	
$\alpha_{1.1}$	0.020(0.028)		0.013(0.050)	
$\alpha_{1.2}$	-0.011(0.289)		-0.007(0.526)	
$\beta_{1.1}$	0.951(0.000)*		0.959(0.000)*	
$\beta_{1.2}$	0.332(0.085)		0.333(0.070)	
d_1	0.037(0.001)*		0.036(0.000)*	
$\alpha_{2.0}$		0.076(0.002)*		0.073(0.001)*
$\alpha_{2.2}$		0.120(0.000)*		0.108(0.000)*
$\alpha_{2.1}$		0.030(0.068)		0.012(0.416)
$\beta_{2.2}$		0.767(0.000)*		0.788(0.000)*
$\beta_{2.1}$		0.906(0.109)		0.815(0.172)
d_2		0.062(0.043)*		0.053(0.022)*
Panel C: Residuals Diagnostic				
Q-Stat	3.637(0.603)	10.808(0.055)	1.984(0.851)	13.16(0.022)
ARCH Test	2.06(0.067)	1.246(0.285)	1.858(0.098)	1.858(0.098)
LLH	-15272		-15086	

Note: 1 symbolizes Oil and 2 symbolizes Oil and Gas sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-4: VAR (1)-AGARCH (1,1) Estimates for Oil and Industry

	Unadjusted Returns		Adjusted Returns	
	Oil	Industry	Oil	Industry
Panel A: Mean Equation				
$C_{1,0}$	-0.004(0.893)		-0.008(0.79)	
$\Phi_{1,1}$	-0.005(0.771)		0.003(0.897)	
$\Phi_{1,2}$	-0.005(0.849)		-0.012(0.623)	
$C_{2,0}$		0.06(0.000)*		0.061(0.002)*
$\Phi_{2,2}$		0.079(0.000)*		0.072(0.000)*
$\Phi_{2,1}$		0.01(0.146)		0.010(0.196)
Panel B: Variance Equation				
$\alpha_{1,0}$	-0.015(0.029)*		-0.013(0.010)*	
$\alpha_{1,1}$	0.014(0.158)		0.008(0.103)	
$\alpha_{1,2}$	-0.011(0.305)		-0.013(0.114)	
$\beta_{1,1}$	0.952(0.000)*		0.963(0.000)*	
$\beta_{1,2}$	0.714(0.069)		0.611(0.085)	
d_1	0.040(0.000)*		0.040(0.000)*	
$\alpha_{2,0}$		0.217(0.004)*		0.174(0.001)*
$\alpha_{2,2}$		0.119(0.000)*		0.104(0.000)*
$\alpha_{2,1}$		-0.022(0.336)		-0.018(0.356)
$\beta_{2,2}$		0.691(0.000)*		0.779(0.000)*
$\beta_{2,1}$		0.772(0.309)		-0.079(0.884)
d_2		0.108(0.016)*		0.076(0.015)*
Panel C: Residuals Diagnostic				
Q-Stat	3.54(0.617)	8.563(0.128)	1.864(0.868)	6.638(0.249)
ARCH Test	2.781(0.016)	0.315(0.904)	2.175(0.03)	0.072(0.996)
LLH	-14992		-14770	

Note: 1 symbolizes Oil and 2 symbolizes Industry sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-5: VAR (1)-AGARCH (1,1) Estimates for Oil and Consumer Goods

	Unadjusted Returns		Adjusted Returns	
	Oil	Consumer Goods	Oil	Consumer Goods
Panel A: Mean Equation				
$C_{1,0}$	-0.001(0.967)		-0.005(0.848)	
$\Phi_{1,1}$	-0.007(0.71)		0.001(0.967)	
$\Phi_{1,2}$	0.014(0.569)		0.020(0.422)	
$C_{2,0}$		0.055(0.069)		0.06(0.001)*
$\Phi_{2,2}$		0.121(0.000)*		0.121(0.000)*
$\Phi_{2,1}$		0.004(0.632)		0.006(0.302)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.004(0.541)		-0.001(0.808)	
$\alpha_{1,1}$	0.018(0.018)		0.014(0.004)*	
$\alpha_{1,2}$	-0.023(0.108)		-0.008(0.505)	
$\beta_{1,1}$	0.959(0.000)*		0.962(0.000)*	
$\beta_{1,2}$	0.543(0.612)		0.712(0.492)	
d_1	0.041(0.000)*		0.039(0.000)*	
$\alpha_{2,0}$		0.007(0.807)		0.014(0.143)
$\alpha_{2,2}$		0.092(0.008)*		0.083(0.000)*
$\alpha_{2,1}$		-0.007(0.342)		-0.01(0.028)*
$\beta_{2,2}$		0.904(0.000)*		0.919(0.000)*
$\beta_{2,1}$		0.003(0.996)		-0.298(0.527)
d_2		0.02(0.178)		0.002(0.859)
Panel C: Residuals Diagnostic				
Q-Stat	3.356(0.645)	22.195(0)	1.889(0.864)	19.261(0.002)
ARCH Test	1.501(0.186)	0.705(0.62)	0.847(0.516)	0.557(0.733)
LLH	-14389		-14178	

Note: 1 symbolizes Oil and 2 symbolizes Consumer Goods sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-6: VAR (1)-AGARCH (1,1) Estimates for Oil and Healthcare

	Unadjusted Returns		Adjusted Returns	
	Oil	Healthcare	Oil	Healthcare
Panel A: Mean Equation				
$C_{1,0}$	0.003(0.929)		-0.004(0.91)	
$\Phi_{1,1}$	-0.008(0.713)		0.000(0.991)	
$\Phi_{1,2}$	-0.005(0.811)		-0.005(0.821)	
$C_{2,0}$		0.072(0.002)*		0.072(0.005)*
$\Phi_{2,2}$		0.117(0.000)*		0.120(0.000)*
$\Phi_{2,1}$		0.024(0.014)		0.024(0.052)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.000(0.997)		0.001(0.896)	
$\alpha_{1,1}$	0.016(0.024)*		0.012(0.024)	
$\alpha_{1,2}$	-0.024(0.01)*		-0.013(0.120)	
$\beta_{1,1}$	0.963(0.000)*		0.969(0.000)*	
$\beta_{1,2}$	0.198(0.844)		0.003(0.994)	
d_1	0.044(0.000)*		0.04(0.000)*	
$\alpha_{2,0}$		0.158(0.000)*		0.153(0.000)*
$\alpha_{2,2}$		0.131(0.000)*		0.117(0.000)*
$\alpha_{2,1}$		-0.004(0.818)		0.001(0.969)
$\beta_{2,2}$		0.804(0.000)*		0.835(0.000)*
$\beta_{2,1}$		-1.005(0.528)		-1.674(0.293)
d_2		0.031(0.193)		0.028(0.162)
Panel C: Residuals Diagnostic				
Q-Stat	3.232(0.664)	12.431(0.029)	1.833(0.872)	10.625(0.059)
ARCH Test	1.457(0.2)	0.293(0.917)	0.748(0.587)	0.339(0.889)
LLH	-15191		-15034	

Note: 1 symbolizes Oil and 2 symbolizes Healthcare sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-7: VAR (1)-AGARCH (1,1) Estimates for Oil and Utility

	Unadjusted Returns		Adjusted Returns	
	Oil	Utility	Oil	Utility
Panel A: Mean Equation				
$C_{1,0}$	-0.003(0.935)		-0.004(0.867)	
$\Phi_{1,1}$	-0.003(0.846)		0.001(0.943)	
$\Phi_{1,2}$	0.019(0.178)		0.018(0.240)	
$C_{2,0}$		0.002(0.945)		-0.004(0.871)
$\Phi_{2,2}$		0.004(0.84)		-0.001(0.953)
$\Phi_{2,1}$		0.024(0.131)		0.013(0.241)
Panel B: Variance Equation				
$\alpha_{1,0}$	0.003(0.696)		-0.004(0.507)	
$\alpha_{1,1}$	0.018(0.007)*		0.014(0.002)	
$\alpha_{1,2}$	-0.016(0.045)*		-0.01(0.136)	
$\beta_{1,1}$	0.960(0.000)*		0.963(0.000)*	
$\beta_{1,2}$	0.315(0.648)		0.318(0.295)	
d_1	0.039(0.001)*		0.037(0.000)*	
$\alpha_{2,0}$		0.147(0.010)*		0.154(0.000)*
$\alpha_{2,2}$		0.082(0.000)*		0.076(0.000)*
$\alpha_{2,1}$		0.030(0.187)		0.009(0.605)
$\beta_{2,2}$		0.821(0.000)*		0.871(0.000)*
$\beta_{2,1}$		2.843(0.533)		-0.46(0.529)
d_2		0.058(0.018)*		0.044(0.038)*
Panel C: Residuals Diagnostic				
Q-Stat	3.057(0.691)	3.687(0.595)	1.874(0.866)	3.276(0.657)
ARCH Test	1.567(0.166)	0.683(0.636)	0.831(0.527)	0.503(0.774)
LLH	-16010		-15733	

Note: 1 symbolizes Oil and 2 symbolizes Utility sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-8: VAR (1)-AGARCH (1,1) Estimates for Oil and Financial

	Unadjusted Returns		Adjusted Returns	
	Oil	Financial	Oil	Financial
Panel A: Mean Equation				
$C_{1,0}$	-0.009(0.769)		-0.011(0.709)	
$\Phi_{1,1}$	-0.007(0.716)		0.001(0.943)	
$\Phi_{1,2}$	0.014(0.581)		0.012(0.582)	
$C_{2,0}$		0.067(0.005)*		0.063(0.009)*
$\Phi_{2,2}$		0.143(0.000)*		0.143(0.000)*
$\Phi_{2,1}$		0.039(0.000)*		0.033(0.005)*
Panel B: Variance Equation				
$\alpha_{1,0}$	-0.005(0.391)		-0.004(0.351)	
$\alpha_{1,1}$	0.011(0.078)		0.010(0.047)*	
$\alpha_{1,2}$	-0.028(0.011)*		-0.014(0.131)	
$\beta_{1,1}$	0.961(0.000)*		0.964(0.000)*	
$\beta_{1,2}$	0.718(0.288)		0.422(0.181)	
d_1	0.039(0.000)*		0.038(0.000)*	
$\alpha_{2,0}$		0.106(0.000)*		0.07(0.003)*
$\alpha_{2,2}$		0.084(0.000)*		0.088(0.000)*
$\alpha_{2,1}$		0.016(0.375)		0.007(0.691)
$\beta_{2,2}$		0.748(0.000)*		0.823(0.000)*
$\beta_{2,1}$		2.298(0.344)		0.57(0.441)
d_2		0.132(0.000)*		0.092(0.002)*
Panel C: Residuals Diagnostic				
Q-Stat	3.056(0.691)	13.243(0.021)	1.923(0.86)	15.558(0.008)
ARCH Test	1.204(0.304)	0.732(0.599)	0.895(0.484)	1.685(0.135)
LLH	-15274		-15085	

Note: 1 symbolizes Oil and 2 symbolizes Financial sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.

Table A-3-9: VAR (1)-AGARCH (1,1) Estimates for Oil and Telecom

	Unadjusted Returns		Adjusted Returns	
	Oil	Telecom	Oil	Telecom
Panel A: Mean Equation				
$C_{1.0}$	0.002(0.952)		-0.002(0.942)	
$\Phi_{1,1}$	-0.006(0.792)		0.001(0.960)	
$\Phi_{1,2}$	-0.013(0.37)		-0.01(0.417)	
$C_{2,0}$		-0.014(0.651)		0.013(0.673)
$\Phi_{2,2}$		0.051(0.003)*		0.050(0.014)*
$\Phi_{2,1}$		0.021(0.144)		0.014(0.331)
Panel B: Variance Equation				
$\alpha_{1.0}$	0.007(0.422)		0.004(0.557)	
$\alpha_{1,1}$	0.020(0.026)		0.015(0.008)*	
$\alpha_{1,2}$	-0.006(0.504)		-0.004(0.572)	
$\beta_{1,1}$	0.96(0.000)*		0.967(0.000)*	
$\beta_{1,2}$	0.014(0.966)		0.027(0.888)	
d_1	0.039(0.002)*		0.036(0.000)*	
$\alpha_{2,0}$		0.201(0.020)*		0.209(0.000)*
$\alpha_{2,2}$		0.096(0.000)*		0.113(0.000)*
$\alpha_{2,1}$		0.059(0.026)*		0.032(0.084)
$\beta_{2,2}$		0.830(0.000)*		0.84(0.000)*
$\beta_{2,1}$		1.444(0.343)		-0.422(0.653)
d_2		0.008(0.715)		0.012(0.531)
Panel C: Residuals Diagnostic				
Q-Stat	3.699(0.594)	5.112(0.402)	2.073(0.839)	5.971(0.309)
ARCH	1.692(0.133)	0.85(0.514)	0.81(0.542)	3.563(0.003)
LLH	-16520		-16170	

Note: 1 symbolizes Oil and 2 symbolizes Telecom sector. P-values have been reported in parenthesis and * denotes the statistical significance at 5% level.