ANALYSIS OF THE RELATIONSHIP OF STOCK MARKET WITH EXCHANGE RATE AND SPOT GOLD PRICE OF SRI LANKA

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By

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DECLARATION OF THE CANDIDATE

I hereby declare that the research titled ANALYSIS OF THE RELATIONSHIP OF STOCK MARKET WITH EXCHANGE RATE AND SPOT GOLD PRICE OF SRI LANKA submitted by me is based on actual and original work carried out by me. Any reference to work done by any other person or institution or any material obtained from other sources have been duly cited and referenced. I further certify that the research thesis has not been published or submitted for publication anywhere else nor it will be send for publication in the future.

…………………………… ………………….

Signature of the Candidate Date

DECLARATION OF THE SUPERVISOR

To the best of my knowledge the above particulars are correct.

………………………………… ………………………………..

Signature of the Supervisor Date

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ABSTRACT

Intention of this thesis is to analyze the interrelationship of stock market volatility with LKR/USD exchange rate and spot gold prices in Sri Lankan stock market. There are several statistical techniques used in this study, such as Unit Root Augmented Dickey Fuller test, Box-Pierce test, Ljung–Box test, ARCH LM test in order to identify the relationship between stock returns and macroeconomic variables. Daily data for All Share Price Index, Exchange rate and Spot gold prices were collected over six-year period from 4th Jan 2010 to 4th Mar 2016. EGARCH specification, which was proposed by Nelson was used to model the variables in order to derive an equation to forecast the future behavior of stock returns. Evidently, statistical model depicted a strong evidence on non-existence of relationship between stock returns and exchange rate but it was proven the strong negative relationship between stock returns and spot gold price returns.

Key Words *– Volatility, Stock Return, Exchange Rate Return, Unit Root Augmented Dickey Fuller test, GARCH,EGARCH*

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LIST OF ABBREVIATIONS

Abbreviation	Description
GDP	Gross Domestic Production
CAPM	Capital Asset Pricing Model
ASPI	All Share Price Index
ARCH	Auto Regressive Conditional Heteroscedasticity
GARCH	Generalized Auto Regressive Conditional Heteroscedasticity
EGARCH	Exponential Generalized Auto Regressive Conditional Heteroscedasticity
GJR-GARCH	Glosten-Jagannathan-Runkle Generalized Auto Regressive Conditional Heteroscedasticity
USD	United State Dollars
GBP	Great Britain Pounds
LKR	Lankan Rupees
GFET	Guide to Foreign Exchange Transactions
US	United State
UK	United Kingdom
BRICs	Brazil, Russia, India, China and South Africa
VAR	Vector Auto Regression
ISE	Istanbul Stock Exchange
AR	Auto Regression
DF	Dickey–Fuller
ADF	Augmented Dickey–Fuller
JB	Jarque–Bera
AIC	Akaike Information Criterion

HQ	Hannan–Quinn information criterion
RMSE	Root Mean Square Error
MAE	Mean Square Error
MAPE	Mean Absolute Percentage Error

CHAPTER 1 INTRODUCTION

Identifying the movements of exchange rate is essential in many trades as well as in financial policy making process. Accurate prediction of exchange rate fluctuations can be considered as the key to mitigate the risk not only in international market but also in country's economy as a whole. Further foreign investors are not interested in investing on local stocks when countries currency is depreciating, as it would be a reason to diminish their return on invested assets. In such situations investors try to diversify their investments across multiple portfolios such as precious metal, bonds etc. As a result, they tend to shift from high risk instruments to less risk instruments with the intention of minimizing the loss. Commodities are among these instruments that may protect themselves from particular risks. Therefore, precious metals such as gold and silver are popular among investors in past decades. Generally, there are many factors such as company performance, dividends, GDP, interest rate, exchange rate, gold rate etc., which have a significant impact on daily stock prices (Kurihara, 2006). Presently, relationship among stock return, exchange rate return and spot gold price return has become a commonly and widely discussed topic among economist, due the impact they have on economy of a country. Future behaviour of above three variables are closely monitored by investors and economic policy makers in order to make accurate decisions regarding investments. As an example when exchange rate increases, exporters lose money, in contrast importers gain more profits. Suppose, Sri Lankan tea exporters trade tea at a specific price, due to increase of exchange rate exporters may keep price intact, hence the new price becomes lower than the previous price. Therefore, exporters may end up with a loss. In the other hand, if exchange rate diminishes, exporters have advantages over other countries as they can increase the sales as well as the stock values (Yau & Nieh, 2006). Exchange rate impact is not only for the importers and exporters; as domestic firms also has a stake in fluctuations of foreign exchange. Most of the domestic firms import raw materials for businesses, hence impact on exchange rate affect them as well. It is plausible that there is a relationship between foreign exchange and stock market, hence having clear idea on these may help international and local investors to understand the behaviour of stock market and mitigate the associated risk due changes of these variables ((Stavarek, 2005).

(Brealey, 2007), the relationship between exchange rate and stock return are explained by Capital Asset Pricing Model (CAPM) and Arbitrage Pricing Theory. CAPM explains exchange rate risk is a firm specific risk hence it is non-systematic in nature.

The main intention of the research is to identify the dynamic relationship among exchange rates, gold prices and stock market movements. Economists use this relationship to interpret three aspects naming, portfolio approach, investment approach and transmission mechanism.

The final aspect explains the direction of three variables, meaning the impact of exchange rate and spot gold price on stock values and wise versa. In order to determine the direction of stock movements, Granger Causality test can be used however, this thesis will not discuss about Granger Casualty Model in depth. In addition, the impact of gold prices on stock market volatility is discussed in this research thesis as most of the countries consider gold as a prevalence investment option. Furthermore, identifying the volatility clusters of ASPI (All share price index) is the onset of the research, following this ARCH-GARCH family equations are applied to capture the volatility of stocks in order to derive a reliable equation to predict the stock behaviour. As far back in the history (Black, 1976)pointed out that volatility of the stock returns changes over time while responding asymmetrically to good or bad news. Aforementioned properties associated with stocks are analysed by collecting data over a period of six years, from 4th January 2010 to 4th March 2016. Data sets consist of daily closing values of ASPI, USD/LKR exchange rates and gold prices.

1.1 All Share Price Index

All Share Price Index (ASPI) is the longest and most common measure of Sri Lankan Stock market. It measures the movement of stock prices of all listed companies under ASPI and index is calculated using weighted market capitalization method. The weighted mechanism allows price movements in larger companies to decide the index value, on assumption that large companies have greater influence on counties economy in Sri Lanka. The base year and the base value of the index is 1985 and 100 respectively.

$$All\ Share\ Price\ Index = \left(\frac{Market\ Capitalization\ of\ all\ Listed\ Companies}{Base\ Market\ Capitalization}\right) * 100$$

$$Market\ Capitalization = Current\ Stock\ Price * Share\ Outstanding$$

1.2 Foreign Exchange Market

Foreign exchange market serves as a platform to trade foreign currency based on the specific conditions. Foreign exchange transactions govern by exchange control act no 24 of 1953. Public awareness of foreign exchange transactions was given through Guide to Foreign Exchange Transactions (GFET) 2008, which was published by Central Bank of Sri Lanka. It contains rules, regulations and methods in performing foreign exchange transactions. According to the statistics of foreign exchange brokers, US Dollars, Euros and UK Pounds are the mostly traded and most popular currencies in Sri Lanka.

1.3 Gold Market

Gold is renowned as a precious metal over many decades and people had a habit of using gold in financial transactions due to its value (Baur & Mcdermott, 2010) Gold has been used as a subject of commodity contracts, which serves the purpose of hedging in the financial markets (Whaley, 2006)

It is also considered gold as a reserve asset, which helps to maintain the value of the currencies in the world. Gold market can be defined as a location meets gold supply and demand. Gold supply is enabled by mining facilities, recycling sale of gold by central bank and investors. Gold is used in various ways such as, dental fillings, industrial use and personal use.

Moreover, gold can be liquid in extreme conditions such as inflation, political unrest, thus it may help investors to establish portfolios with the aim of mitigating the risk. At present, supply and demand of gold are governed by the World Gold Council.

1.4 Objective of the Research

There are plenty of researches on stock returns in recent past to prove its importance to a country's economy. Researches have analysed the behaviour of stocks market against the changes of numerous microeconomic and macroeconomic parameters in order to make financial and economic policies. However, most of these researches were done in international context by analysing the foreign stock markets. In contrast, there are a few researches, which were carried out in local context to study about Sri Lankan stock market. The main objective of the research is to find out relationship among stock market returns, daily exchange rate and daily gold prices in Sri Lanka. Moreover, it will be sought the possibility of creating time series model to forecast future stock returns and its volatilities to get a clear view of stock market behaviour.

Moreover, as mentioned above there are a quite limited number of researches to address stock market volatility in the local context. Moreover, most of the researches in this domain have been done using monthly or weekly data. However, subject research is governed by daily data; hence it is expected to produce better results with high accuracy in forecasting future stock returns and its direction.

1.5 Content of the Thesis

Overall thesis is structured as follows:

Chapter 2 examines similar studies and theories about volatility of the stocks and impact of external factors on volatility. Chapter 3 consists of research methodology and relevant theories/tests in order to achieve research objectives.

Results of the research is descriptively discussed in Chapter 4 along with outcomes of respective tests and hypothesis in order to interpret the real meaning of numbers which derive under results. General discussion is followed by Chapter 4 in order to conclude the study with potential future improvements.

CHAPTER 2 LITERATURE REVIEW

The existence of relationship among stock return, exchange rate and gold prices is commonly discussed topic in financial world, thus there were many studies with the aim of identifying the interrelationship among these variables. Some studies showed that there is a relationship between exchange rate and stock returns. Theory in such researches explained that exchange rate has a significant impact on volatility of stocks. Especially, if firm operates in international market then exchange rate impacts their profits and ultimately on share prices. There was a similar study which was done by (Mayasami & Koh, 2000)in order to identify the relationship between stock return and microeconomic factors. Further above study showed that there is a strong relationship among exchange rate, interest rate and price of stocks.

(Apte, 2001)examined about the interrelationship between volatility of the stock market and foreign exchange market. His model provides a clear evidence, that there is unidirectional linkage in volatility and foreign exchange. (Sohrabian & Oskooee, 1992) checked the impact of exchange rate on stock prices by employing co-integration method; this explored the long run and short run behaviour of two variables and concluded that there is very little evidence of long run relationship of exchange rate with stock prices. But the Granger casualty results confirmed, that the nature of relationship of the two variables is bi-directional. (Muntazir, 2013) investigated the dynamic relationship stock market volatility and exchange rate volatility for Asian countries, Pakistan, India and China for the period, from 2007 to 2012. GARCH model was applied to show the volatility of stock and exchange rate returns. Granger casualty test was carried out in order to investigate the dynamics of the relationship between exchange and volatility. Moreover, he concluded that there is a little evidence about co-integration relationship between exchange and stock return volatility. Along with this, it is provided a clear evidence to prove the non-existence of causality relationship between considered return variables. Further there was another descriptive research on Nifty returns and Indian rupee – US dollar exchange rate, which was carried out by (Gaurav, 2010) Several statistical tests have been used in this research thesis in order to study the behaviour and dynamics of the two variables.

Mainly this study investigated the impact of one series on the other series. Study was carried out using daily stock value of Nifty index over less than two-year period. As per the outcomes it was found, that both distributions are non-normal. Through unit root test it was found that both exchange and Nifty returns are stationary. Moreover, causality test concluded that relationship between these two variables is unidirectional.

Research which was carried out for Sri Lankan stock market index (ASPI) and foreign exchange rates concluded that all the exchange rates have a strong explanatory power of ASPI returns (Malintha, 2015) Particularly, findings exhibited negative relationship between USD/LKR returns and stock returns while GBP/LKR and stock returns had slightly positive correlation. Aforesaid evaluation was carried out using multiple regression model but it was capable of providing a clear view of equity market for the investors who intend to invest in Sri Lankan market. There was another research which was carried out by (Menike, 2006)to identify the impact of macroeconomic variables on stock prices in the local market. Required data for the research was collected over a period of 11 years, from September 1991 to December 2002. Research revolved around eight macroeconomic factors in Sri Lanka such as interest rate, foreign exchange rate, inflation, money supply etc. Statistical analysis of the research was conducted using multivariate regression and null hypothesis was stated as money supply, exchange rate, inflation rate etc. variables collectively do not accord any impact on equity prices was rejected at 0.05 level of significant. In conclusion, study indicated that macroeconomic factors have higher explanatory power in explaining stock prices. (Chkili & Nguyen, 2014)claimed that exchange rate movements do not affect stock market returns of BRICs (Brazil, Russia, India, China and South Africa) countries but the inverse relationship exists except for South Africa. Therefore, it was concluded that stock market returns of BRIC countries have a significant impact on the exchange rate.

When considering external economic factors such as crude oil, gold price, it was found that these variables have a significant impact on stock price fluctuations. According to (Smith, 2001)there is a slight negative correlation between spot gold price returns and US stock index returns.

It is also mentioned that there is no co-integrated relationship between the spot gold price returns and US stock market index returns. (Arouri, 2013)stated on the significance of predicting Chinese stock market return on one period gold price. Research was conducted using bivariate VAR (1)-GARCH(1,1) model in order to identify the relationship between Chinese gold market and stock return.

It was also claimed that there is a significant volatility transmission between the returns in world spot gold price and Chinese stock market. In some financial markets investing on gold is a different alternative for saving money as price fluctuation of gold is different to the other riskier assets. (Akar, 2011) Another research demonstrated that following the 2001 crisis, Istanbul Stock Exchange (ISE) 100 Index and gold returns were inversely related.

The study by (Baur & Lucey, 2010) made a dilemma, where gold is a hedging instrument or a reliable security. Relationship between gold prices and stocks returns setup the ground for this dilemma.

Hence, constant and time varying relations between US, UK and German stock and bond returns were used to find answers to this question. The results of this study generally support the characteristics of gold both as a hedging instrument and a reliable security. However, (Albeni & Demir, 2005) an unexpected positive relationship between gold prices and stock prices was revealed in Turkey by contradicting the role of gold as a substitute for stocks. (Mishra, 2010) examined the existence of causality relation between Indian gold prices and stock returns from January 1991 to December 2009 and found causality relation. Hence, it was proven the importance of each variable in forecasting the behaviour of the other variable.

It is noticed in the past literature that several researches have been done in order to identify the characteristics of the distribution of the stock price returns. According to (Fama, 1965) the first difference logarithmic series of stock price tend to deviate from normality conditions. As mentioned above for this research he has used American stock prices. He also stated that stock prices of large mature companies tend to follow a stable Paretian distribution with character exponents close to two.

It is also claimed that log return of thirty stocks in the American stock market tend to have extreme tails under the normality hypothesis. Similarly, (Bollerslev, 1987) built a Generalized Autoregressive Conditional Heteroskedastic (GARCH) model in his analysis allowing for conditionally t-distributed errors. He also stated that speculative price changes or returns of stocks nearly uncorrelated and can be well described using the unimodal symmetric distributions with fatter tails than the normal distribution. All these results suggest that the stock returns tend to deviate from normality assumption in modelling.

According to the above literature there are many empirical studies that have been conducted to examine the relationship between stock returns, exchange rate returns, gold prices returns etc . Most of these researches are carried out in developed countries in order to help their investors to identify the risks and relationships, which are associated with investments. However only a few researches were carried in Sri Lankan context in order to explore the behaviour of local market thoroughly. The main limitation of these researches is the day of the week effect in Colombo Stock Exchange, which creates the inconsistence in investing patterns. Further the seasonal patterns or stock market anomalies are crucial for both investors as well as policy makers, to consider during the investment planning process. Thus, this gap needs to be fulfilled in order to equip investors with adequate information and knowledge in order make their portfolio strategies.

It is also noticed that the variables such as spot gold price and daily exchange rates have been used in limited manner when modelling local stock market volatility. Furthermore, most of the researches have been conducted their studies considering monthly or weekly data of ASPI. Therefore, this subject research was carried out using daily ASPI data to increase the level of accuracy by considering a large number of data points. Hence it is hoped, this study addresses aforementioned gaps adequately and encourage investors to use the derived forecasting model to obtain better returns from investments.

CHAPTER 3 METHODOLOGY

This chapter mainly describes the statistical terms and techniques, which are applied throughout the study. According to the introduction and literature review main intention of this exercise is to identify the impact of daily exchange rate and daily gold prices on volatility of daily stock return. Hence this chapter mainly consists with a bunch of time series methods and techniques. In addition, descriptive statistic terms are also introduced in this section to provide a general understanding about the data sets.

3.1 Descriptive Statistics

Skewness

Skewness measures the symmetric/asymmetric dispersion of data around the mean level of a given data set. When skewness index is zero then data set dispersed around the mean symmetrically.

Positive and negative skewness can be identified by analysing the tail of correlogram as if it is right tail; distribution is positively skewed in contrast if it is left tailed distribution is negative skewness.

Kurtosis

This measures the peak of the data set. If the kurtosis is higher, then the distribution tends to have a peak within the limits of mean, conversely low kurtosis signifies spread of data over wider area. Theoretically, if the kurtosis is greater than 3, it implies deviation of data set from normality conditions. This means data set tends to have more extreme values.

Time Series Analysis

Time series analysis is a collection of data which is collected in sequential points in time. It can be continuous or discrete depending on the sequence of data collected. In time series the distance between two data points is same.

A significant feature in time series analysis is that the stationary condition. Therefore, before further analysis on time series models stationary conditions should be examined. There are three main properties in stationary process,

- Mean constant
- Variance constant
- Covariance between two time periods is only depending on lag between two periods of time.

3.2 Unit Root Test

Unit root is an indication of the stationarity. The existence of a unit root indicates that the series is not stationary while lack of a unit root conveys that the series is stationary. Therefore, in this statistical test, there are two test hypotheses as below,

H_0: Time series is non – stationary (There is a unit root)

H_1: Time series is stationary (There is no unit root)

$$Y_t = c + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \dots\dots\dots + \alpha_p Y_{t-p} + \varepsilon_t$$

Above mentioned stochastic process $\{Y_t\}$ is called as an autoregressive process of order p. It can be also denoted as AR(p) and ε_t represents the white noise.

$$Y_t - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-2} - \dots\dots\dots - \alpha_p Y_{t-p} = c + \varepsilon_t$$

Alternatively, it can be represented with lag operator L, as below,

$$(1 - \alpha_1 L - \alpha_2 L^2 - \dots\dots\dots - \alpha_p L^p) Y_t = c + \varepsilon_t$$

$$\text{Let,} \quad \varphi(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \dots\dots\dots - \alpha_p L^p$$

$$L^k Y_t = Y_{t-k} \ (k = 1, 2\dots\dots\dots\dots\dots, p)$$

The AR (p) process is said to be stationary if the roots of φ(L) lie strictly outside the unit circle. Then Yt is said to be stationary. φ(L) is also known as the character polynomial of AR (p) process.

Where, Yt -Variable of interest at time t, αi – Coefficient i, L- Lag operator, ε_t – error at time t and C- constant.

3.3 Dickey-Fuller (DF) test

Dickey Fuller test is used to test whether there exists a unit root in the autoregressive model. This test was found by Dickey and Fuller in 1979.

Let's consider a simple AR (1) process.

$$Y_t = c + \alpha Y_{t-1} + \varepsilon_t$$

In order to test the stationarity, the null hypothesis of $|\alpha|=1$ (non-stationary) is tested against the alternative hypothesis $|\alpha|<1$ (stationary).

$$\Delta Y_t = c + \beta Y_{t-1} + \varepsilon_t$$

Where, Y_t -Variable of interest at time t, α and β – Coefficients, ε_t –error at time t and c- constant

According to the equation 3.2

$$\beta = \alpha - 1$$

Then it can be said that testing $|\alpha|=1$ implies that $|\beta|=0$

Therefore, the test statistic will be $\hat{\beta}/(S.E.(\hat{\beta}))$

But it was found that the above sampling distribution of the above test statistic was left skewed. Therefore, it was suggested that the test statistic doesn't follow the student t-distribution. Therefore, they have introduced new critical values depending on the sample size.

As an extension of the Dickey-Fuller test, Augmented Dickey-Fuller (ADF) test was introduced which removes the structural effects in the series.

3.4 Augmented Dickey-Fuller (ADF) test

As clear from the name, this test is an augmented version of the Dickey-Fuller test for larger and more complex time series models. This test is useful if the series is correlated at higher order lags and the assumption of the white noise disturbance ε_t is violated.

A parametric correction for higher order correlation has been done by the ADF test in these situations by assuming that y series follows a AR (p) process. In this test p lagged difference terms of the dependent variable is added to the right hand side of the equation (3.2).

$$\Delta Y_t = c + \beta Y_{t-1} + \rho_1 \Delta Y_{t-1} + \rho_2 \Delta Y_{t-2} + \dots\dots\dots + \rho_p \Delta Y_{t-p} + \varepsilon_t$$

Then the test proceeds in the same way as explained above. It has found that the asymptotic distribution of the t-ratio for β is independent of the number of lagged first differences included in the ADF regression

3.5 Order of a Series

Suppose that non stationary series is said to be differenced d times in order to make the series to be stationary. Then it is said to be integrated of order d. It can be also written as I(d).

Example: Suppose $y_t = y_{t-1} + u_t$

Then y_t is I (1) where y_t-y_{t-1} is I(0)

This can be derived through unit root test.

It is known that from the ADF test,

H_0: $Y_t \sim$ I (1) Vs H_1: $Y_t \sim$ I(0) is tested.

If the test statistic rejects the null hypothesis, it can be concluded that the series is stationary. In those situations the series is said to be I(0). But if the test statistic doesn't reject the null hypothesis, it conveys that the series is not stationary. Then in order to find the order of the integration, the ADF test or another unit root test has to be carried for the differenced series also.

Then

H_0: $\Delta Y_t \sim$ I(1) Vs H_1: $\Delta Y_t \sim$ I(0) is tested.

The same testing procedure will also be carried here. If the test statistic rejects the null hypothesis, then it can be said that ΔY_t is stationary. Then ΔY_t is said to have the order of integration zero. Another way it implies that the original series $Y_t \sim$ I(1). If the test statistic doesn't reject the null hypothesis, then the above process will be carried further to find the order of the integration.

3.6 Volatility Modelling

Volatility is an important factor in equity markets. It refers to the variation or dispersion over time. If the specific series is fluctuating rapidly within a short period of time, then it can be said that the series is highly volatile whereas if the series varies slightly within a period, then it is said to be low volatile. It can be also said that volatility is the conditional deviation of the underlying asset. Usually return series is obtained in analysing the volatility because volatility can be clearly seen in the return series. Therefore, in this study the log return series of the daily ASPI is taken in order to analyse the volatility.

$$R_t = \log\left[\frac{ASPI_t}{ASPI_{t-1}}\right]$$

Where, R_t :-Log return of ASPI at time t

$ASPI_t$:- ASPI value at time t

$ASPI_{t-1}$:-ASPI value at time t-1

There are few important characteristics exist in volatility. A special characteristic of the volatility is that it is not possible to observe the volatility directly through the naked eye. This nature makes it hard to evaluate the performance of volatility models. Therefore, in most of the time high frequency data will be obtained in order to model the volatility.

In option market 'implied volatility' is another important term. It is the volatility forecast over the life of an option which equates the model price of an option with the observed price.

Implied volatility is done on the assumption of that the distribution follows a geometric Brownian motion. But this is always not true and it might be different from true volatility.

Therefore 'stochastic volatility' is a term that depends on the chosen statistical model which is applied to the historical asset return data. Volatility clustering is another important feature in volatility.

This means that periods with high volatility followed by the periods of high volatility whereas periods with low volatility followed by the periods of low volatility. Conversely, volatility will be high for some time period and low for another time period.

Another feature of the volatility is that it does not diverge to the infinity and it is continuous in nature. That means volatility varies within a fixed range and does not jump over the periods. Leverage effect is another important characteristic that has to be concerned in volatility modelling. In other words, there might be an asymmetry nature in volatility where volatility will be increased more, when stock prices are falling than the stock price decrease by the same amount. Therefore, appropriate volatility model needs to be selected in fitting the volatility.

3.7 Testing the existence of Volatility Clusters

As mentioned above it is one of the main characteristics exist in volatility. This implies that the existence of the strong autocorrelation of the squared returns. Therefore, first order autocorrelation of the squared returns can be obtained to test the volatility clustering. Box-Pierce LM test can be used for this purpose.

In this test,

H_0: There's no autocorrelation in squared returns (no volatility clusters)

H_1: There exist an autocorrelation in squared returns. (There exist volatility clusters)

1st order autocorrelation in squared returns is given by,

$$\Phi(1) = \frac{\sum_{t=2}^{T} r_t^2 r_{t-1}^2}{\sum_{t=2}^{T} r_t^4}$$

Then the Box-Pierce test statistic is given by

$$Q = T\sum_{t=1}^{T} \Phi(1)^2 \;\sim \chi_1^2 \; (under\ null\ hypothesis)$$

T: Number of observations

If the test statistic ($Q > \chi_1^2=3.84$), then the null hypothesis can be rejected under 5% significant level. Hence, it provides sufficient evidence to conclude the existence of volatility clusters.

This is not a very robust test. But the results of the above test can be enhanced through some adjustments to the series. If the above test suggests that there exist no volatility clustering, then it needs to be checked whether the low volatility clustering is due to the large negative returns. This is because the above test checked for the chi-squared distribution (more suitable for large positive returns). This can be analysed using the skewness and kurtosis as well.

3.8 Testing the presence of asymmetry in volatility clusters

In some situations, some equity markets tend to show an asymmetry in volatility clustering. As mentioned above this will be happened due to the increase of volatility more, when stock prices are falling than the stock price decrease by the same amount. Therefore, depending on the symmetry/ asymmetry of the volatility clusters, an appropriate GARCH model (volatility model) needs to be selected in order to obtain the correct results. If a symmetric GARCH model is used in a place where there is asymmetric volatility clusters present, then it will lead to unreliable results. Therefore, testing asymmetric nature in volatility is very important.

The asymmetry of the volatility can be detected by the autocorrelation between the yesterday's return and the today's squared return. This is because when asymmetry present, the volatility will be higher following a negative return than following a positive return.

$$\nu = \frac{\sum_{t=2}^{T} r_t^2 r_{t-1}}{\sqrt{\sum_{t=2}^{T} r_t^4 \sum_{t=2}^{T} r_{t-1}^2}}$$

r_t: Return at time t

If the above mentioned autocorrelation (ν) is negative in value or the Box-Pierce test statistic corresponds to the above function is significantly different from zero, then it implies the existence of the asymmetry in volatility.

3.9 GARCH Models

In most of the equity markets the volatility on asset returns seem to exist. In these markets the unexpected returns are not independent and identically distributed where the variance is conditional on time. In other words, the error terms would have a time varying variance. It is also known that returns of the equity markets are non-linear in nature. Therefore, using linear time series techniques or regression would give unreliable results since these techniques assume there exist a constant variance. Therefore, modelling the conditional volatility is important in equity markets. Family of GARCH models contains such statistical volatility models which can be used to model the conditional volatility. In a GARCH model returns are assumed to be produced by a time varying volatility stochastic process.

In order to use a GARCH model, first it needs to clarify whether the series contains volatility clusters. For that purpose, the above mentioned Box-Pierce LM test can be used. If the test suggests the existence of the volatility clusters, then symmetric/asymmetric nature of volatility clusters can be assessed using the test explained under above section. Then as mentioned above, depending on the results a suitable GARCH model needs to be selected form the GARCH family.

3.10 Symmetric GARCH Model

These symmetric GARCH models should be used after confirming the presence of volatility cluster and symmetric nature in volatility. The GARCH model has two main components namely the conditional mean equation and the conditional variance equation. The conditional mean equation of the return process can be generated through a simple linear regression.

The conditional variance is captured by its historical squared errors (ARCH terms) as well as from the lagged conditional variance (GARCH terms).

This equation is the most important component in the model which represents the evolution of the conditional variance of the unexpected returns (the error of the mean equation). It is argued that simple GARCH model is able to give a better fit than the ARCH model with a higher order.

GARCH (p,q) process with the simplest form in the mean equation can be denoted as follows.

Conditional Mean Equation : $y_t = c + \varepsilon_t$

Conditional Variance Equation : $\sigma_t^2 = c' + \sum_{j=1}^{p} \alpha_j \varepsilon_{t-j}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2$

Where y_t: Returns at time t

c: Constants

ε_{t-j}: Residuals from t he mean equation at lag j

α_j : Coefficients of ARCH terms (j=1……., p)

σ_{t-i}^2: Conditional variance at lag i

β_i : Coefficient of GARCH terms (i=1………., q)

Constraints introduced in to the GARCH model are denoted below.

1. $p \geq 0, q \geq 0$
2. $c > 0, \beta i \geq 0$ for, j = 1…………, p and i = 1…………, q

The simplest GARCH (1,1) model is known as the vanilla GARCH model. The return series is said to be stationary if the sum of α and β is less than one.

It should be noted that the above conditional mean equation can be updated with autoregressive terms as well as exogenous variables appropriately. Conditional variance equation can also be updated with external factors as well. Then the format of the GARCH (p,q) model will be as follows.

Conditional Mean Equation : $y_t = c + \sum_{a=1}^{r} A_a y_{t-a} + \sum_{b=1}^{n} u_b X_b + \varepsilon_t$

Conditional Variance Equation: $\sigma_t^2 = c' + \sum_{j=1}^{p} \alpha_j \varepsilon_{t-j}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2 + \sum_{c=1}^{m} \partial_c y_c$

According to (Nelson & Cao, Inequality Constraints in the Univariate GARCH Model, 1992) the 2nd constraint is sufficient but not necessary to hold in order to have a positive variance. Therefore, it can be relaxed when adding the exogenous variables. When this relaxation happened, the coefficient of the conditional variance equation can be negative values while the total variance is constrained to be positive at each point of time.

3.11 EGARCH Model

Let $r_{j,t}$ return of the market index at time t.

$r_{j,t=}\ \delta_j\ I_{j\ t-1} + \xi_{j\ t-1}$

$\xi_{j\ t-1} =\ \sigma_{j,t}\ Z_{j\ t}$

$Z_{j\ t}|\Omega_{j\ t-1} \sim\ \Psi(0,1,v)$

$$\ln \sigma^2{}_{j\ t} =\ \omega_j\ +\ \beta_j\ \ln \sigma^2{}_{j\ t-1} + \frac{\xi_{t-1}}{\sqrt{\sigma^2 t-1}}\ +\ \alpha\,[\frac{|\xi_{t-1}|}{\sqrt{\sigma^2 t-1}}\ -\ \sqrt{\frac{2}{\Pi}}]$$

In above equations $\sigma^2(j\ t)$ is known as conditional variance since it is one period ahead estimate for variance which calculates based on the fact that any past information is relevant. $Z_{j\ t}$ is the standard residuals. Ψ (.)is the conditional density function and v signifies the vector parameters that needed to notify the probability distribution. ω,α,β,γ denote the parameters to be estimated.

The major advantage of EGARCH model is even parameters are negative σ^2 is positive. EGARCH model is mainly to evaluate asymmetric volatility which is known as leverage effect, which occurs when there is a negative correlation between stock value and stock volatility.

Parameter α measures the symmetric effect of the model; it is called as GARCH or magnitude effect. β measures the conditional volatility irrespective of any other factor in the market. The γ parameter measures the asymmetry or leverage effect. When addressing facts pertaining to asymmetric volatility EGARCH model is highly recommended as generic ARCH model is not capable of identifying negative correlation between changes in stock prices and volatility.

If $\gamma = 0$ then volatility is symmetric, if $\gamma > 0$ then it is a positive shock due to good news in the market and it generates less volatility than negative shocks (bad news).

3.12 GJR GARCH Model

The GJR-GARCH model was introduced by, Glosten, Jagannathan and Runkle in 1993. It extends the standard GARCH (P, Q) and it is similar to EGARCH model. Main GJR-GARCH model is also capable of capturing asymmetric volatility clusters in the conditional variance equation.

The propensity for the volatility to rise more subsequent to large negative shocks than to large positive shocks (known as the "leverage effect").

GJR-Generalized Autoregressive Conditional Heteroscedasticity (GJR-GARCH) process.

GJR-GARCH (P, O, Q) process is defined as

$r_t = \mu_t + \varepsilon_t$

$$\sigma_t^2 = \omega + \sum_{p=1}^{p} \alpha_p \varepsilon_{t-p}^2 + \sum_{o=1}^{q} \Upsilon_o \sigma_{t-o}^2 + \sum_{q=1}^{q} \beta_q \sigma_{t-q}^2$$

$r_t = \sigma_t e_t$

$e_t \sim N(0,1)$

where μ_t can be any adapted model for the conditional mean.

3.13 Distributional Assumptions

It is clear from the literature review, that most of the researches done on stock returns confirm that there is a tendency for the stock market returns to deviate from normality. But it should be tested in the study in order to gain correct estimates. The normality of the returns can be tested using the Jarque-Bera test for normality. This test will measure the skewness and kurtosis of the series compared to the normal distribution.

H_0: Series is normally distributed

H_1: Series is not normally distributed

Test statistic will be : $L = \frac{N}{6}(S^2 + \frac{(K-3)^2}{4})$

Where S: Skewness

K: Kurtosis

N: Number of observations

Under the null hypothesis, $L \sim \chi_2^2$

Therefore if L > $\chi^2_{2,5\%}$, the null hypothesis will be rejected. That means it suggests returns are not normally distributed. Then normality assumption for returns or conditional distribution of errors is not valid. Therefore, student –t distribution would be assumed for parameter estimation under maximum likelihood method. Finally, a Q-Q plot (for the assumed distribution) will be used for the residuals in order to test the reasonability of assumed distribution. If the innovations or errors are plotted on the expected line, then the assumed distribution is reasonable.

3.14 Diagnostic Tests for the Fitted Models

The main objective under this section is to check the model adequacy. There are few tests that can be carried out to under the model adequacy testing. They are denoted below.

3.15 Ljung-Box Q-Statistics for standardized squared residuals/returns

This test is done in order to test the null hypothesis of no serial correlation in standardized squared residuals/returns up to lag k.

Test statistic will be $Q_{LB} = T(T+2)\sum_{j=1}^{k}\frac{\Gamma_j^2}{T-J}$

Where Γ_j: j^th autocorrelation of standardized squared residuals/returns

T: Number of observations

It is known that asymptotically Q~ $\chi^2_{k\,(5\%)}$. Therefore, if Q statistic is not rejected it provides sufficient grounds to claim non-existence of serial correlation up to lag k. This implies that the fitted EGARCH/GJR GARCH models are sufficiently adequate or well specified.

3.16 ARCH-LM test

ARCH-LM tests for autoregressive conditional heteroskedasticity (ARCH) in residuals. This tests the null hypothesis of there are no ARCH up to order q in the standardized residuals. ARCH-LM test statistic is computed from the below mentioned auxiliary equation.

$$e_t^2 = \beta_0 + \left(\sum_{s=1}^{q}\beta_s\, e_{t-s}^2\right) + \nu_t$$

Where e is the residuals,

Under this test there are two test statistics that will be generated. F-statistic tests for the joint significance of all the lagged squared residuals. The Obs*R-squared statistics means the number of observations times the R^2 from the above regression. If both of these test statistics rejects the null hypothesis, then it can be said that the model is adequate.

3.17 Empirical Quantile - Quantile plot for residuals

As mentioned above Q-Q plot will test the reasonability of the assumed conditional distribution of errors. In this plot Quantiles of the residuals are plotted against the quantiles of the assumed distribution. If the assumed distribution is reliable then the residuals needs to be fitted appropriately on the assumed distributional line.

3.18 Information Criteria

Below mentioned criterions are used within this study in order to compare two EGARCH models with same parameters. The model with the lowest information criterion value will be selected.

3.19 Akaike Information Criteria

This will measure the relative quality of a statistical model for a given data set. But this won't give an indication of the quality of the model in absolute sense.

$$AIC = \frac{-2}{T}\ln(likelihood) + \frac{2}{T}(number\ of\ parameters)$$

3.20 Schwarz Criteria

This also used in model selection process. This information criterion is also based on the likelihood function and it is very much close to the AIC but more powerful than it.

$$SC = \frac{-2}{T}ln(likelihood) + \frac{K}{T}(log\,T)$$

Where T is the number observations and K is the number of free parameters.

3.21 Hannan–Quinn information criterion

HQ criterion is mainly used for model selection as it can be considered as an alternative to AKAIKE information criterion and Bayesian information criterion.

$$HQC = -2Loglikelihood\ (max) + 2Klog(log\ N)$$

Where L_{max} is the log-likelihood, K is the number of parameters and n is the sample size.

CHAPTER 4 ANALYSIS

4.1 Preliminary Data Analysis

Table 4.1 presents the descriptive statistics for ASPI stock index, daily exchange rate and daily gold price. Table 4.2 represents the same statistics for return series of three variables. Below depicted calculation was used in order to calculate the respective return values.

$$\text{Return} = X_{t} - X_{t-1}$$

Statistic	ASPI	Exchange Rate	Gold Price
Mean	6164.868	124.9892	5519.515
Median	6220.820	130.1300	5347.460
Std. Dev	967.8127	10.22762	819.6003
Kurtosis	3.048876	1.805311	2.536788

Table 4-1 Descriptive Statistics: Level Series Stock Indices, Daily Exchange Rates and Daily Gold prices

Statistic	ASPI	Exchange Rate	Gold Price
Mean	0.000388	0.000163	0.000245
Median	0.000213	0.000000	0.000111
Std. Dev	0.008232	0.002792	0.012051
Kurtosis	7.663870	6.04521	6.550507

Table 4-2 Descriptive Statistics: Return Series of Stock Indices, Daily Exchange Rates and Daily Gold prices

4.2 ADF Unit Root Test: Evaluating Stationary Conditions

Unit root test is to check the stationary condition of a model. In order to consider a data series under time series assumptions that series should satisfy stationary conditions which are Mean constant, variance constant and covariance between two time periods is only depending on lag between two periods.

If and only is aforesaid criteria satisfied data can be modelled with a time series model. Hence, all three data sets were examined for stationary condition using unit root test with below hypothesis,

H_0: Data set has a unit root

H_1: Data Set doesn't have a unit root

First test was applied on level series including both intercept and trend parameters as plotted below, data set shows the existence of trend and intercept,

Respective results for three data sets are as follow,

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.952802	0.6259
Test critical values:	1% level	-3.964488	
	5% level	-3.412962	
	10% level	-3.128477	

Table 4-3 ADF Unit Root Test: ASPI stock index level series

As per the above results P value of the test is 0.6259 which is greater than 0.05. Hence null hypothesis should be accepted and conclude that level series of ASPI has a unit root. Therefore, ASPI level data series is non stationary.

Further P value of the intercept is 0.0102, which is significant at 0.05 level. However, level series is not significant, therefore ADF test was carried out on first log differenced series of ASPI and results are depicted below,

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-31.55328	0.0000
Test critical values:	1% level	-3.964488	
	5% level	-3.412962	
	10% level	-3.128477	

Table 4-4 ADF Unit Root Test: ASPI 1st Differenced Series

P value of the first log differenced series is 0 (P value is < 0.05), therefore it can be concluded that null hypothesis is rejected and series doesn't have a unit root. Therefore, 1st differenced series is stationary.

Similarly, ADF test was carried out on daily exchange rate and gold rate as below,

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.570677	0.8042
Test critical values:	1% level	-3.964484	
	5% level	-3.412960	
	10% level	-3.128476	

Table 4-5 ADF Unit Root Test: Daily Exchange Rate Level Series

As per the P value of ADF test, null hypothesis of daily exchange rate level series laid on the rejection region, due to the fact that respective P value is greater than 0.05, hence the test was continued on 1st differenced series to check the stationarity condition.

Below table depicts the ADF test results for 1st differenced series, as per the results it can be considered that 1st differenced series of exchange rate doesn't have a unit root, therefore series is stationary.

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-36.12096	0.0000
Test critical values:	1% level	-3.964488	
	5% level	-3.412962	
	10% level	-3.128477	

Table 4-6 ADF Unit Root Test: Daily Exchange Rate 1st Differenced Series

Stationarity conditions for daily gold rate was also evaluated and it is found that 1st differenced series of daily gold rate behaves within the stationary limits by rejecting the null hypothesis at 5% significant level.

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.956343	0.6240
Test critical values:	1% level	-3.964484	
	5% level	-3.412960	
	10% level	-3.128476	

Table 4-7 ADF Unit Root Test: Daily Gold Rate Level Series

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-39.66090	0.0000
Test critical values:	1% level	-3.434724	
	5% level	-2.863359	
	10% level	-2.567787	

Table 4-8 ADF Unit Root Test: Daily Gold Rate 1st Differenced Series

After applying ADF test on all the independent and dependent variables it was shown that the 1st difference series of all three data sets are stationary. Therefore, differenced series of each variable was used to build a time series model in order to predict future stock values. Generally, return series is commonly considered in analysing the volatility of the stocks as it provides a better view of volatility. Therefore, log returns of daily ASPI were taken in to consideration to model conditional returns and volatility.

4.3 Testing Volatility Clusters

Below graph depicts daily returns of ASPI over considered time period and it can be easily seen the fluctuations/volatility of returns based on factors, which prevailed during the same period. The impact on volatility due to bad and good news can be explained by analysing the patterns of the graph. High stabilities may be due to unexpected bad news, while lower volatilities represent expected good news. Similar scenario can be led to asymmetric scenario in volatility clusters,

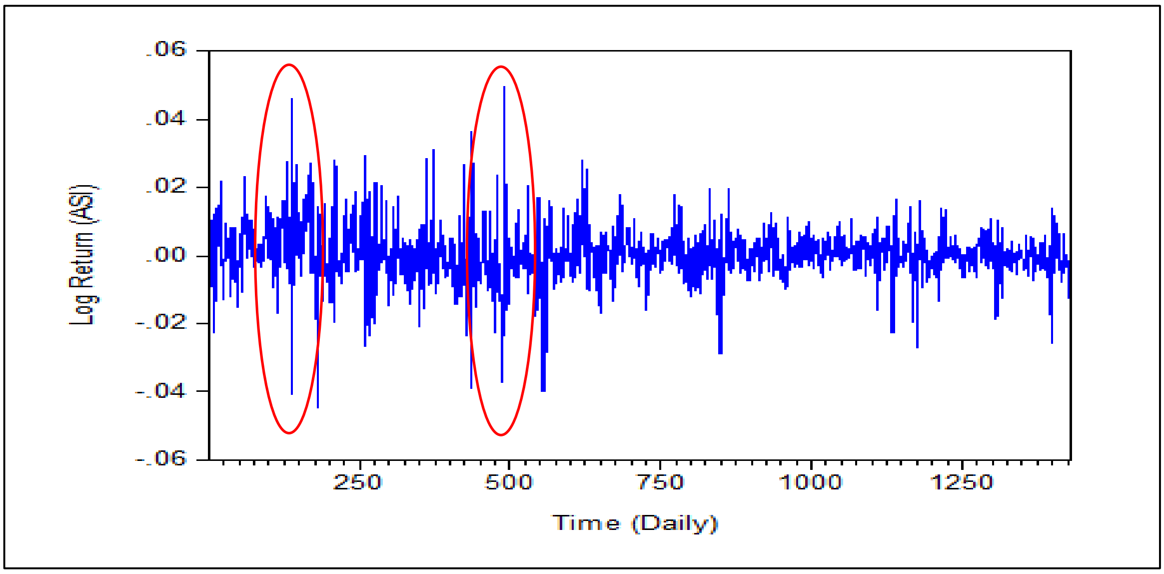

Figure 4-1 Time series plot of daily returns of All Share Price Index

As volatility clustering depicts a strong autocorrelation in squared returns, the same series of ASPI was obtained as below to get a clear view of the volatility clusters,

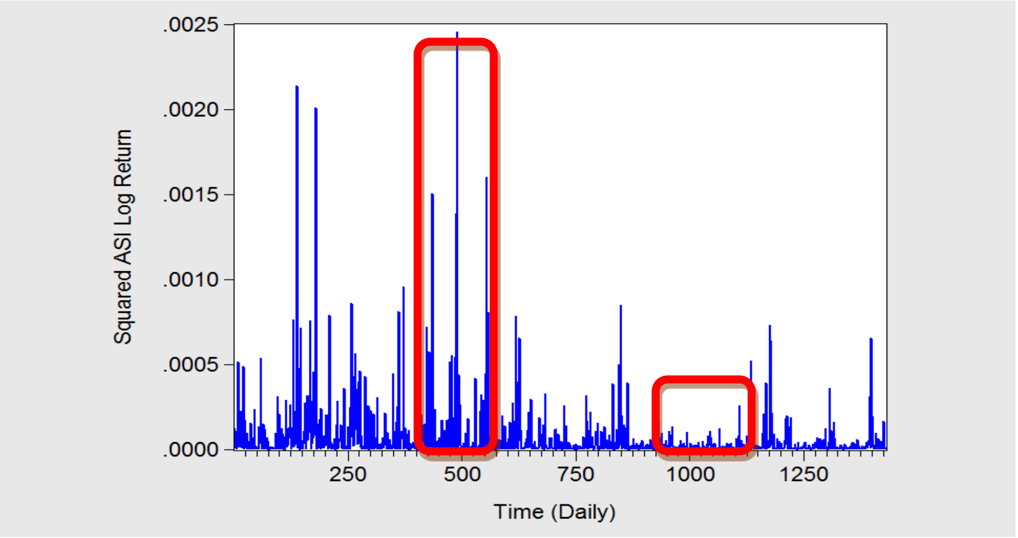

Figure 4-2 Squared ASPI log returns

It is completely clear that there are multiple volatility clusters in the above diagrams. Moreover, high volatility is followed by another period high volatility and low volatility is followed by another period of low volatility and this pattern prolonged over a considerable amount of time. Clusters, which depict aforesaid properties were highlighted in the above figures.

Therefore, it can be considered that daily values of ASPI comprise volatility clusters with high and low volatilities. In order to assure the existence of volatility clusters ASPI return series was tested against statistical significance using Box- Pierce LM test.

As per the results respective Q statistic value was Q = 87.861 which is greater than test statistic criterion of 3.84, at 5% significant level. Hence this provided clear evidence to reject null hypothesis and it reassured non-existence of autocorrelation in squared return at 5% significance level. Similarly, this provided a sufficient evidence to prove that there exists a conditional heteroscedasticity in daily returns of ASPI. Now it is clear that the existence of significant volatility clusters in ASPI log return series, therefore it is safe to conclude that there is an ARCH effect in the data set during the considered time period. Hence, this can be considered as the entry criteria to use ARCH model in order to forecast the stock behaviour.

Following descriptive statistics depicts few more important properties of ASPI log return series,

Skewness	0.011685
Kurtosis	7.663870
Jarque-Bera	1294.258
Probability	0.000000

Table 4-9 Skewness, kurtosis and normality test for ASPI log return series

As per the above table now it is clear that daily ASPI returns has high Kutosis with positive skewed distribution. According to the finding of Fama (1965), it was stated that stock returns tend to follow non- normal unconditional distribution if it has high kurtosis and skewness. Hence result of above table is in par with the same with higher kurtosis and positive skewness.

Further as per the studies carried out by Bollerslev (1987) it is recommended the appropriateness of using conditional student-t density than a conditional normal distribution.

JB (Jarque- Bera) statistics which is depicted in the above table provides further evidence on deviating from normal distribution. As per the above table, JB test deviated from normality conditions by rejecting the null hypothesis. Hence, it is safe to conclude, that ASPI log returns are not normally distributed. Therefore, it was assumed the student-t distribution is the most suitable distribution to model errors in the model building process.

After identifying volatility clusters of ASPI log returns, symmetricity in the volatility clusters is analysed to select proper time series model between ARCH, EGARCH and GJR GARCH in order to build the forecasting model for future stock returns.

4.4 Asymmetric/Symmetric Nature of the Volatility

Prior to apply ARCH/ EGARCH/ GJR GARCH models, it is required to analyse symmetricity of the volatility clusters. In case, there is asymmetry in volatility, fitting ARCH model doesn’t produce accurate outcomes as ARCH model is incapable of capturing asymmetric volatility.

Asymmetry in volatility occurs due to significant increase in volatility when stock prices fall, compared to rise of the same. As mentioned in the methodology, below test can be used to identify the asymmetric volatility.

$$V \quad = \frac{\sum_{t=2}^{T} R_{t^2} * R_{t-1}}{\sqrt{(\sum_{t=2}^{T} R_{t^4}} * \sum_{t=2}^{T}(R_{t-1})^2)}$$

As per the above formula, if autocorrelation between yesterday's return and today's square returns are negative, it can be concluded the existence of asymmetric volatility. In order to calculate the above V value, test was carried out on Microsoft excel and the result is as below,

$$\sum_{t=2}^{T} R_{t^2} * R_{t-1} = -0.000127948$$

$$\sqrt{(\sum_{t=2}^{T} R_{t^4}} * \sum_{t=2}^{T}(R_{t-1})^2 = \ 0.002206656$$

$$V \quad = \frac{\sum_{t=2}^{T} R_{t^2} * R_{t-1}}{\sqrt{(\sum_{t=2}^{T} R_{t^4}} * \sum_{t=2}^{T}(R_{t-1})^2)} = -0.057982693$$

Result of the above test is negative hence, it provides sufficient grounds to conclude that volatility in ASPI returns is asymmetric. Therefore, EGARCH and GJR GARCH models can be used to derive a forecasting models.

Subsequent to the above test corresponding Box Pierce LM statistic was calculated to reassure the asymmetric nature of the volatility.

Box Pierce LM statistic,

$$Q = (-0.057982693)^2 \text{ x } 1{,}429$$

$$= 4.804287584 \ (> \chi^2_{1,5\%} = 3.84)$$

Since Q statistics corresponding to v value is greater than $\chi^2_{1,5\%}$ (= 3.84), implies that it is significantly different from zero. Therefore, it rejects null hypothesis and safe to conclude that there exists asymmetric nature in volatility. Hence, using EGARCH and GJR GARCH model is more suitable in deriving forecast equations.

ASPI daily closing data from 4th Jan 2010 to 4th March 2016 is used to derive the model in order to evaluate the impact of daily exchange rate and daily spot gold price on ASPI. Aforesaid period contains 1429 data points.

Model fitting was carried out on EViews, as the first step log returns of ASPI, Daily exchange rate and daily spot gold rate modelled using EGARCH method. As mentioned above, error distribution is modelled using student-t distribution. Log returns of daily exchange rate, gold rate and intercept are considered in the mean equation while keeping ARCH, GARCH and Asymmetry orders one in order to keep the model simple.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Conditional Mean Equation			
Dlngold_price	0.018975	0.011826	1.604480	0.1086
Dlnexchange_rate	-0.093698	0.065673	-1.426731	0.1537
C	0.000307	0.000151	2.035369	0.0418
	Conditional Variance Equation			
C(4)	-0.917347	0.171312	-5.354847	0.0000
C(5)	0.397171	0.049218	8.069594	0.0000
C(6)	-0.044093	0.022561	-1.954406	0.0507
C(7)	0.936533	0.015778	59.35578	0.0000

Table 4-10 Coefficient and p values of the model

Mean Equation

dlnASPI $_t$ = 0.000307 + 0.018975dlngold_price-0.093698dlnexchange_rate+∊

Variance Equation

$$LOG(\sigma^2{}_t) = C(4) + C(5)\left(\left|{\varepsilon^2{}_{t-1}}/{\sqrt{\sigma^2{}_{t-1}}}\right|\right) + C(6)\left({\varepsilon_{t-1}}/{\sqrt{\sigma^2{}_{t-1}}}\right) + C(7)(Log\ (\sigma^2{}_{t-1}))$$

As depicted above, mean equation was derived using two independent variables and intercept. Respective coefficients of daily gold price, daily exchange rate and intercept are 0.018975, -0.093698, 0.000307 respectively. However, when analysing the probabilities of each parameter it is clear that respective P value of intercept is only significant at 5% level as probability is less than 5%. In the variance equation almost all the parameters are significant at 5% level (C (6) coefficient is marginally higher than .05 but it can be considered as significant)

Both daily exchange rate and gold prices appeared to be insignificant hence, both variables are removed and check the behaviour of ASPI log returns with its own past values. Hence the process of model fitting was continued using past values of ASPIs (yesterday log return ASPI, day before yesterday log return ASPI etc.) in order to evaluate the impact on today's ASPI log return value due to past ASPI log return values. Therefore, AR terms are added to the equation and checked for the statistical significance as below,

Results after adding one AR term for the model,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000247	0.000190	1.301300	0.1932
AR(1)	0.219969	0.026579	8.276148	0.0000

Table 4-11 Coefficient of AR(1) terms and Constant of EGARCH (1,1) Model

As per the above table “yesterday’s” ASPI value is significant in deciding todays ASPI value, hence, it can be considered that there is a relationship between today’s ASPI value and yesterday’s ASPI value. Another AR term is added to the model to analyse the impact of “Day before yesterday’s” ASPI value on today’s ASPI value and results are as follow,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000211	0.000205	1.025085	0.3053
AR(1)	0.205458	0.027535	7.461712	0.0000
AR(2)	0.081055	0.027892	2.906024	0.0037

Table 4-12 Coefficient of AR(1), AR(2) and Constant of EGARCH(1,1) Model

AR (2) terms is also significant and it can be considered in the model. Hence there is a sufficient evidence to consider that today’s ASPI value depends on last two of days ASPI values.

As AR (2) is significant another AR term is added to the equation and result is as follows,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000200	0.000216	0.929304	0.3527
AR(1)	0.204410	0.027608	7.403884	0.0000
AR(2)	0.069281	0.028862	2.400433	0.0164
AR(3)	0.047778	0.026595	1.796519	0.0724

Table 4-13 Coefficients of AR(1), AR(2), AR(3) and Constant of EGARCH(1,1) Model

As depicted in the above table AR (3) term is insignificant hence, it can be considered that behaviour of today’s ASPI value can only be described using previous two day’s ASPI values and it doesn’t rely on past values of itself more than past two-days period.

Hence, AR (3) term was removed and following this model was tested adding daily exchange rate as an independent variable with two AR terms of ASPI. Output of the mean equation is as follows,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
$Dlnexchange\_rate_t$	-0.059824	0.065448	-0.914060	0.3607
C	0.000221	0.000205	1.080390	0.2800
AR(1)	0.204468	0.027527	7.427792	0.0000
AR(2)	0.080173	0.027930	2.870492	0.0041
AR(3)	-0.059824	0.065448	-0.914060	0.3607

Table 4-14 EGARCH Model(1,1) Coefficients of Mean Equation

	Conditional Variance Equation			
C(5)	-0.882550	0.167846	-5.258090	0.0000
C(6)	0.378038	0.047196	8.009972	0.0000
C(7)	-0.055768	0.025763	-2.164655	0.0304
C(8)	0.939177	0.015426	60.88226	0.0000

Table 4-15 EGARCH (1,1) Model Coefficient of Variance Equation

As per mean equation log return of daily exchange rate is insignificant as respective P-value is greater than 0.05 at 5% significant level. Hence, ASPI values are independent from daily exchange rate. However, all the coefficients of variance equation appeared significant, therefore, all of them can be considered in variance equation.

Next model is tested adding past exchange rate terms and the results are as follow,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
$Dlnexchange\_rate_{t-1}$	-0.042084	0.049965	-0.842274	0.3996
C	0.000208	0.000206	1.013595	0.3108
AR(1)	0.205260	0.027564	7.446804	0.0000
AR(2)	0.080702	0.027980	2.884266	0.0039
AR(3)	-0.042084	0.049965	-0.842274	0.3996

Table 4-16 EGARCH Model Coefficient of Mean Equation with three AR lag terms

As depicted in the above table, it is appeared that there is no dependency of lagged daily exchange rate on ASPI hence, model fitting is continued considering daily gold prices as independent variable and results are shown in the below table. Results showed that there is no relationship between ASPI and gold rate on a considered day. Therefore, test is continued using lagged terms of gold rate,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
$Dlnexchange\_rate_{t}$	0.017629	0.011162	1.579278	0.1143
C	0.000199	0.000204	0.976263	0.3289
AR(1)	0.206447	0.027489	7.510265	0.0000
AR(2)	0.076915	0.027984	2.748478	0.0060

Table 4-17 EGARCH Model Coefficient of Mean Equation with two AR lag terms

Variable	Coefficient	Std. Error	z-Statistic	Prob.
$Dlngold\_price_{t-1}$	-0.038894	0.012093	-3.216231	0.0013
C	0.000271	0.000203	1.333134	0.1825
AR(1)	0.203607	0.027585	7.381202	0.0000
AR(2)	0.080737	0.027917	2.892050	0.0038

Table 4-18 EGARCH Model Coefficient of Mean Equation with two AR terms and a Daily Exchange Rate lag term

As previous day spot gold price seems significant, previous two-days gold prices are included in to the model and checked for significance,

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Dlngold_price $_{t-1}$	-0.040972	0.012395	-3.305529	0.0009
Dlngold_price $_{t-2}$	-0.011070	0.011871	-0.932553	0.3511
C	0.000246	0.000205	1.201380	0.2296
AR(1)	0.204217	0.027597	7.399980	0.0000
AR(2)	0.082174	0.027864	2.949133	0.0032

Table 4-19 EGARCH Model Coefficient of Mean Equation with two AR lag terms and two lag Daily Gold Rate lag terms

Based on the output in the above table day before yesterday spot gold price is not significantly related in deciding current ASPI value hence it can be eliminated from the model.

Subsequently further modelling is carried by adding daily exchange rate with previous day spot gold price in order to identify the impact of both variables together.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Dlngold_price $_{t-1}$	-0.038903	0.012010	-3.239337	0.0012
Dlnexchange_rate $_{t}$	-0.062530	0.066078	-0.946306	0.3440
C	0.000267	0.000202	1.321078	0.1865
AR(1)	0.202599	0.027563	7.350279	0.0000
AR(2)	0.080941	0.027916	2.899451	0.0037

Table 4-20 EGARCH Model Coefficient of Mean Equation with two AR lag terms, Daily Gold Rate lag term and Daily Exchange Rate lag term

Log returns of exchange rate depicted as insignificant therefore it can be concluded that among daily exchange rate and gold price, only spot gold price has a significant impact on ASPI. Further constant term has also been removed from the model due to insignificance of its P value.

Therefore, EGARCH model can be finalized as below,

	Conditional Mean Equation			
Variable	Coefficient	Std. Error	z-Statistic	Prob.
Dlngold_price $_{t-1}$	-0.037875	0.012120	-3.125009	0.0018
AR(1)	0.205450	0.027606	7.442254	0.0000
AR(2)	0.084630	0.027862	3.037458	0.0024
	Conditional Variance Equation			
C(4)	-0.887334	0.167240	-5.305745	0.0000
C(5)	0.380926	0.047467	8.025130	0.0000
C(6)	-0.059763	0.025763	-2.319749	0.0204
C(7)	0.938768	0.015379	61.04115	0.0000

Table 4-21 Mean and variance equation of EGARCH(1,1) model

Using the coefficients depicted in the above table mean and variance equations of EGARCH (1,1) model can be written as below,

Mean Equation:

$$dlnASPI_t = 0.205170 \text{ dlnASPI}_{t-1} + 0.085419 \text{ dlnASPI}_{t-2} - 0.037448 dlngold\_price_{t-1}$$

Variance Equation

$Ln\sigma^2 =$ -0.887334+ 0.380926x $|[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]|$ -0.059763x $[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]$ + 0.938768x Ln σ^2_{t-1}

As per the final results which were shown in the above table it can be concluded that daily exchange rate is not significant on deciding ASPI values but, there is a significant negative relationship between yesterday's spot gold price and today's ASPI. Backward elimination method was used to identify the significant variable in order to derive the best fit model. Moreover, another model was built using higher order EGARCH terms.

The results obtained on both models are depicted below,

Model 1-EGARCH (1,1)			Model II-EGARCH (2,1)		
Variable	Coefficient	Probability	Variable	Coefficient	Probability
Conditional Mean Equation					
$Dlngold\_price_{t-1}$	-0.037875	0.0018	$Dlngold\_price_{t-1}$	-0.037714	0.0019
AR(1)	0.205450	0.0000	AR(1)	0.204557	0.0000
AR(2)	0.084630	0.0024	AR(2)	0.082381	0.0020
Conditional Variance Equation					
C	-0.887334	0.0000	C	-1.016608	0.0000
$\|\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}\|$	0.380926	0.0000	$\|\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}\|$	0.453905	0.0000
$\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}$	-0.059763	0.0204	$\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}$	-0.064431	0.0394
$Ln\ \sigma^2_{t-1}$	0.938768	0.0000	$Ln\ \sigma^2_{t-1}$	0.635599	0.0000
			$Ln\sigma^2_{t-2}$	0.295576	0.0492

Table 4-22 Mean and variance equations of EGARCH(1,1) and EGARCH(2,1) models

After observing the negative coefficient of $Dlngold\_price_{t-1}$, it is clear that lag term of the log difference of the spot gold price shows negative relationship to log return of ASPI, as coefficient of $Dlngold\_price_{t-1}$ is appeared to be negative. So it can be concluded that, when there is an increase (decrease) in yesterday's log differences of gold prices, today's ASPI log return will decrease (increase).

Therefore, below models were finalized in order to evaluate today's ASPI log return value,

Model 1 : EGARCH (1,1)

Mean Equation

$$dlnASI_t = 0.205450\text{dlnASPI}_{t-1} + 0.084630\ \text{dlnASPI}_{t-2} - 0.037875 dlngold_{price_{t-1}} + \epsilon$$

Variance Equation

$Ln\sigma^2 = -0.887334 + 0.380926x\ |[\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}]| - 0.059763x\ [\epsilon_{t-1}/\sqrt{\sigma^2_{t-1}}] + 0.938768x\ Ln\ \sigma^2_{t-1}$

Model 2 : EGARCH(2,1)

Mean Equation

$$dlnASI_t = 0.204557\text{dlnASPI}_{t-1} + 0.082381\ \text{dlnASPI}_{t-2} - 0.037714 dlngold_{price_{t-1}} + \in$$

Variance Equation

$Ln\sigma^2 = -1.016608 + 0.453905 \times |[\epsilon_{t-1}/\sqrt{\sigma^2}_{t-1}]| - 0.064431 \times [\epsilon_{t-1}/\sqrt{\sigma^2}_{t-1}] + 0.635599 \times Ln\ \sigma^2_{t-1} + 0.295576\ Ln\ \sigma^2_{t-2}$

4.5 Model I and Model II diagnostic testing

Both models finalized under the above section depicted a sufficient capability in deriving future log return values of ASPI. Therefore, it was decided to run below diagnostic test on each model to check their adequacy of the finalized model,

1. Ljung-Box Q-statistics for squared standardized residuals
2. Ljung-Box Q-statistics for squared standardized returns
3. ARCH LM test
4. Empirical Q-Q plot

4.6 Ljung-Box Q-statistics for squared standardized residuals

Ljung-Box Q-statistics test is carried out on squared residual series in order to measure the adequacy of both models and results are as follow,

Lag	Model I-EGARCH (1,1)		Model II-EGARCH (2,1)	
	Q statistic	Probability	Q statistic	Probability
3	1.4931	0.684	0.7854	0.853
4	1.7118	0.789	0.8511	0.931
5	1.7284	0.885	0.8519	0.974
6	2.2153	0.899	1.1710	0.978
7	2.2153	0.947	1.1817	0.991
8	3.1330	0.926	2.1203	0.977
9	3.6222	0.934	2.7927	0.972
10	3.7053	0.960	2.8861	0.984

Table 4-23 Q- statistics and P values of Ljung-Box test on standard residuals of Model I Model II

P values of first two lags are adjusted for two autoregressive terms, thus Q statistics and probabilities are available from the third lag. Main objective of the test is to analyse whether there is a pattern in the squared residual terms. If there is a pattern in the error terms, the fitted model is not adequate as model hasn't been captured the trend in the data set. However, in the above table, all other P values in subsequent lags are insignificant because respective P values are higher than 0.05 at 5% significant level. Therefore, it depicts adequate evidence to conclude that that there is no serial autocorrelation in squared standard residuals. Hence, it provides sufficient evidence on adequacy of the finalized two models accordingly to the test statistics of Ljung-Box Q-statistics.

4.7 Ljung-Box Q-statistics for standardized returns squared

Similar to the above test, main objective of the standardized return squared test is to ensure whether fitted model captures the trend in the data set. However, it has a different approach as it uses return series instead of residuals which were used in the first test. To create a squared return series, firstly GARCH variance series should be created, thereafter ASPI log return series is divided by GARCH variance series. Finally calculated the squares of the results which were obtained by dividing ASPI log returns by GARCH series. Below table depicts the correlogram results of the squared returns,

Lag	Model I-EGARCH (1,1)		Model II-EGARCH (2,1)	
	Q statistic	Probability	Q statistic	Probability
1	0.0216	0.883	0.6385	0.424
2	0.1099	0.947	0.7797	0.677
3	2.3025	0.512	4.0164	0.260
4	2.4415	0.655	4.0638	0.397
5	2.4540	0.783	4.0880	0.537
6	2.5349	0.865	4.2235	0.646
7	2.7504	0.907	4.5524	0.714
8	3.1649	0.924	4.8515	0.773

Table 4-24 Q- statistics and P values of Ljung-Box test on standard returns of Model I Model II

4.8 ARCH LM test

	Model I-EGARCH (1,1)		Model II-EGARCH (2,1)	
	Test statistic	Probability	Probability	Probability
F-Statistic	0.353209	0.8804	0.168667	0.9741
Obs*R-squared	1.771317	0.8798	0.846402	0.9740

Table 4-25 Test statistic values and P values of ARCH LM test on Model I Model II

In order to test the presence of additional autoregressive conditional heteroscedasticity, ARCH-LM test is used.

According to the above table, it is clear that two test statistics do not reject the null hypothesis, of non-existence of autoregressive conditional heteroscedasticity (ARCH) in the residuals at 5% significant level. This means residuals of both models do not contain autoregressive conditional heteroscedasticity. Thus, these tests provide further assurance on adequacy of the models.

4.9 Empirical Q-Q plot

In order to test whether the assumed student t-distribution is appropriate for modelling residuals, the following Q-Q plots were plotted.

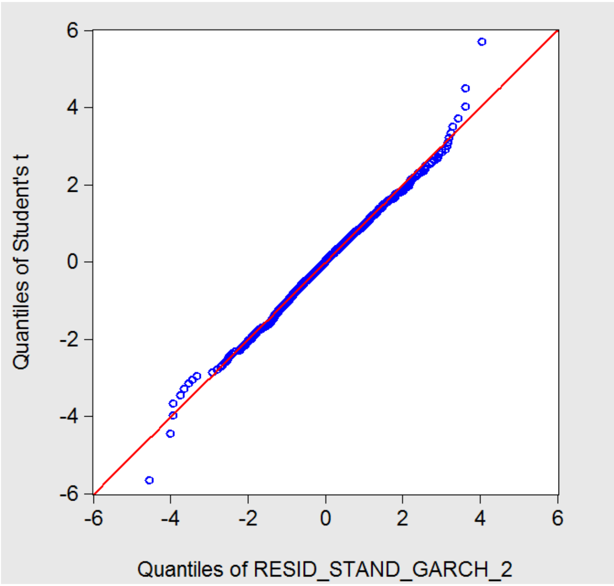

Figure 4-3 Q-Q plot for the Model I

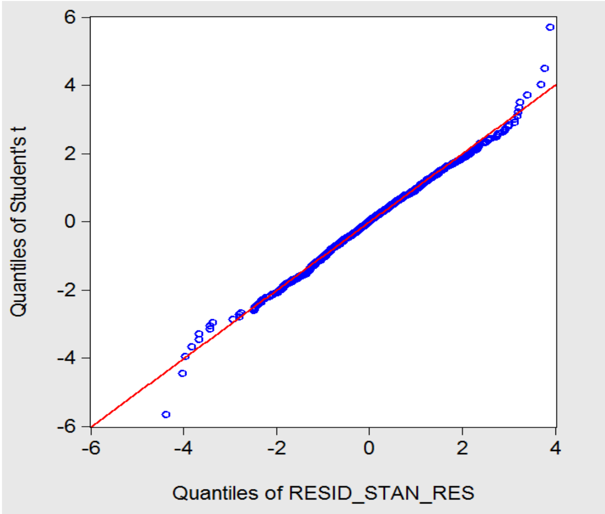

Figure 4-4 Q-Q plot for the Model II

Since the residuals are well fitted on the straight line (except few points which deviate from the line), it can be said, that the considered Student-t distribution is quite sufficient in model building process. Furthermore, it is clear that the assumed student-t distribution is appropriate to model error for both EGARCH models.

The above three test examine sufficiency of the models. Therefore, the following table depicts the three information criteria's related to the Model I and Model II.

	Model I-EGARCH (1,1)	Model II-EGARCH (2,1)
Akaike Information Criterion (AIC)	-7.187367	-7.187324
Schwarz Information Criterion (SIC)	-7.157826	-7.154091
Hannan-Quinn Criterion	-7.176334	-7.174912

Table 4-26 Results of information criteria on Model I and Model II

It is clear that model one has the most negative values of information criterion. Thus it implies there is less information loss in Model 1-EGARCH (1,1) compared to Model II-EGARCH (2,1). Therefore, Model I-EGARCH (1,1) can be considered as the best model from two models.

The following plot depicts the actual ASPI return vs the fitted ASPI return for the Model I -EGARCH (1,1) above.

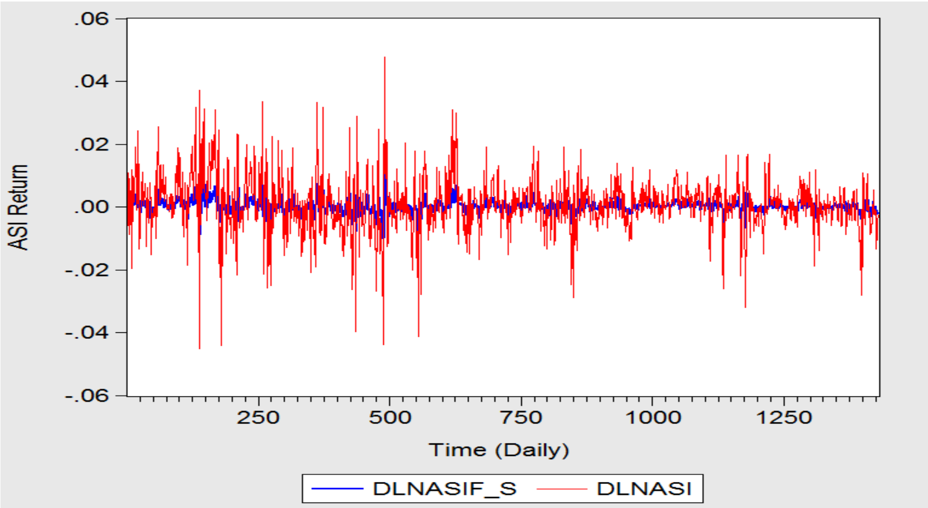

Figure 4-5 Actual ASPI return vs the fitted ASPI return for Model I

It is clear from the above plot, that fitted model is capable of capturing the actual volatility up to an acceptable extent. This is very much clear from the following plot, which depicts the fitted conditional volatility against the actual volatility.

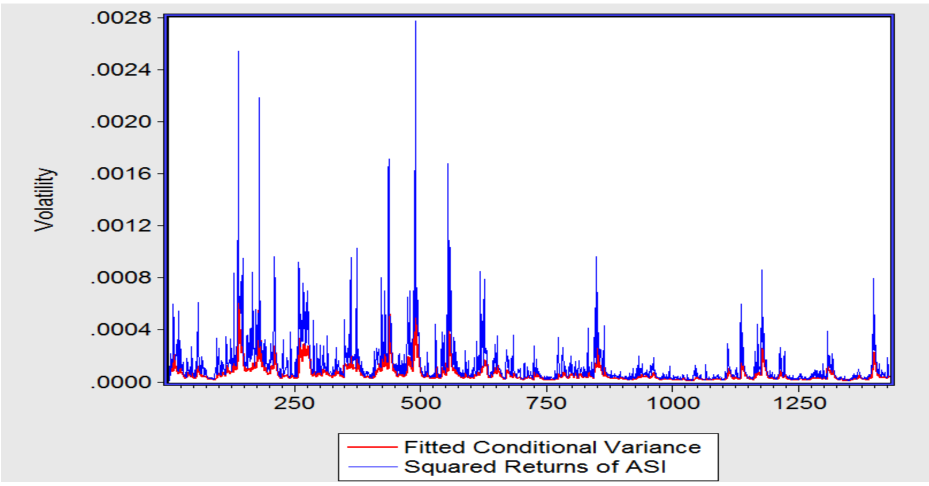

Figure 4-6 Actual volatility vs the fitted conditional volatility Model I

Since the actual volatility is not observed properly, the squared ASPI return series was used as a close proxy for the actual volatility. So it can be said that according to the above figure the fitted model has an ability to capture the volatility, which prevailed in the market.

Table 4-27 Finalized EGACH(1,1) and EGARCH(2,1) models with log return daily spot gold price as a variable in variance equations

Model III-EGARCH (1,1)			**Model IV-EGARCH (2,1)**		
Variable	Coefficient	Probability	Variable	Coefficient	Probability
Conditional Mean Equation					
$Dlngold\_price_{t-1}$	-0.03744	0.0015	$Dlngold\_price_{t-1}$	-0.03801	0.0014
AR(1)	0.20517	0.0000	AR(1)	0.20505	0.0000
AR(2)	0.08541	0.0022	AR(2)	0.08443	0.0015
Conditional Variance Equation					
C	-0.9251	0.0000	C	-1.07269	0.0000
$\|\epsilon_{t-1} /\sqrt{\sigma^2_{t-1}}\|$	0.3644	0.0000	$\|\epsilon_{t-1} /\sqrt{\sigma^2_{t-1}}\|$	0.43900	0.0000
$\epsilon_{t-1} /\sqrt{\sigma^2_{t-1}}$	-0.0628	0.0143	$\epsilon_{t-1} /\sqrt{\sigma^2_{t-1}}$	-0.06812	0.0303
$Ln\ \sigma^2_{t-1}$	0.9340	0.0000	$Ln\ \sigma^2_{t-1}$	0.61232	0.0001
$Dlngold\_price_t$	6.1877	0.0140	$Ln\ \sigma^2_{t-2}$	0.31253	0.0367
			$Dlngold\_price_t$	7.36904	0.0140

Though this model is adequate it was decided to improve the model further. It is a known fact that when the number of related parameters of the model increases, the model is more capable of capturing true variation. For this purpose, the variance equation required to be updated with the relevant exogenous factors such as daily exchange rate and daily gold price. This is because the EGARCH model provides a more flexible structure in capturing and modelling the conditional variance. However, after adding daily exchange rate to the variance equation, the respective coefficients of the exchange rate variable became insignificant hence testing process was continued using gold rate in order to improve the variance equation.

After introducing daily spot gold price to the variance equation of EGARCH (1,1) and EGARCH (2,1) models, signs of the coefficients of both mean equations remain intact.

Further, none of the variables in the mean equations are insignificant even after changing the variables in the variance equation.

Hence, it can be concluded, that the spot gold price has a significant impact on both mean and the variance equations of these models.

All the diagnostic tests, which were carried out on both models. Outcomes of the tests are as follow,

Model III – EGARCH (1,1)

Mean Equation

$$dlnASPI_t = 0.205170 \text{ dlnASPI}_{t-1} + 0.085419\text{dlnASPI}_{t-2} - 0.037448 dlngold_{price_{t-1}} + \epsilon$$

Variance Equation

$Ln\sigma^2 =$ -0.925102+ 0.364411x$|[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]|$ -0.062828 x$[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]$ + 0.934085 x Ln σ^2_{t-1} + 6.187711x $Dlngold\_price_t$

Model IV – EGARCH (2,1)

Mean Equation

$$dlnASPI_t = 0.205056\text{xdlnASPI}_{t-1} + 0.084439 \text{ dlnASPI}_{t-2} - 0.038014 \text{ x} dlngold\_price_{t-1} + \epsilon$$

Variance Equation

$Ln\sigma^2 =$ -1.072694+ 0.439002 x $|[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]|$ -0.068125 x $[\epsilon_{t-1} / \sqrt{\sigma^2}_{t-1}]$ + 0.612325 x Ln σ^2_{t-1} + 0.312537 Ln σ^2_{t-2}+ 7.369040 x $Dlngold\_price_t$

4.10 Model III - EGARCH (1,1) and Model IV - EGARCH (2,1) diagnostic checking

4.10.1 Ljung-Box Q-statistics for standardized squared residuals

	Model III - EGARCH (1,1)		Model IV - EGARCH (2,1)	
Lag	Q statistic	Probability	Q statistic	Probability
3	1.7852	0.618	0.6956	0.874
4	2.2338	0.693	0.8532	0.931
5	2.4104	0.790	0.9188	0.969
6	2.8432	0.828	1.2101	0.976
7	2.8432	0.899	1.2218	0.990
8	3.9204	0.864	2.3180	0.970
9	4.1095	0.904	2.6968	0.975
10	4.1285	0.941	2.7289	0.987

Table 4-28 Q- statistics and P values of Ljung-Box test on standard residuals of Model III Model IV

According to the above table it is clear that none of the lags in model III and model IV contain serial correlation in squared residuals. So it implies that the model is adequate.

4.10.2 Ljung-Box Q-statistics for squared standardized returns

	Model III - EGARCH (1,1)		Model IV - EGARCH (2,1)	
Lag	Q statistic	Probability	Q statistic	Probability
1	0.0846	0.771	0.4984	0.480
2	0.2008	0.904	0.6228	0.732
3	0.3113	0.958	1.0221	0.796
4	0.4104	0.982	1.0350	0.904
5	0.5355	0.991	1.0655	0.957
6	0.8220	0.991	1.4467	0.963
7	1.4064	0.985	2.4505	0.931
8	1.5222	0.992	2.5190	0.961

Table 4-29 Q- statistics and P values of Ljung-Box test on standard returns of Model III Model IV

It is clear from the above table that there is no autocorrelation in the squared standardized returns exist in both model III and model IV. Therefore, it can be said that model III and model IV are also well specified.

4.10.3 ARCH LM test

	Model III - EGARCH (1,1)		Model IV - EGARCH (2,1)	
	Test statistic	Probability	Probability	Probability
F-Statistic	0.491532	0.7828	0.191999	0.9657
Obs*R-squared	2.463798	0.7819	0.963410	0.9655

Table 4-30 Test statistic values and P values of ARCH LM test on Model III Model IV

Both test statistics denoted in the above table, do not reject the null hypothesis of 'non-existence of ARCH effect in the standardized residuals'. So it can be said that the both of these prepared models do not consist additional ARCH effect.

In order to test whether the assumed student t-distribution is appropriate for the parameter estimates in the prepared models, the following Q-Q plots were plotted.

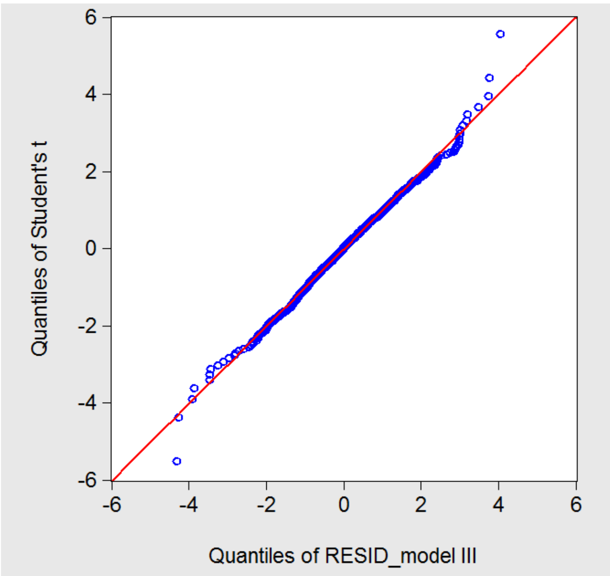

Figure 4-7 Q-Q plot for the model III

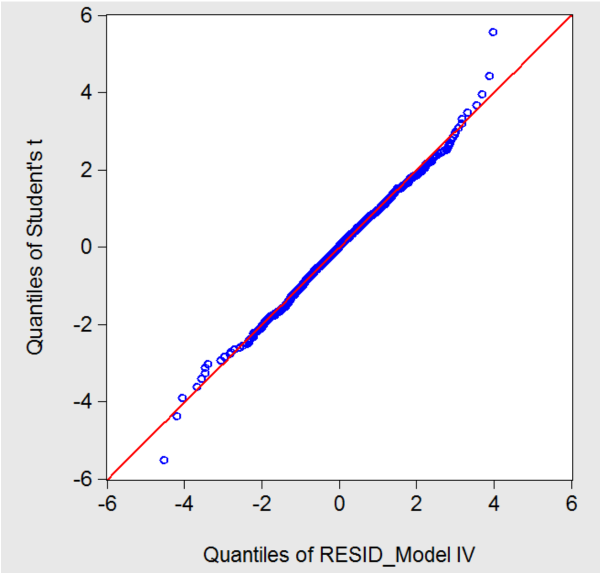

Figure 4-8 Q-Q plot for the model IV

It is clear from the above plot, the residuals of the model III and model IV fit well to the straight line. This implies that the assumed student t-distribution is appropriate for the parameter estimation.

All three diagnostic test suggests that the above model is well specified. Therefore, the following table depicts the log likelihood along with two information criteria's related to the model III and model IV.

	Model III EGARCH (1,1)	Model IV EGARCH (1,2)
Akaike Information Criterion (AIC)	-7.190080	-7.190191
Schwarz Information Criterion (SIC)	-7.156846	-7.153266
Hannan-Quinn Criterion	-7.177667	-7.176400

Table 4-31 Results of information criteria on Model III and Model IV

As per the above table; Model III has achieved the lowest value in two information criteria out of three. Therefore, it can be said that EGARCH (1,1) model is more appropriate to interpret the behaviour of the data set.

The following plot represents the actual ASPI return vs the fitted ASPI return obtained for model III - EGARCH (1,1).

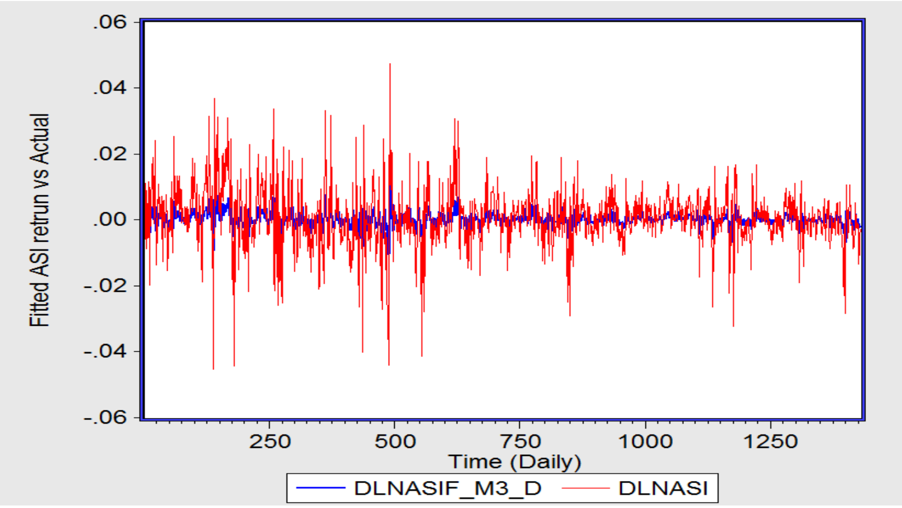

Figure 4-9 Actual ASPI return vs the fitted ASPI return for model III

When examined through the naked eye, the above figure is very much similar to the figure which was obtained under Model I - EGARCH (1,1). But it needs to be tested statistically when forecasting. The fitted conditional variance vs. the squared return series of ASPI is plotted in the following graph.

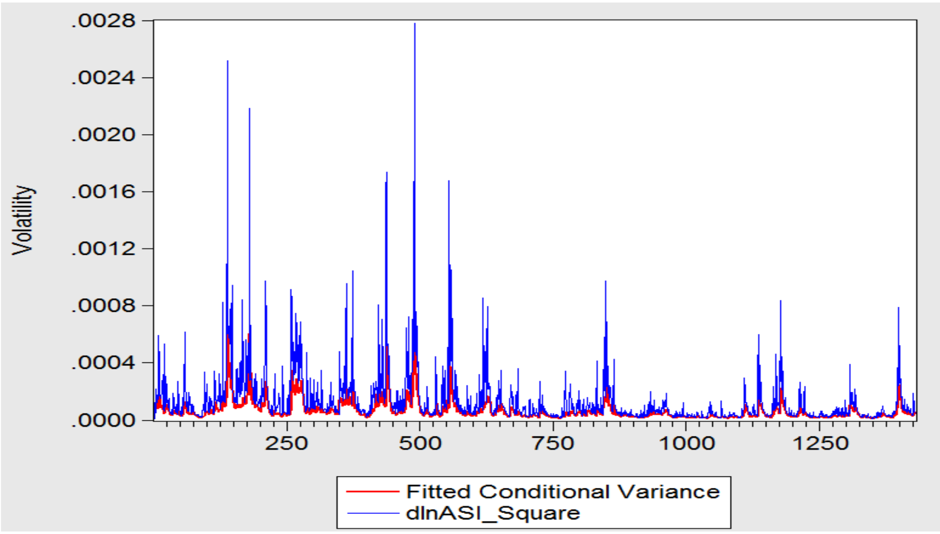

Figure 4-10 Actual ASPI return vs the fitted ASPI return for model IV

4.11 Model V - GJR- GARCH Model

Since both EGARCH and GJR GARCH models are capable of capturing asymmetric volatilities, data set was also evaluated using GJR GARCH model as below to identify the best model in forecasting future stock behaviour.

Model V-GJR- GARCH (1,1)		
Mean Equation		
Variable	Coefficient	Probability
$Dlngold\_price_{t-1}$	-0.039202	0.0011
AR(1)	0.214502	0.0000
AR(2)	0.073648	0.0095
Variance Equation		
C	0.0000295	0.0002
ϵ^2_{t-1}	0.158647	0.0000
$\epsilon^2_{t-1}*(\epsilon_{t-1}<0)$	0.134402	0.0125
σ^2_{t-1}	0.756614	0.0000

Table 4-32 Mean and variance equation s of GJR-GARCH (1,1) Model (Model V)

Mean Equation

$$dlnASI_t = 0.214502 \text{ x dlnASPI}_{t-1} + 0.073648 \text{ x dlnASPI}_{t-2} - 0.039202 \text{ x } dlngold\_price_{t-1} + \epsilon$$

Variance Equation

$$\sigma^2_t = 0.0000295 + 0.158647 \text{ x } \epsilon^2_{t-1} + 0.134402 \text{ x } \epsilon^2_{t-1}*(\epsilon_{t-1}<0) + 0.756614 \text{ x } \sigma^2_{t-1}$$

Below information criterion were used to evaluate the information loss through GJR GARCH model.

Description of Information Criterion	Model V GJR - GARCH (1,1)
Akaike Information Criterion (AIC)	-7.181903
Schwarz Information Criterion (SIC)	-7.152396
Hannan-Quinn Criterion	-7.170883

Table 4-33 Results of information criteria on Model V

4.12 Comparison of Finalized Models

As it is difficult to identify the best model by evaluating information criteria values in isolation, information criteria values of each model compared with each other as depicted below,

Description of Information Criterion	Model I EGARCH (1,1)	Model III EGARCH (1,1) (with modified variance equation with daily gold rate)	Model V GJR - GARCH (1,1)
Akaike Information Criterion (AIC)	-7.187367	-7.190080	-7.181903
Schwarz Information Criterion (SIC)	-7.157826	-7.156846	-7.152396
Hannan-Quinn Criterion	-7.176334	-7.177667	-7.170883

Table 4-34 Comparison of Information criteria of three models

Above table provides sufficient evidence to conclude the high accuracy associated with model three in forecasting ASPI stock value as it has the least information loss as per above information criterion values.

If these models are well specified, error distribution should behave in random manner, in other words Skewness and Kurtosis of residuals tend depict properties of normality by depicting values 0 and 3 Skewness and Kurtosis respectively. Hence, Kurtosis and Skewness of errors were checked for all three models as below.

Description	Model I EGARCH (1,1)	Model III EGARCH (1,1) (with modified variance equation with daily gold rate)	Model V GJR - GARCH (1,1)
Skewness	0.015745	0.00886	0.021214
Kurtosis	4.238995	3.947066	4.936871

Table 4-35 Residual test results of three models

It is clear that error distributions of all three models depict properties of normality conditions. Hence, it is safe to consider that errors are randomly distributed without any trend or seasonality.

Moreover, it is difficult to compare Model I - EGARCH (1,1), Model III - EGARCH (1,1) (including spot gold price as a variable in the variance equation) and Model V GJR - GARCH (1,1) with the naked eye, therefore to select the best model, log return values of ASPI are forecasted for additional fifteen data points from 8th March 2016 to 31st March 2016. In stock market predictions, direction of the volatility is more important than the exact stock value. Main reason for this is, that investors tend to make decisions mostly relying on the direction of the volatility rather absolute value of them. Therefore 8th March 2016 to 31st march 2016 log return ASPI values are forecasted using both models and compared with the actual values for the same period.

Forecast accuracy of three models were assessed using Mean Square Error, Absolute Mean Square Error and Mean Absolute Percentage Error. In addition, forecasted and actual values are compared to derive the direction of the stock movement. All the results pertaining to above tests and comparisons are depicted below.

	Model I - EGARCH (1,1)	Model III - EGARCH (1,1) (including spot gold price in the variance equation)	Model V GJR - GARCH (1,1)
Root Mean Square Error (RMSE)	0.008796	0.008794	0.008832
Mean Absolute Error (MAE)	0.007127	0.007125	0.007453
Mean Absolute Percentage Error (MAPE)	8.04%	7.77%	8.62%

Table 4-36 Comparison of three models on forecast errors

Both mean square error and mean absolute error are less in the Model III compared to Model I and Model V, hence it provides clear direction on selecting best model among three models. Evidently, Model III is the most suitable model to explain the behaviour of the stock movements. Particularly, only Model I and Model III were used to forecast the direction of future stock movements due to the fact that high accuracy in Model I and Model III compared to Model V. Hence, 15 data points were forecasted as below using Model I and Model III.

4.12.1 Forecast values of Model I and Actual log returns of ASPI

Date	Forecasted Log return Value	Difference between consecutive Forecasted Log Return Values	Sign of Consecutive Forecasted Log return value Differences
8-Mar-16	-0.0000937	N/A	N/A
9-Mar-16	-0.0001399	-0.0000462	-
10-Mar-16	0.0001682	0.0003081	+
11-Mar-16	-0.0004196	-0.0005879	-
14-Mar-16	0.0006303	0.0010500	+
15-Mar-16	0.0003067	-0.0003237	-
16-Mar-16	0.0001038	-0.0002028	-
17-Mar-16	-0.0004144	-0.0005182	-
18-Mar-16	-0.0004509	-0.0000365	-
21-Mar-16	0.0001961	0.0006470	+
23-Mar-16	0.0002200	0.0000239	+
24-Mar-16	0.0006202	0.0004003	+
28-Mar-16	-0.0001698	-0.0007900	-
29-Mar-16	0.0002003	0.0003701	+
30-Mar-16	-0.0010780	-0.0012783	-
31-Mar-16	0.0000206	0.0010986	+

Table 4-37 Forecasted directions of ASPI returns using EGARCH (1,1) (Model I)

Differences of consecutive log return ASPI values were calculated as depicted in the "Difference" column in the above table and sign of the movement was observed in order to compare with the direction of the actual data points.

"+" represents the upward movement of the stock values and "- "for negative movements. Similarly differences of consecutive data points were calculated for model III as depicted in the below section.

4.12.2 Forecasted Values of Model III and Actual log returns of ASPI

Date	Forecasted Log Return Values	Difference between Consecutive Forecasted Log Return Values	Sign of Consecutive Forecasted Log return value Differences
8-Mar-16	-0.0000992	N/A	N/A
9-Mar-16	-0.0001400	-0.0000408	-
10-Mar-16	0.0001653	0.0003053	+
11-Mar-16	-0.0004153	-0.0005806	-
14-Mar-16	0.0006230	0.0010383	+
15-Mar-16	0.0003031	-0.0003199	-
16-Mar-16	0.0001026	-0.0002005	-
17-Mar-16	-0.0004097	-0.0005123	-
18-Mar-16	-0.0004458	-0.0000361	-
21-Mar-16	0.0001939	0.0006397	+
23-Mar-16	0.0002175	0.0000236	+
24-Mar-16	0.0006132	0.0003957	+
28-Mar-16	-0.0001679	-0.0007811	-
29-Mar-16	0.0001981	0.0003660	+
30-Mar-16	-0.0010658	-0.0012639	-
31-Mar-16	0.0000204	0.0010862	+

Table 4-38: Forecasted directions of ASPI returns using EGARCH (1,1) with log return daily spot gold price as a variable in variance equation (Model III)

Accuracy of the Model I and Model III compared in terms of the sign in each consecutive stock movement as depicted below. It is proven that model I and model III give identical result whilst predicting with 60% accuracy. When actual stock returns go down/up, both models have the same movement with an accuracy level up to 60%.

As mentioned in the above sections it is crucial to identify the direction of the stocks rather the value as investment decision is mainly made by looking at the direction of the stock returns.

4.12.3 Model I - EGARCH (1,1) vs Model III - EGARCH (1,1) (spot gold price as a variable in the variance equation)

Model I - EGARCH (1,1)	Model III - EGARCH (1,1) (including spot gold price in the variance equation)	Actual	Model I - EGARCH (1,1) vs Actual	Model III - EGARCH (1,1) (including spot gold price in the variance equation) vs Actual
-	-	+	0	0
+	+	+	1	1
-	-	-	1	1
+	+	-	0	0
-	-	+	0	0
-	-	+	0	0
-	-	-	1	1
-	-	-	1	1
+	+	+	1	1
+	+	-	0	0
+	+	+	1	1
-	-	-	1	1
+	+	+	1	1
-	-	+	0	0
+	+	+	1	1
Total (count "1" s)			**9**	**9**
% of prediction of correct direction			**60%**	**60%**

Table 4-39: Forecasted vs Actual directions of ASPI return

Considering above facts, it is safe to conclude that model III is the best model to forecast the volatility of the ASPI returns due to below reasons,

- Model III has the lowest root mean square error among three models.
- Model III has the lowest mean absolute error among three models.
- Model III has the lowest Mean Absolute Percentage Error among three models.
- Model III has the lowest information loss as per the three information criteria.
- Model I and Model III have the same accuracy in forecasting future values.

CHAPTER 5 RESULTS, CONCLUSIONS AND FURTHER ANALYSIS

Main intention of this study is to analysing the interrelationship among ASPI (Stock values), daily exchange rate and daily gold price. After identifying the relationship among variable, EGARCH model was used to derived an equation to explain the behaviour of future stock returns and it's direction. As shown in the results it is said that there is a relationship between spot gold price and ASPI returns but such relationship doesn't not exist between ASPI returns and exchange rate returns in the local context. Particularly, the reason for non-existence of relationship between stock returns and exchange rate could be due to the fact that, most of the companies which considered under ASPI are local companies, thus fluctuations in exchange rates are not directly impacted on respective stock returns. However, it is shown that the importance of previous ASPI return values in predicting future return value of ASPI. The model consists of two auto regressive terms; therefore, it gives a clear picture to the investor about the importance of analysing the behaviour of stock returns over previous two days before making the investment decision. In general, analysing historical data has become a common practice in making decisions on investments and also it can be considered as the beacon, which helps to make accurate decisions. Behaviour of the spot gold price is a quite similar as in the reality, because models manipulated previous day gold price in forecasting log return values of ASPI. Even in the stock market, most of the investors consider previous day spot gold price in order to make decisions on procuring spot gold or stocks. Commonly investors tend to consider previous day spot gold price than today's value, if gold return is higher than stock returns investors compel to invest on gold and vice versa. Hence, returns of spot gold price and stock returns have a negative relationship. However, even in the variance equation exchange rate was appeared as insignificant but return of gold rate showed a significant impact. Mainly in reality, fluctuations of daily gold prices have a significant impact on stock returns thus return values of gold extensively contribute to the variations of stock returns.

5.1 Limitation of the Research

The main limitation of the study is the fact, that stock market was closed during poya days and other Sri Lanka holidays therefore gap between successive data points is sometimes more than a day. Another limitation is volatility of the stocks is not only depending on exchange rate and gold prices. Variables such as crude oil and SLIBOR (Sri Lanka Inter Bank Offered Rate) rate may effect on stock behaviour, hence stock value cannot be solely defined using exchange rate and gold rate. In addition, investors are reluctant to invest on first couple of days in each week due to the fact, that majority of investors explore investment opportunities during the weekends and they are highly sensitive to “bad news” in the market. As a result, investors have a resistance to invest on first two days of the week. Particularly, they tend to evaluate the market behaviour during these days before executing the decisions. Further there is a tendency, that investors are following “dab news” rather “good news” to eliminate the risk of investments. Hence, some investors follow the risk averse approach and avoid investing in first couple of days of the week. This development could be a reason for lack of consistency in investing over a period of week.

5.2 Conclusion and recommendation

In present most of the investors tend to diversify their investments in order to mitigate the risk associated with the investments. Therefore, investors keen to exploit various ways to make accurate decisions. One of the objectives of the study is to analyse the interrelationship among stock returns, daily exchange rates and gold rates. as data collection was done in different points of time line it is recommended to use time series techniques to model the data. ADF unit root test provided sufficient evidence to use time series techniques on all three data sets. Subsequently ASPI return series was routed through Box-Pierce test and concluded that there are volatility clusters with asymmetry. Consequently, EGARCH and GJR GARCH model were used to derive the relationship among depended and independent variables whilst capturing leverage effect of the volatility clusters. As per the outcome of the model it is found that there is not relationship between stock returns and daily exchange rate in Sri Lankan stock market. In contrast existence of negative relationship between stock returns and daily gold prices was identified at 5% significant level. Moreover, it is shown that most recent past two days stock return values, have significant positive relationships with today's stock return value. Therefore, mean equation of the ERACH and GJR GARCH models comprise with three variables. As in reality most of the investors tend to use previous stock values in order to get a view on future behaviour of stock market. Thus output of the study depicted similarity with the actual scenario of the stock market. Further the relationship with previous day spot gold price emerged as significant in the model, because of the fact that investors tend to use previous day spot gold price in order to make decisions on today's investment. In addition, negative relationship between stock return and daily spot gold prices explained under general discussion. However, today's gold prices considered as a significant variable in measuring volatility as it appeared with a positive coefficient in variance equation of the GARCH models. Derived models are tested against its adequacy in order to forecast the future values of ASPI returns and found that three models naming Model I – EGARCH (1,1), Model III – EGARCH (1,1) (daily returns of spot gold price as a variable in variance equation) and GJR GARCH (1,1) are suitable to explain the behaviour of future stock returns.

Three models were tested in order to finalize the best model for forecasting with higher precision. Consequently, it was found that the forecast accuracy of model III is superior to other two models.

Further ASPI returns were forecasted for future data points using derived equations to prove the accuracy of the finalized model. In results, it was found, that the finalized EGARCH equation is capable of forecasting future ASPI returns with 60% accuracy.

5.3 Future Improvement Area

Subject research is to examine the stock market behaviour and derive a time series model, to forecast the behaviour of stocks using daily exchange rate and gold price. However, exchange rate and spot gold price are not only factors which impact on stock market behaviour, there can be many other factors such as company performance, industry performance, investor confidence, economic factors, political factors, financial factors and local and foreign investments. Hence, this research can be further developed by introducing above parameters in order to enrich the accuracy of forecasting stock returns.

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