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Modeling and Forecasting Volatility in Pakistan Stock Exchange

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Abstract

Analysis of time series is used to develop simple models which can forecast, interpret, and analyze the result concerning its field of application. The main purpose of this study was to check and model the volatility in Pakistan Stock Exchange (PSX) for the near future. The stock exchange data are highly volatile and there are many factors which affect the daily market returns. A developing country like Pakistan is interfered by the conditions of International Monetary Fund (IMF), dollar fluctuations and thus, it becomes very difficult to forecast these returns due to continuous effect of above and many other factors (which are unknowns). Generally, in the presence of these factors, the naive or simple models do not perform efficiently because of their ability to model averages and thus volatility models are used which model variation in the data. We used dataset from 2nd June 2006 to 23rd August 2020 using rolling window technique and find GARCH (3,2) as best model to forecast PSX returns.

Keywords: Expanding window; COVID-19; Financial timeseries; Volatility.

1. Introduction

The issue pertaining to volatility in stock market have always been the interest of the researcher in modern financial theory as it has a significant impact on the investment.

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Volatility, apparently an easy and discerning concept, refers to unexpected return due to unexpected events resulting in huge price movement with non-constant variance. Analyzing the foreign stock markets by volume indicates that globally 93 trillion United states (US) dollar amount of trading occurred worldwide in the fiscal year 2019, whereas the share of Pakistan was $27.53 billion. Therefore, it is not surprising that stable stock returns have served as a catalyst of economic growth for most developed countries while a highly volatile stock market returns is a major problem for many developing countries. Pakistan Stock Exchange (PSX) is the stock exchange of Pakistan with exchanging floors in Karachi, Islamabad, and Lahore. PSX was built up on 11 January 2016 after the merger of individual stock trades of Karachi, Lahore, and Islamabad. PSX starting point was laid with the foundation of the Karachi Stock Exchange in 1947, the Lahore Stock Exchange in 1970 and the Islamabad Stock Exchange in 1992. As of February 23, 2020, there are 667 organizations recorded in PSX and the all-out market capitalization is $84 billion. Reference [1] studies the effect of China Pakistan Economic Corridor (CPEC), a $75 billion project between Pakistan and China. Given the size of project, PSX will affect more positively than SSE, it will stabilize the market while reducing the effects of sudden shocks. High interest rates in Pakistan demoralize investors, Reference [2] concludes in their study that high interest rates have negative effect on PSX stock returns. To find the impact of outlier on returns and volatility linkages [3] conducted an analysis on PSX and Brent oil using traditional volatility models. In their analysis they concluded that outliers do not affect the conditional mean and variance of the Brent oil significantly, but they do reactive to PSX as PSX is highly fluctuated in the presence of outliers. The interesting outcome of their analysis was the urge to make investment in Brent oil, as this is safe investment compared to stock returns. it is a general practice and have been observed that complex volatility models are good enough to capture market fluctuation as they model variance of the lag term. But this is not always the case, and sometimes few stock returns are more stable, and they could be accounted with the help of simple and naive models. Classical models are equally important in forecasting for less volatile markets. Reference [4] used fuzzy logic approach to model volatility in Iran Stock Exchange and find that sometimes naïve classical models are efficient as well. Reference [5] measured the effects of political uncertainty on PSX and find that political uncertainty has adverse effects on PSX 100, and we have seen market crash on one pollical strike call in Karachi. Reference [6] used Bi-variate GARCH model on cash and future in commodities prices. The Optimal Hedge Ratio (OHR) is calculated as a ratio of the conditional covariance between cash and futures to the conditional variance of future. The findings of clustered volatility and ARCH effects is ubiquitous in financial data. Reference [7] presents a possible explanation for this phenomenon within a multi-agent framework of speculative activity. In their study both, chartist and fundamentalist, approaches were considered with agents switching between behavioral variants according to observed differences in payoffs. The clustered volatility was clarified as the outcome of market being the focus to rare short-term volatility. Reference [8] evaluate the performance of nine alternative models for predicting stock price volatility using New Zealand data. The competing models contain both simple models such as the random walk, smoothing models, and complex models such as ARCH-type models and a stochastic volatility model.

2. Methodology

2.1. Auto-regressive moving average model (ARMA)

Autoregressive moving average (ARMA) model consider the AR and MA component to model the time series. If integration is included, the ARMA model is written as Autoregressive integrated moving average (ARIMA) model. The ARMA (p,q) can be written as

$$Y_t = C + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \ldots + \varphi_p Y_{t-p} + \Theta_1 Z_{t-1} + \Theta_2 Z_{t-2} + \ldots + \Theta_q Z_{t-q} + Z_t \qquad (1)$$

The equation could also be written as.

$$Y_t - \varphi_1 Y_{t-1} - \ldots - \varphi_p Y_{t-p} = Z_t + \Theta_1 Z_{t-1} + \ldots + \Theta_q Z_{t-q} \qquad (2)$$

Where $Z_t \sim WN(0,\sigma^2)$ and $\boldsymbol{\varphi_{p \text{ and}}}\ \boldsymbol{\Theta_q}$ are the coefficients of AR and MA respectively. It is convenient to use more concise form of (2)

$$\Phi(B)\, Y_t = \Theta(B)\, Z_t \qquad (3)$$

Where $\varphi(.)$ and $\Theta(.)$ are the p^{th} and q^{th} degree polynomials such that $\Phi_z = 1 - \Phi_1 z - \ldots - \Phi_p z^p$ and $\theta_z = 1 + \theta_1 z + \ldots + \theta_q z^q$. Where B is the backward shift operator.

2.2. ARCH Model

Auto-regressive restrictive Heteroskedasticity (ARCH) is a statistical model that depicts the change of the present error term or innovation as an element of the genuine sizes of the past time frames error terms, frequently the difference is identified with the squares of the past innovation. ARCH models are generally utilized in demonstrating financial time series that display time-shifting unpredictability and instability grouping, for example times of swings sprinkled with times of relative calm. ARCH type models are occasionally viewed as in the group of stochastic volatility models. To model a time series using an ARCH process, let εt denote the residual series of an AR process. These ε_t are split into a stochastic piece zt and a time-dependent standard deviation σ_t characterizing the typical size of the terms so that $\varepsilon t = \sigma t z t$, where zt is strong white noise process. The series is modeled by

$$\sigma^2_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \ldots + \alpha_q \varepsilon^2_{t-q} = \alpha_0 + \Sigma \alpha_i \varepsilon^2_{t-1} \qquad (4)$$

The ARCH model has been widely applied to the study of stock return rate. The property of uncertainty or unpredictability" in determining the behavior of various economic variables, force economists to replace the non-conditional mean as in ARMA models for the conditional mean as a contribution towards improving forecast.

2.3. GARCH Model

GARCH model is the generalization of ARCH model introduced by [9]. GARCH models provide less weights to past residual which do not approach to zero in GARCH model. A time series _t is given at each instance by:

$\varepsilon_t = \sigma_t w_t$

where w_t is white noise, with zero mean and unit variance, and σ^2_t is given by:

$$\sigma^2_t = \alpha_0 + \Sigma\alpha_i\varepsilon^2_{t-1} + \beta_j\sigma^2_{t-j} \qquad (5)$$

3. Analysis and results

3.1. Data and construction of variables

For the current study, data are collected from Pakistan Stock Exchange (PSX) official website. The collected data covers a period of 20 years and 3 months, i.e. from 2nd June 2006 to 23rd August 2020. The macroeconomic variable ``daily closing prices of stock market'' is analyzed for the study. Since the market is not operational on weekends and Public holidays, therefore the total data points included in our study is 3509. The first nineteen years and eight months corresponding to 3383 data points are used for model estimation and the remain seven months, i.e., 126 data points are used for one-day-ahead out-of-sample forecasting using rolling window technique. It is also observed that the stock returns are highly unpredictable and any uncertain condition effects the market instantaneously. A smooth upward trending market at noon results in crash of market in evening is also part of the history of stock market.

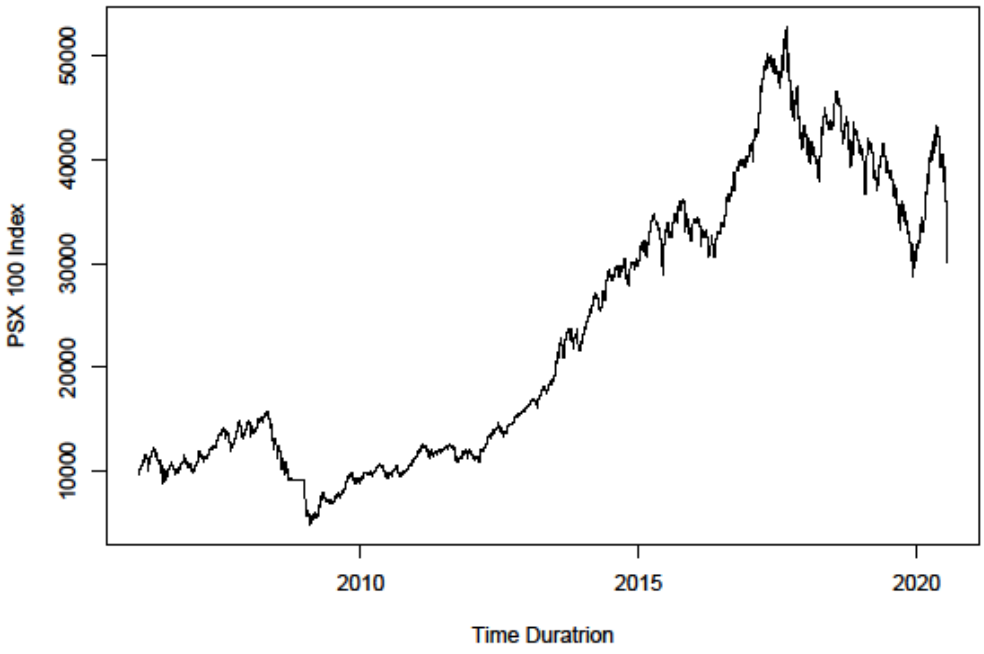

Figure 1: PSX 100 index series for the period 2nd June 2006 to 23rd August 2020

Figure 1 shows the time series plot of the closing 100 index. It can be observed from the plot that series is non-stationary. the series shows random behavior and an upward trend till the mid-2015. A mix behavior, including low and high can be seen in the remaining series. In the year 2017, the series reached to its maximum index ever in history. At the end of 2017, the series showed a decreasing trend due to political uncertainty as Supreme

Court of Pakistan disqualify elected Prime minister due to which political vacuum, instability and uncertainty increased, that directly affect the stock market. After 2018 general elections we witnessed a change in ruling party and later stock market start declining which showed the approach of investors towards change in politics. And of course, COVID-19 shattered the economies around the world and hence to PSX as well. Series was non-stationary and was made stationary through first order difference. The stationarity condition was tested through Augmented Dickey Fuller and Phillips-Perron stationarity tests. After fulfilling all assumptions before making predictions, we run our analysis both through classical and volatility models and find efficiency of each model.

3.2. Predictive modeling

This section will discuss the performance of different predictive models used for modeling and forecasting PSX 100 returns.

3.3. Forecast through ARIMA Model

Although, Autoregressive Integrated Moving Average (ARIMA) models are generally not recommended by researchers for highly volatile data, as these models are not well capable of capturing sudden changes, we used these models as their predictive performance is generally very high compared to other classical models. In addition, although our data set contains high fluctuations indicating volatility in the series, yet we are not sure about its level and strength and hence ARIMA may perform better than those models that can account for volatility. The MAPE and RMSE for different ARIMA models are listed in Table 1. From Table 1 we can see that, although the differences among the MAPE (or RMSE) values are very small, ARIMA (1,1,2) has produced lowest MAPE and RMSE.

Table 1: KSE 100 index: MAPE and RMSE values for different ARIMA Models

Model	MAPE	RMSE
ARIMA (1,1,1)	0.62873	337.12308
ARIMA (1,0,0)	0.62518	336.03516
ARIMA (1,1,2)	0.62518	336.03516
ARIMA (2,1,2)	0.62910	337.71860
ARIMA (2,0,0)	0.62871	337.16064

3.4. Forecasting though ARCH Model

Autoregressive conditional heteroskedasticity (ARCH) models are known for their better performance in capturing volatility. Stock markets are highly diversified and reactive to minor indicators. The stock markets in developed countries are also directly affected by many macro and micro indicators. So, in these situations models like ARCH are recommended to use.

From Table 2 we can see that, although the differences among the MAPE (or RMSE) values are very small, ARCH (3,1) has produced lowest MAPE and RMSE.

Table 2: KSE 100 index: MAPE and RMSE values for different ARCH Models

Model	MAPE	RMSE
ARCH (1,0)	0.71448	391.11671
ARCH (1,1)	0.62183	338.14514
ARCH (2,1)	0.62908	337.36105
ARCH (3,1)	0.61907	336.01860
ARCH (2,0)	0.62773	336.65381

3.5. Forecasting through GARCH Model

GARCH model is the extension of ARCH model and widely used for capturing volatility. The performance of this model is better among other volatility models. Specially GARCH (1,1) is highly recommended for stock market studies. The MAPE and RMSE for different GARCH models are listed in Table 3

Table 3: KSE 100 index: MAPE and RMSE values for different GARCH Models

Model	MAPE	RMSE
GARCH (2,1)	0.63448	340.11194
GARCH (3,2)	0.61105	336.01225
GARCH (1,1)	0.71448	391.11671
GARCH (2,0)	0.63422	339.75678
GARCH (2,3)	0.63168	338.46142

From Table 3 we can see that, although the differences among the MAPE (or RMSE) values are very small, GARCH (3,2) has produced lowest MAPE and RMSE. Thus GARCH (3,2) is chosen for our data. Note that GARCH model produces better forecast than both, ARIMA and ARCH models as this model is good in capturing sudden changes. Figure 2 is showing the forecasting performance of GARCH (3,2) by plotting the observed and forecasted values. From this plot we can see that the forecasted line followed the observed remarkably well indicating the good performance of our model. To check the model adequacy, the ACF and PACF plots for the residuals obtained by using our best model are plotted in Figure 3. Both the graphs show that the residual series is whitened, hence indicating the good performance of our model.

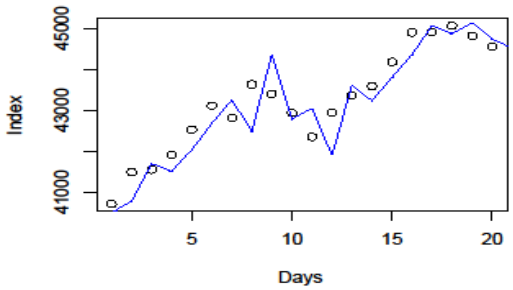

Figure 2: PSX 100: observed (black dotted) and forecasted (blue line) using GARCH (3,2)

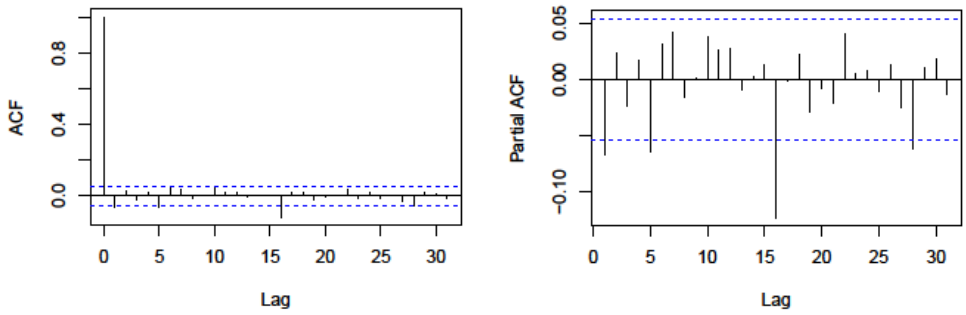

Figure 3: ACF and PACF generated by GARCH (3,2)

4. Conclusion

Poor forecasting not only shakes investor confidence, but also mark a question on researcher skills and ability of forecasting. Forecasting of Stock market returns is one of challenging task for researchers, as there are several factors effecting stock market returns directly or indirectly. Pakistan Stock market is also one of a highly volatile market, so there is always a chance of ambiguity and uncertainty. As PSX is an emerging market of a developing country, it is generally more volatile and easily get effected by external factors including political uncertainty, terrorism etc. in this study we divide the data into two components i.e., estimation and forecasting datasets. Once the sample completes first cycle in the loop, then for the next observation we include original value in data and now the points becomes i+1, whereas a separate window keeps the difference between observed and actual value. GARCH (3,2) captured the difference efficiently compares to other models and they have least difference between actual and predicted value which shows the efficiency of our model. The results of the study indicated that although the models, ARCH and GARCH, that can account for volatility produces better results however ARIMA was competitive. The best forecasting results in term of MAPE were obtained by GARCH (3,2). The selection of model was based on least MAPE and RMSE error values. From figure 2 we could observe that observed points are quite near to forecasted value which reflects the efficiency of our statistical models.

5. Limitations of the study

- Live datasets were not available, and we only had approach to one single closing price at the end of the day which hinder the deep and intrinsic data analysis.
- Datasets from 2008-2013 were no comprehensive due to continuous terrorism and political uncertainty in Pakistan. Usually market was forced to shut down after few hours of its opening due to destabilization in the country.
- Intangible assets of companies were not recorded due to which cointegration was not possible to record between top companies.

6. Recommendations

- Size of PSX is not that influential and big compare to other stock markets in Asia, because major chunk of Pakistan economy is informal. Government needs to formulate the economy by facilitating companies to register in PSX and formulate their accounts.
- Majority of brokerage houses listed in PSX do not provide updated research to investors and due to which new investors falls pray and lose their savings. Brokerage houses needs to provide small investors proper training sessions, tips, and tricks to invest and encourage them to make investment.
- Role of Federal Board of Revenue (FBR) and National Accountability Bureau (NAB) should be limited. Specially we have observed that role of NAB is destructive. Incentives and apprehensions should be given to those investors who pay highest taxes.
- Government must encourage ease of doing business policies, it took months and other bureaucratic hurdles to register a company in Pakistan, whereas in developed countries the same process took hours to complete.

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