CSC 425 Time Series Analysis

Time Series model for Mylan(MYL) Stock Price

Trinadh Gupta
Akhil Kumar Ramasagaram

Abstract:

In a relatively free market economy like United States, it's always a big bet on stock markets, as the price index is highly volatile to global sentiments in the current globalized world and apparently America being the epicentre of sentiment across entire world. Since pharmaceuticals is $300B global market and one of the predominant part of America's economy, stakes are high in this space and major player like Mylan , being the world's 2nd largest and America's 3rd largest firm in this space, stocks of this company play a dominant role in the market sentiments and volatility assessment. Our goal in this project is to observe and predict the trends in Mylan stocks over the time, using different time series analysis techniques. The information is extracted from Yahoo finance.

Goal:

To identify the best fit model that represents Mylan stock prices.

Data:

The data for Mylan is collected from Yahoo finance website, for a period of 8 years of daily stock prices from Nov 19th 2007 to Nov 3rd 2015. The nature of the data would be interesting mainly because it's the phase of suffering and resilience for all companies during global depression and gives an opportunity for us to understand how the Mylan as an organization was performing during those tough times. This data set contains the open, high, low, close and adjusted closing prices of Mylan stock on every Monday - Friday period throughout these eight years. It also contains trading volume values on those days. To achieve consistency, the close prices are used as a general measure of stock price of Mylan over the past 8 years.

Assumptions:

The historical weekly close prices of Mylan stocks reflect changes in the real values of Mylan Company during this period of time.

Exploratory Analysis

```
x
nobs        2011.000000
NAs            0.000000
Minimum       -0.188013
Maximum        0.186468
1. Quartile   -0.010223
3. Quartile    0.011497
Mean           0.000648
Median         0.000822
Sum            1.303323
SE Mean        0.000509
LCL Mean      -0.000351
UCL Mean       0.001647
```

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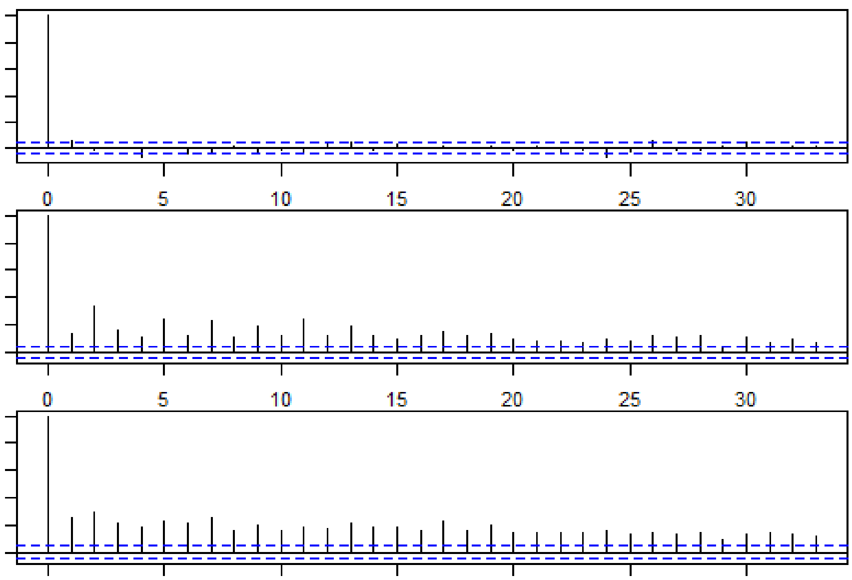
Variance	0.000522
Stdev	0.022845
Skewness	-0.119360
Kurtosis	10.614145

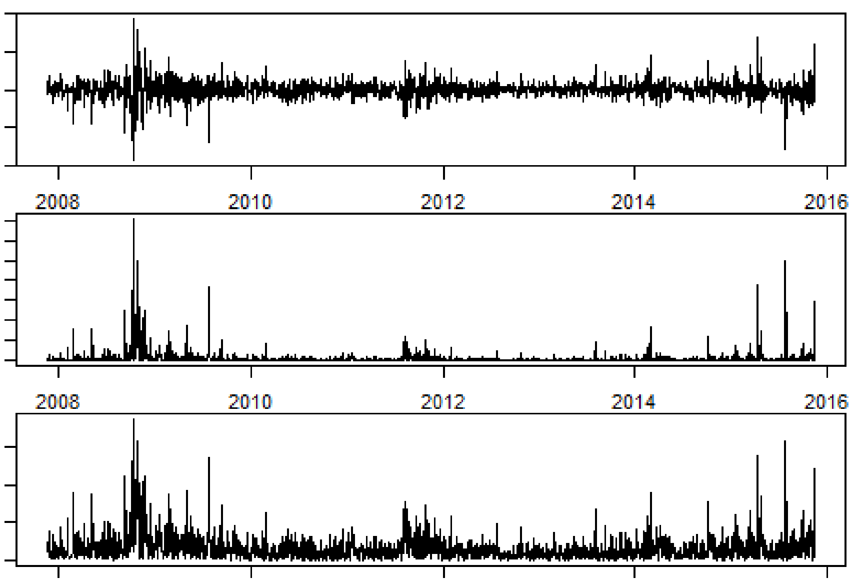
Based on the returns data it is observed that the data is slightly negatively skewed with a high peak than normal Gaussian distribution of returns.

ACF Plot Analysis



The ACF plot indicates that the log returns are not correlated indicating a constant mean model for r_t. We can also observe that the squared returns time series and absolute time series show large autocorrelations. Based on McLeod & Li test we can conclude log returns process has a strong nonlinear dependence. So it is evident that there is an ARCH/ GARCH effect where the volatility is non-constant, and is affected by past shocks.

Time plot Analysis



The time plot shows that the stocks are typically varying around zero except for some extreme negative behaviors observed during the period of depression, followed by period of slight volatility during 2012 and then during last quarter of 2015. The volatility spike in 2012 can be attributed to Healthcare act. Also the volatility in Q4 of 2015 is predominantly seems attributed to the Perrigo Co. takeover issues.

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Ljung-Box test (Square of Returns):

Lag-6

```
Box-Ljung test

data:  coredata(rets^2)
X-squared = 475.6621, df = 6, p-value < 2.2e-16
```

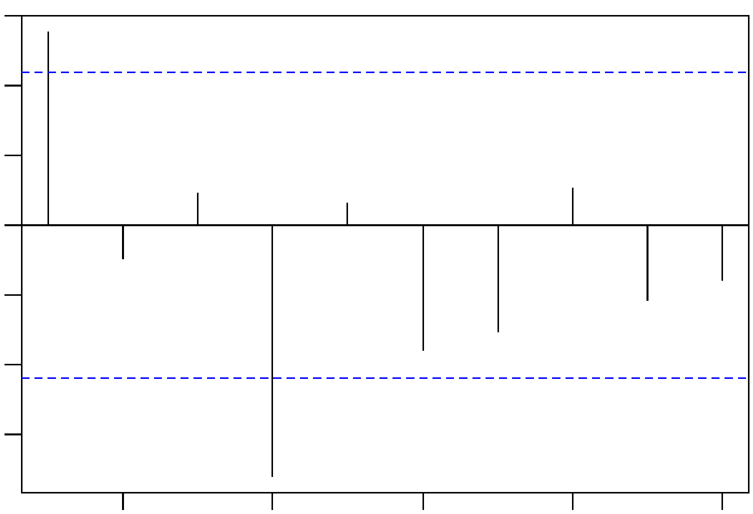
Lag-12

```
        Box-Ljung test

data:  coredata(rets^2)
X-squared = 834.7234, df = 12, p-value < 2.2e-16
```

The LB tests on squared returns confirm that the squared returns are auto correlated (p-values < 0.01 we can reject H0 of no autocorrelation)

PACF for AR Model Identification:



Since the autocorrelation analysis showed that the returns are not correlated but have non constant volatility, we start by fitting a AR(0) - GARCH(1,1) model. We'll show the application of GARCH modeling using three distributions for the errors (normal, t-distribution, and skewed t-distribution). The analysis will be conducted using the rugarch package. See appendix for application of fGarch package.

MODEL 1: AR(0)-GARCH(1,1) with normally distributed errors

```
*---------------------------------*
*          GARCH Model Fit        *
*---------------------------------*

Conditional Variance Dynamics
-----------------------------------
```

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```
GARCH Model     : sGARCH(1,1)
Mean Model      : ARFIMA(0,0,0)
Distribution    : norm

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001120    0.000397   2.8204 0.004797
omega   0.000003    0.000003   1.0252 0.305292
alpha1  0.048731    0.014374   3.3903 0.000698
beta1   0.947456    0.015564  60.8754 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001120    0.000459  2.43870  0.01474
omega   0.000003    0.000022  0.14675  0.88333
alpha1  0.048731    0.095065  0.51261  0.60823
beta1   0.947456    0.105715  8.96240  0.00000

LogLikelihood : 5029.424

Information Criteria
------------------------------------

Akaike       -4.9979
Bayes        -4.9868
Shibata      -4.9979
Hannan-Quinn -4.9938

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      3.185 0.07431
Lag[2*(p+q)+(p+q)-1][2]     3.387 0.11029
Lag[4*(p+q)+(p+q)-1][5]     5.436 0.12172
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                     0.2317  0.6302
Lag[2*(p+q)+(p+q)-1][5]    1.5274  0.7332
Lag[4*(p+q)+(p+q)-1][9]    2.4553  0.8443
d.o.f=2

Weighted ARCH LM Tests
```

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```
------------------------------------
             Statistic Shape Scale P-Value
ARCH Lag[3]     0.9652 0.500 2.000  0.3259
ARCH Lag[5]     1.1833 1.440 1.667  0.6794
ARCH Lag[7]     1.5950 2.315 1.543  0.8021

Nyblom stability test
------------------------------------
Joint Statistic:  6.5073
Individual Statistics:
mu     0.07971
omega  1.43983
alpha1 0.16785
beta1  0.18965

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:        1.07 1.24 1.6
Individual Statistic:   0.35 0.47 0.75

Sign Bias Test
------------------------------------
                   t-value   prob sig
Sign Bias          0.04790 0.9618
Negative Sign Bias 1.52664 0.1270
Positive Sign Bias 0.02498 0.9801
Joint Effect       3.10203 0.3762


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     86.81    1.212e-10
2    30     96.92    3.023e-09
3    40    111.74    6.089e-09
4    50    129.50    3.413e-09


Elapsed time : 0.2575951
```

The p-value from weighted Ljung box test results for standardized residuals shows no evidence of auto correlation in residuals and acts as a white noise.

The p-value from weighted Ljung box test results for standardized square residuals and ARCH LM test shows no evidence of serial correlation and acts as a white noise.

The goodness of fit test rejects the assumption of normal distribution in this case.

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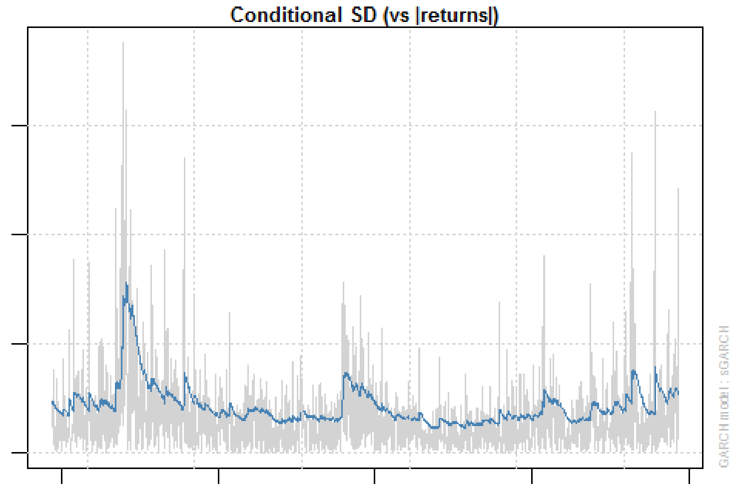

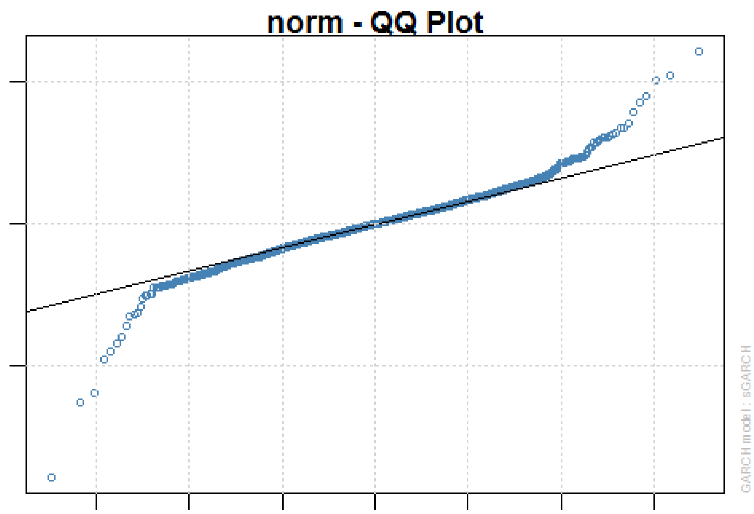

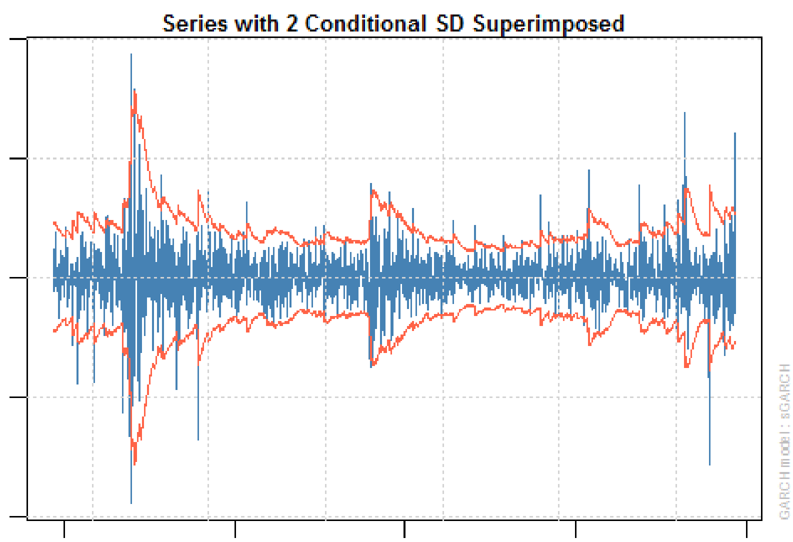

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MODEL 2: AR(0)-GARCH(1,1) with t-distributed errors

```
*---------------------------------*
*          GARCH Model Fit        *
*---------------------------------*

Conditional Variance Dynamics 	
-----------------------------------
GARCH Model	: sGARCH(1,1)
Mean Model	: ARFIMA(0,0,0)
Distribution	: std 

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.000788    0.000350   2.2532 0.024247
omega   0.000005    0.000003   1.6509 0.098760
alpha1  0.059813    0.012640   4.7320 0.000002
beta1   0.930410    0.014281  65.1525 0.000000
shape   4.853968    0.497479   9.7571 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.000788    0.000317  2.48235 0.013052
omega   0.000005    0.000007  0.79643 0.425781
alpha1  0.059813    0.021362  2.79995 0.005111
beta1   0.930410    0.026552 35.04105 0.000000
shape   4.853968    0.577046  8.41175 0.000000

LogLikelihood : 5162.085 

Information Criteria
------------------------------------
                    
Akaike       -5.1289
Bayes        -5.1149
Shibata      -5.1289
Hannan-Quinn -5.1238

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      2.923 0.08734
Lag[2*(p+q)+(p+q)-1][2]     3.060 0.13515
Lag[4*(p+q)+(p+q)-1][5]     5.116 0.14406
```

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```
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.07649  0.7821
Lag[2*(p+q)+(p+q)-1][5]   1.23042  0.8057
Lag[4*(p+q)+(p+q)-1][9]   2.10261  0.8924
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     1.267 0.500 2.000  0.2603
ARCH Lag[5]     1.550 1.440 1.667  0.5794
ARCH Lag[7]     1.821 2.315 1.543  0.7551


Nyblom stability test
------------------------------------
Joint Statistic:  1.1717
Individual Statistics:
mu     0.06518
omega  0.24037
alpha1 0.20680
beta1  0.20095
shape  0.27867

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:        1.28 1.47 1.88
Individual Statistic:   0.35 0.47 0.75

Sign Bias Test
------------------------------------
                   t-value   prob sig
Sign Bias          0.15262 0.8787
Negative Sign Bias 1.25807 0.2085
Positive Sign Bias 0.05688 0.9546
Joint Effect       2.67928 0.4438


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     27.02      0.10417
2    30     40.11      0.08209
```

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```
3    40      59.83      0.01754
4    50      68.29      0.03557


Elapsed time : 0.394907
```

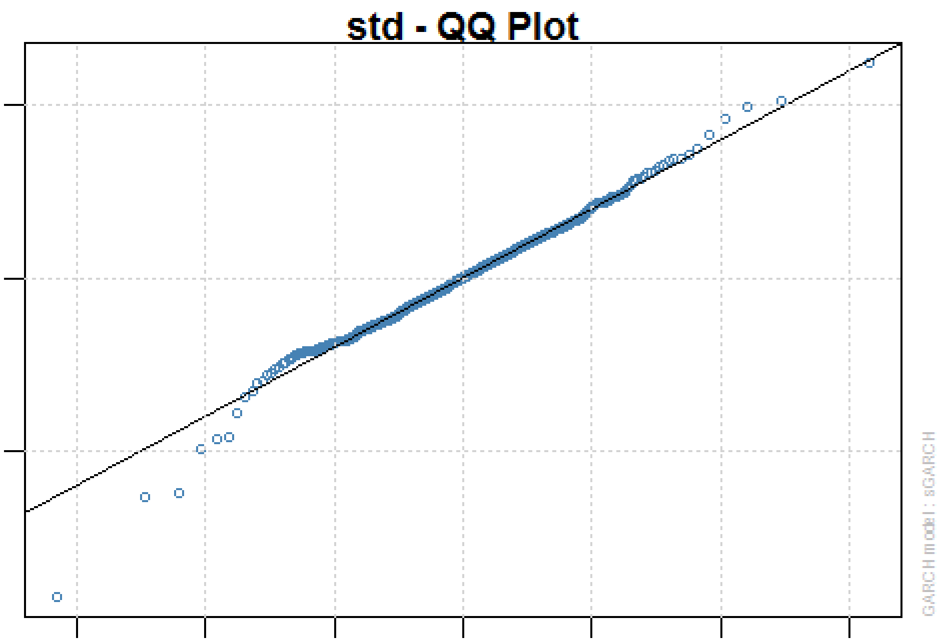
$$r_t = 0.000788 + a_t, a_t = \sigma_t e_t$$

$$\sigma_t^2 = 0.000005 + 0.06a_{t-1}^2 + 0.93\sigma_{t-1}^2$$

With t distribution with 5 degrees of freedom (approximated to nearest integer). Shape parameter is significant, indicating that the t-distribution is a good choice.

No evidence of serial correlation in squared residuals. They behave as a white noise process.

Also, t-distribution assumption cannot be rejected. This supports the choice of the t-distribution based on group 20 & 30 sizes.



Show that t-distribution is appropriate. Some departure is seen under the left tail for extreme residuals (associated to extremely low returns).

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MODEL 3: AR (0)-GARCH (1, 1) with skewed t-distributed errors

```
*---------------------------------*
*          GARCH Model Fit        *
*---------------------------------*

Conditional Variance Dynamics
-----------------------------------
GARCH Model     : sGARCH(1,1)
Mean Model      : ARFIMA(0,0,0)
Distribution    : sstd

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.000814    0.000383   2.1249 0.033595
omega   0.000005    0.000003   1.6493 0.099080
alpha1  0.059812    0.012648   4.7290 0.000002
beta1   0.930452    0.014283  65.1421 0.000000
skew    1.005505    0.031375  32.0480 0.000000
shape   4.854133    0.497744   9.7523 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.000814    0.000368  2.21281 0.026911
omega   0.000005    0.000007  0.79345 0.427518
alpha1  0.059812    0.021451  2.78836 0.005298
beta1   0.930452    0.026676 34.87924 0.000000
skew    1.005505    0.034018 29.55810 0.000000
shape   4.854133    0.577899  8.39962 0.000000

LogLikelihood : 5162.1

Information Criteria
------------------------------------

Akaike       -5.1279
Bayes        -5.1112
Shibata      -5.1279
Hannan-Quinn -5.1218

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      2.921 0.08744
Lag[2*(p+q)+(p+q)-1][2]     3.058 0.13534
Lag[4*(p+q)+(p+q)-1][5]     5.115 0.14420
```

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```
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.07656  0.7820
Lag[2*(p+q)+(p+q)-1][5]   1.23247  0.8052
Lag[4*(p+q)+(p+q)-1][9]   2.10392  0.8922
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     1.269 0.500 2.000  0.2600
ARCH Lag[5]     1.551 1.440 1.667  0.5790
ARCH Lag[7]     1.822 2.315 1.543  0.7548

Nyblom stability test
------------------------------------
Joint Statistic:  1.4694
Individual Statistics:
mu     0.06546
omega  0.24281
alpha1 0.20525
beta1  0.19893
skew   0.29475
shape  0.27333

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:        1.49 1.68 2.12
Individual Statistic:   0.35 0.47 0.75

Sign Bias Test
------------------------------------
                   t-value   prob sig
Sign Bias          0.14061 0.8882
Negative Sign Bias 1.26284 0.2068
Positive Sign Bias 0.06198 0.9506
Joint Effect       2.67182 0.4450


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     25.75      0.13737
2    30     39.61      0.09058
```

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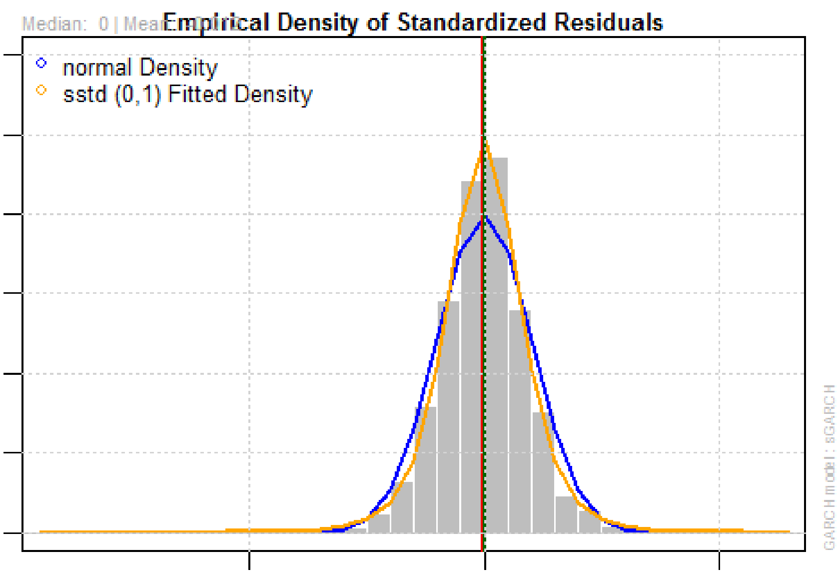
```
3     40      58.00      0.02561
4     50      68.94      0.03167
```

```
Elapsed time : 0.5043042
```

Fitted model is ..

$$r_t = 0.000814 + a_t, a_t = \sigma_t e_t$$

$$\sigma_t^2 = 0.000005 + 0.93 a_{t-1}^2 + 0.93 \sigma_{t-1}^2$$



With t distribution with 5 degrees of freedom (approximated to nearest integer). Both shape and skew parameters are significant. However skew = 1, means a standard t-distribution, that is there is no real skewness in this distribution. No evidence of serial correlation in squared residuals. They behave as a white noise process. Empirical Density of Standardized Residuals is displayed below (created in R using plot(garch11.skt.fit) – selection 8). The distribution is symmetric and consistent with a t-distribution.

<u>PRODUCING FORECASTS:</u> Based on the analysis above, the best model is the AR(0)-GARCH(1,1) model with t-distributed error terms. The analysis supports the choice of the t-distribution, and the model has also the smallest BIC value. Up to 20-step ahead Forecasts are computed using the ugarch forecast function.

```
*------------------------------------*
*       GARCH Model Forecast         *
*------------------------------------*
Model: sGARCH
Horizon: 20
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2015-11-13]:
```

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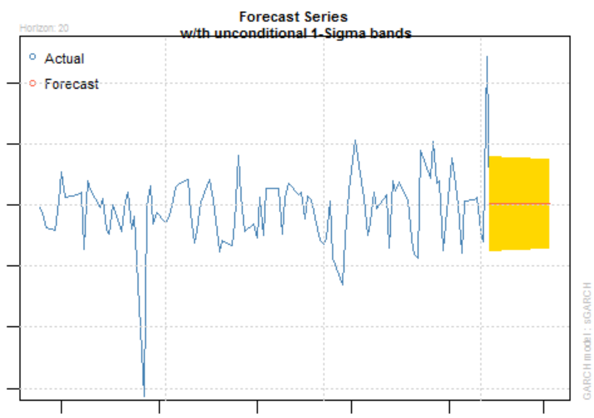
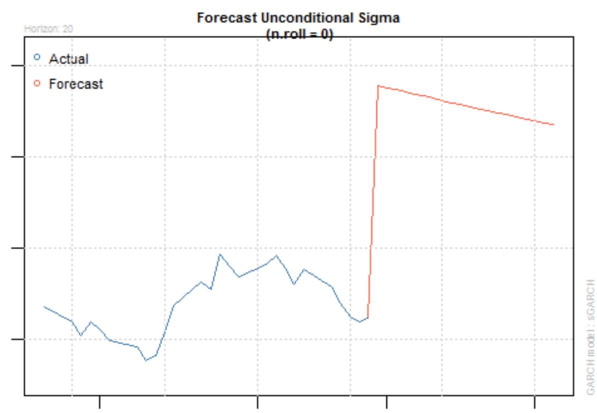
```
          Series   Sigma
T+1   0.0008143 0.03891
T+2   0.0008143 0.03878
T+3   0.0008143 0.03866
T+4   0.0008143 0.03855
T+5   0.0008143 0.03843
T+6   0.0008143 0.03831
T+7   0.0008143 0.03819
T+8   0.0008143 0.03808
T+9   0.0008143 0.03796
T+10 0.0008143 0.03784
T+11 0.0008143 0.03773
T+12 0.0008143 0.03762
T+13 0.0008143 0.03751
T+14 0.0008143 0.03739
T+15 0.0008143 0.03728
T+16 0.0008143 0.03717
T+17 0.0008143 0.03706
T+18 0.0008143 0.03695
T+19 0.0008143 0.03685
T+20 0.0008143 0.03674
```

Sigma = predicted conditional volatility at time t+h series = predicted conditional mean at time t+h predicted mean is constant because the mean model on rt is constant. Predicted volatility converges to overall (unconditional) standard deviation of time series.





<u>Applying EGARCH Model to Fit Possible Leverage Effect:</u>

```
*---------------------------------*
*          GARCH Model Fit        *
*---------------------------------*
```

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```
Conditional Variance Dynamics
-----------------------------------
GARCH Model     : eGARCH(1,1)
Mean Model      : ARFIMA(0,0,0)
Distribution    : std

Optimal Parameters
------------------------------------
        Estimate  Std. Error    t value Pr(>|t|)
mu      0.000466    0.000615    0.75757 0.448706
omega  -0.107690    0.007408  -14.53657 0.000000
alpha1 -0.074580    0.013865   -5.37902 0.000000
beta1   0.986289    0.000945 1043.54396 0.000000
gamma1  0.117122    0.023720    4.93778 0.000001
shape   4.988152    0.559680    8.91251 0.000000

Robust Standard Errors:
        Estimate  Std. Error   t value Pr(>|t|)
mu      0.000466    0.001053   0.44251 0.658117
omega  -0.107690    0.007609 -14.15355 0.000000
alpha1 -0.074580    0.017845  -4.17934 0.000029
beta1   0.986289    0.001087 907.24556 0.000000
gamma1  0.117122    0.038441   3.04681 0.002313
shape   4.988152    0.706217   7.06320 0.000000

LogLikelihood : 5178.511

Information Criteria
------------------------------------

Akaike       -5.1442
Bayes        -5.1275
Shibata      -5.1442
Hannan-Quinn -5.1381

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      1.747  0.1863
Lag[2*(p+q)+(p+q)-1][2]     1.758  0.3062
Lag[4*(p+q)+(p+q)-1][5]     4.049  0.2481
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
```

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```
Lag[1]                      0.6963  0.4040
Lag[2*(p+q)+(p+q)-1][5]     1.4700  0.7473
Lag[4*(p+q)+(p+q)-1][9]     2.6049  0.8220
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]    0.9475 0.500 2.000  0.3304
ARCH Lag[5]    1.3192 1.440 1.667  0.6411
ARCH Lag[7]    2.1761 2.315 1.543  0.6801

Nyblom stability test
------------------------------------
Joint Statistic:  0.9729
Individual Statistics:
mu     0.08893
omega  0.13883
alpha1 0.25054
beta1  0.12924
gamma1 0.17339
shape  0.21253

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:        1.49 1.68 2.12
Individual Statistic:   0.35 0.47 0.75

Sign Bias Test
------------------------------------
                   t-value   prob sig
Sign Bias           0.2207 0.8253
Negative Sign Bias  0.7290 0.4661
Positive Sign Bias  0.4620 0.6441
Joint Effect        0.7615 0.8586


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     17.83       0.5337
2    30     26.12       0.6190
3    40     33.26       0.7287
4    50     57.60       0.1870


Elapsed time : 0.5204792
```

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$$r_t = 0.000466 + a_t, a_t = \sigma_t e_t$$

$$\ln(\sigma_t^2) = -0.107 + (-0.0745 e_{t-1} + 0.11(| e_{t-1} | - E(| e_{t-1} |)) + 0.9862 \ln(\sigma_{t-1}^2)$$

With t distribution with 6 degrees of freedom (approximated to nearest integer).

Conclusion: By using the method of log likelihood and AIC/ BIC criteria , the present study identified that the AR (0) - eGARCH (1,1) model fits the Mylan Stock data most adequately. The resulting model will be

$$r_t = 0.000466 + a_t, a_t = \sigma_t e_t$$

$$\ln(\sigma_t^2) = -0.107 + 0.9862 \ln(\sigma_t^2) + \begin{Bmatrix} -0.075 e_{t-1} + 0.11 e_{t-1} - 0.11 \times 0.80, if\ (e_{t-1} \geq 0) \\ -0.075 e_{t-1} - 0.11 e_{t-1} - 0.11 \times 0.80, if\ (e_{t-1} < 0) \end{Bmatrix}$$

$$\ln(\sigma_t^2) = -0.195 + 0.9862 \ln(\sigma_t^2) + \begin{Bmatrix} 0.035 e_{t-1}, if\ (e_{t-1} \geq 0) \\ -0.185 e_{t-1}, if\ (e_{t-1} < 0) \end{Bmatrix}$$

Taking the antilog transformations

$$\sigma_t^2 = \exp(-0.195) \sigma_{t-1}^{2 \times 0.9862} + \begin{Bmatrix} \exp(0.035 e_{t-1}), if\ (e_{t-1} \geq 0) \\ \exp(-0.185 e_{t-1}), if\ (e_{t-1} < 0) \end{Bmatrix}$$

Based on this we can say for a standardized shock with magnitude 2 SD, will result In 35% higher than the impact of positive shock.