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Code

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This is an R Markdown (http://rmarkdown.rstudio.com) Notebook. When you execute code within the notebook, the results appear beneath the code.

Try executing this chunk by clicking the *Run* button within the chunk or by placing your cursor inside it and pressing *Ctrl+Shift+Enter*.

Ctrl + Alt + I to add chunk

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```
#Installing required packages
packages = c('quantmod','car','forecast','tseries','FinTS', 'rugarch','utf8','ggplot2')
lapply(packages, require, character.only = TRUE)
```

```
Loading required package: quantmod
Warning: package ‘quantmod’ was built under R version 4.3.3Loading required package: xts
Warning: package ‘xts’ was built under R version 4.3.2Loading required package: zoo
Warning: package ‘zoo’ was built under R version 4.3.2
Attaching package: ‘zoo’

The following objects are masked from ‘package:base’:

    as.Date, as.Date.numeric

Loading required package: TTR
Warning: package ‘TTR’ was built under R version 4.3.2Registered S3 method overwritten by 'qu
antmod':
  method            from
  as.zoo.data.frame zoo
Loading required package: car
Warning: package ‘car’ was built under R version 4.3.3Loading required package: carData
Warning: package ‘carData’ was built under R version 4.3.2Loading required package: forecast
Warning: package ‘forecast’ was built under R version 4.3.2This is forecast 8.21.1
  Crossvalidated is a great place to get help on forecasting issues:
  http://stats.stackexchange.com/tags/forecasting.
Loading required package: tseries
Warning: package ‘tseries’ was built under R version 4.3.2
    ‘tseries’ version: 0.10-55

    ‘tseries’ is a package for time series analysis and computational finance.

    See ‘library(help="tseries")’ for details.

Loading required package: FinTS
Warning: package ‘FinTS’ was built under R version 4.3.2
Attaching package: ‘FinTS’

The following object is masked from ‘package:forecast’:

    Acf

Loading required package: rugarch
Warning: package ‘rugarch’ was built under R version 4.3.2Loading required package: parallel

Attaching package: ‘rugarch’

The following object is masked from ‘package:stats’:

    sigma

Loading required package: utf8
Warning: package ‘utf8’ was built under R version 4.3.2Loading required package: ggplot2
Warning: package ‘ggplot2’ was built under R version 4.3.2
```

```
[[1]]
[1] TRUE

[[2]]
[1] TRUE

[[3]]
[1] TRUE

[[4]]
[1] TRUE

[[5]]
[1] TRUE

[[6]]
[1] TRUE

[[7]]
[1] TRUE

[[8]]
[1] TRUE
```

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```
#Downloading the required data

getSymbols(Symbols = 'ITC',
           src = 'yahoo',
           from = as.Date('2012-01-01'),
           to = as.Date('2023-12-31'),
           periodicity = 'daily')
```

```
Warning: ITC contains missing values. Some functions will not work if objects contain missing values in the middle of the series. Consider using na.omit(), na.approx(), na.fill(), etc to remove or replace them.
```

```
[1] "ITC"
```

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```
data_price = na.omit(ITC$ITC.Adjusted)
class(data_price) # xts (Time-Series) Object
```

```
[1] "xts" "zoo"
```

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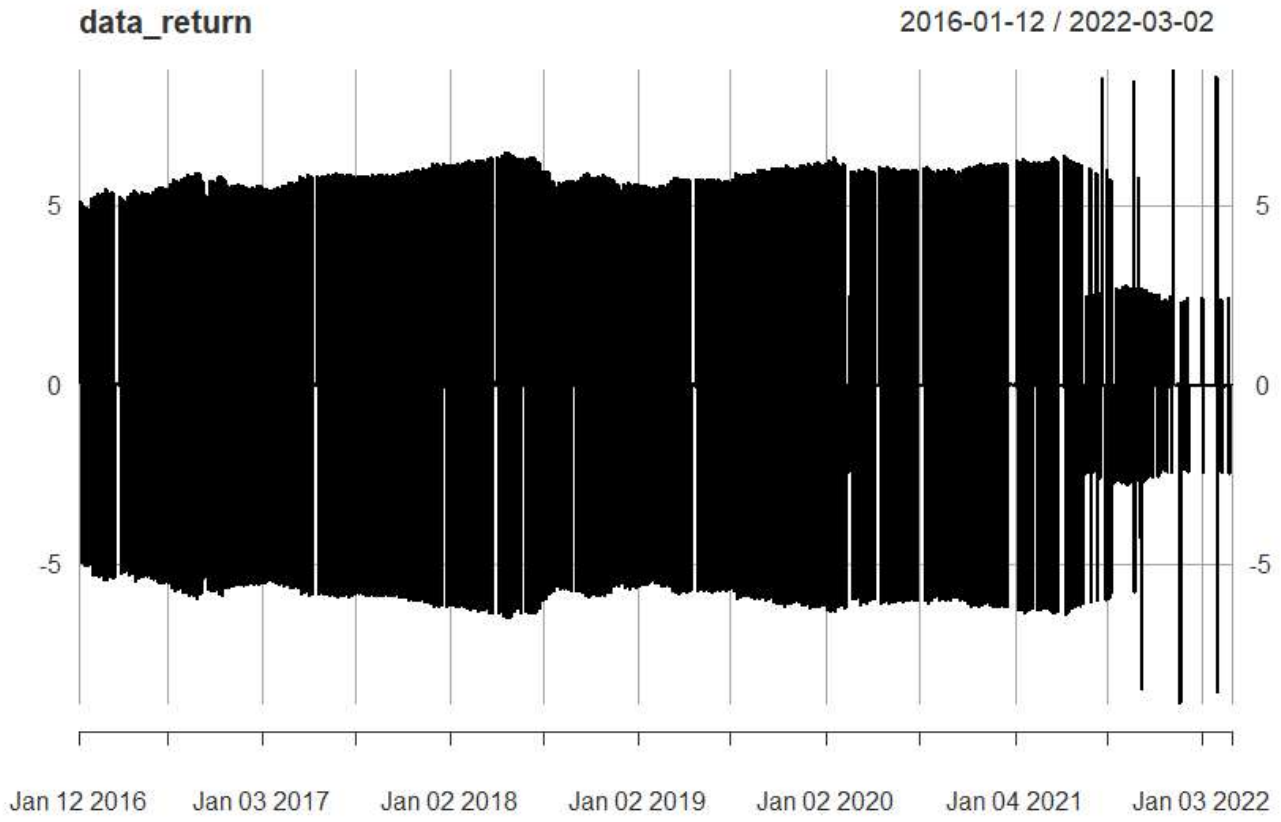
```
data_return = na.omit(diff(log(data_price))); plot(data_return)
```



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```
NA
NA
```

Report:

Objective: To analyze the daily returns of stock from 2012-01-01 to 2023-12-31.

Analysis: Extracted the adjusted closing prices of data stock, calculated daily returns, and visualized them.

Result: The ‘data_return’ plot displays the daily returns of stock over the specified period.

Implication: The plot indicates the volatility and direction of daily returns for stock during the given timeframe.

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```
#Checking the stationarity of returns
adf_test = adf.test(data_return); adf_test
```

```
Warning: p-value smaller than printed p-value
```

```

    Augmented Dickey-Fuller Test

data:  data_return
Dickey-Fuller = -15.423, Lag order = 11, p-value = 0.01
alternative hypothesis: stationary
```

Report:

Objective: To conduct an Augmented Dickey-Fuller (ADF) test for stationarity on the daily returns of stock.

Analysis: Performed the ADF test using the ‘adf.test’ function and obtained results.

Result: The Augmented Dickey-Fuller test for stationarity on data daily returns yields the following p-value: 0.01 - with Null hypothesis that data is non-stationary and Alternate hypothesis that data is stationery.

Implication: The ADF test suggests that the daily returns of data stock are likely stationary. The small p-value (0.01) indicates evidence against the null hypothesis of non-stationarity. Therefore, we reject the null hypothesis and conclude that data is Non-stationary.

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```
#Check for Autocorrlation in Data
# Ljung-Box Test for Autocorrelation
lb_test = Box.test(data_return); lb_test
```

```
    Box-Pierce test

data:  data_return
X-squared = 369.87, df = 1, p-value < 2.2e-16
```

Report:

Objective: To perform a Ljung-Box test for autocorrelation on the daily returns of stock.

Analysis: Conducted the Ljung-Box test using the ‘Box.test’ function and obtained results.

Result: The Ljung-Box test for autocorrelation on data daily returns yields the following p-value: 2.2e-16 with null hypothesis that data is not autocorrelated and alternate hypothesis that data is autocorrelated.

Implication: The Ljung-Box test indicates significant autocorrelation in the data. The small p-value (2.2e-16) suggests evidence to reject the the null hypothesis and data has autocorrelation.Now, we need to use arima to remodel the data.

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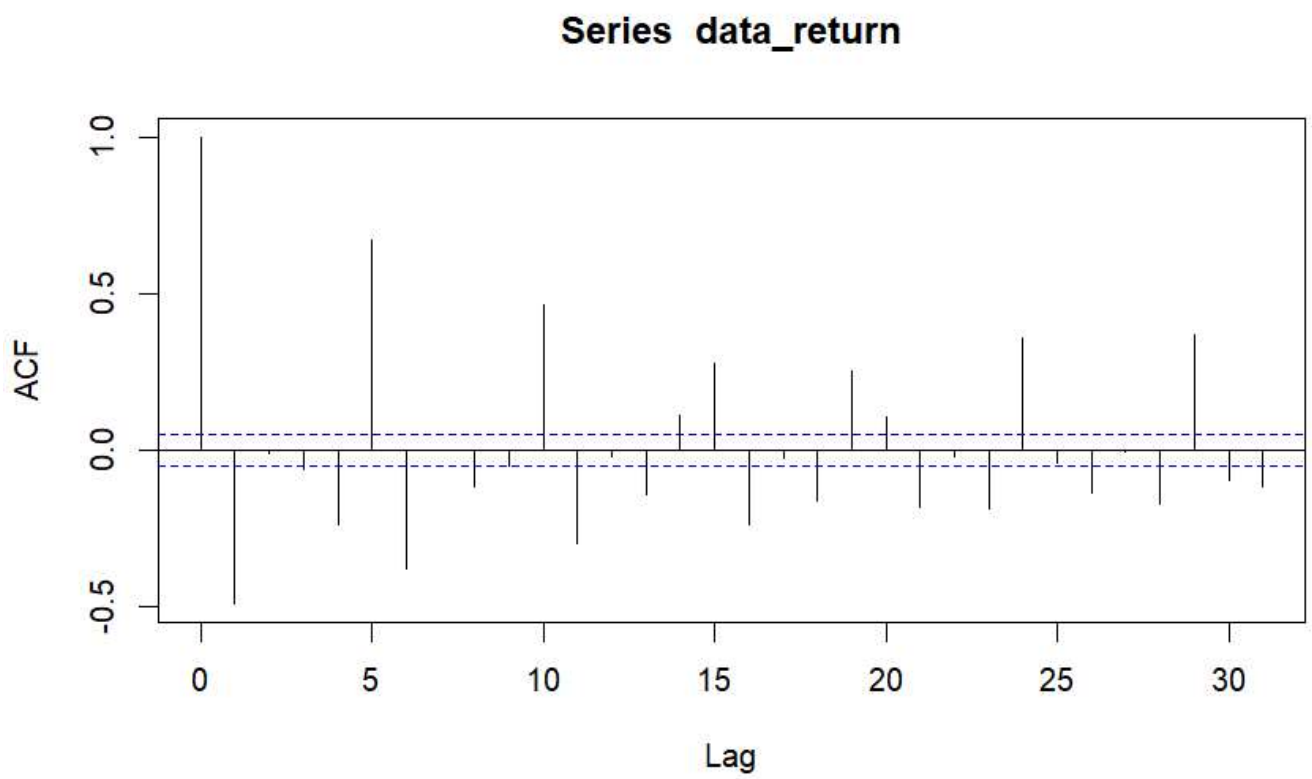
```
#Plot of ACF and PCF
acf(data_return)
```



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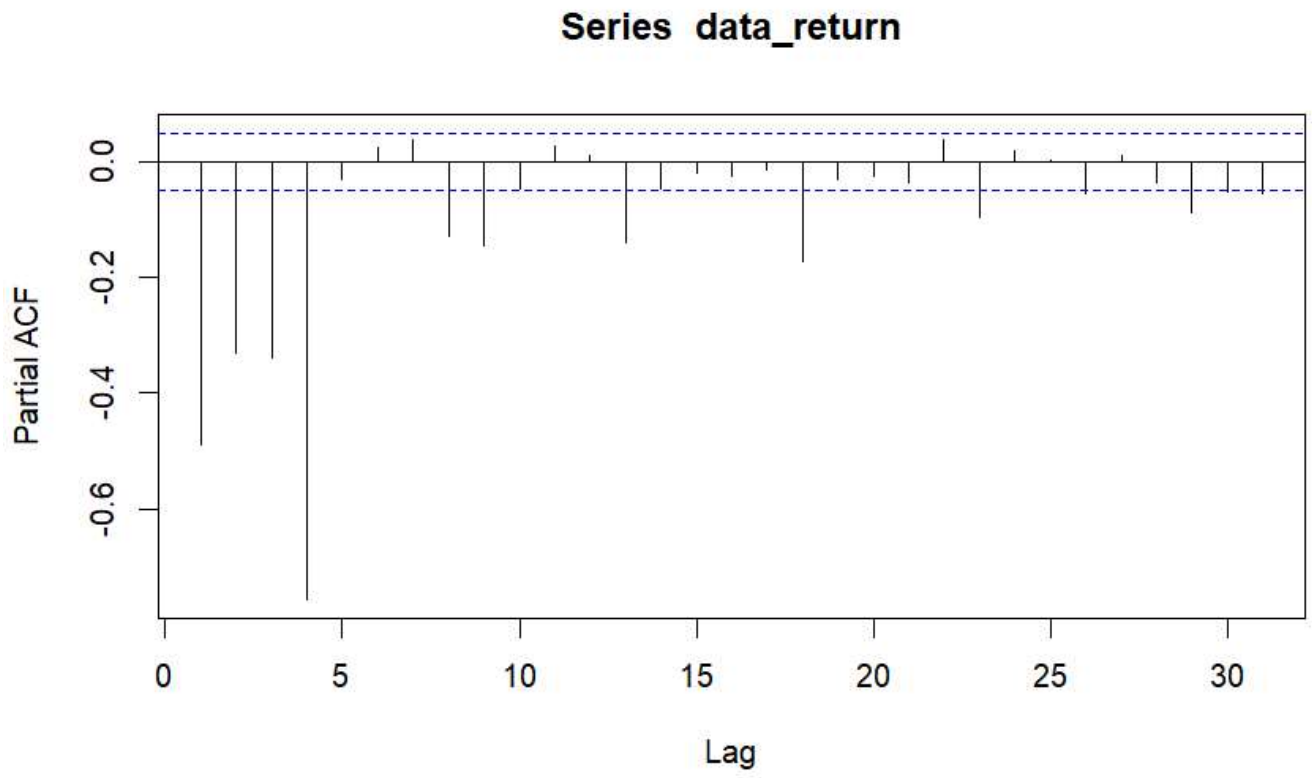
```
pacf(data_return)
```



Report:

Objective: To plot acf and pacf of data to determine p lags and q lags.

Analysis: We use acf and Pacf function of R to plot. Model used is ARIMA i.e. AR (p-Lag) Model : y(t) = c1 + a1*y(t-1)* + *a2*y(t-2) + … + ap*y(t-p)* + *e(t) where e = error == White Noise* | *AR-1 Model : y(t) = c* + *a1*y(t-1) + e(t), MA (q-Lag) Model : y(t) = c2 + b1*e(t-1)* + *b2*e(t-2) + … + bp*e(t-p) where e = Error == White Noise* | *MA-1 Model : y(t) = d* + *b1*e(t-1), ARMA (p, q) Model : y(t) = c + a1*y(t-1)* + *…* + *ap*y(t-p) + b1*e(t-1)* + *…* + *bp*e(t-p) + e(t) | ARMA (1, 1)

Result: Acf shows correlation between series and its lagged value, however pacf shows correlation between series and its lagged value after removing effects of intervening lags. Blueline shows 95% values lie between them.

Implication: Using ACF plot we can interpret that first spike between blue lines come at near 4, So q lag is 4 while similarly in PACF plot it is at 5, So, P lag is 5. So, according to plots arima order should be (5,0,4)

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```
#Using Auto arima
arma_pq = auto.arima(data_return); arma_pq
```

```
Series: data_return
ARIMA(5,0,1) with non-zero mean

Coefficients:
          ar1      ar2      ar3     ar4     ar5      ma1     mean
      -0.1276  -0.0689  -0.0701  0.0356  0.6478  -0.9853  -0.0017
s.e.   0.0206   0.0210   0.0210  0.0210  0.0205   0.0048   0.0012

sigma^2 = 3.211:  log likelihood = -3094.6
AIC=6205.2   AICc=6205.29   BIC=6247.94
```

Report:

Objective: To remodel data using auto arima.

Analysis: We use “auto.arima” function of R to plot.

Result: It also shows same lags as we identified before.

Implication: Now we will use transformed data for further analysis.

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```
#Checking of Autocorrelation in transformed data after auto arima
lb_test_A = Box.test(arma_pq$residuals); lb_test_A
```

```

    Box-Pierce test

data:  arma_pq$residuals
X-squared = 0.66319, df = 1, p-value = 0.4154
```

Report:

Objective: To perform a Ljung-Box test for autocorrelation on the transformed data.

Analysis: Conducted the Ljung-Box test using the ‘Box.test’ function and obtained results.

Result: The Ljung-Box test for autocorrelation yields the following p-value: 0.4154 with null hypothesis that data is not autocorrelated and alternate hypothesis that data is autocorrelated.

Implication: The Ljung-Box test indicates no significant autocorrelation in the data. The p-value (0.4154) suggests evidence to accept the the null hypothesis and data has no autocorrelation now.

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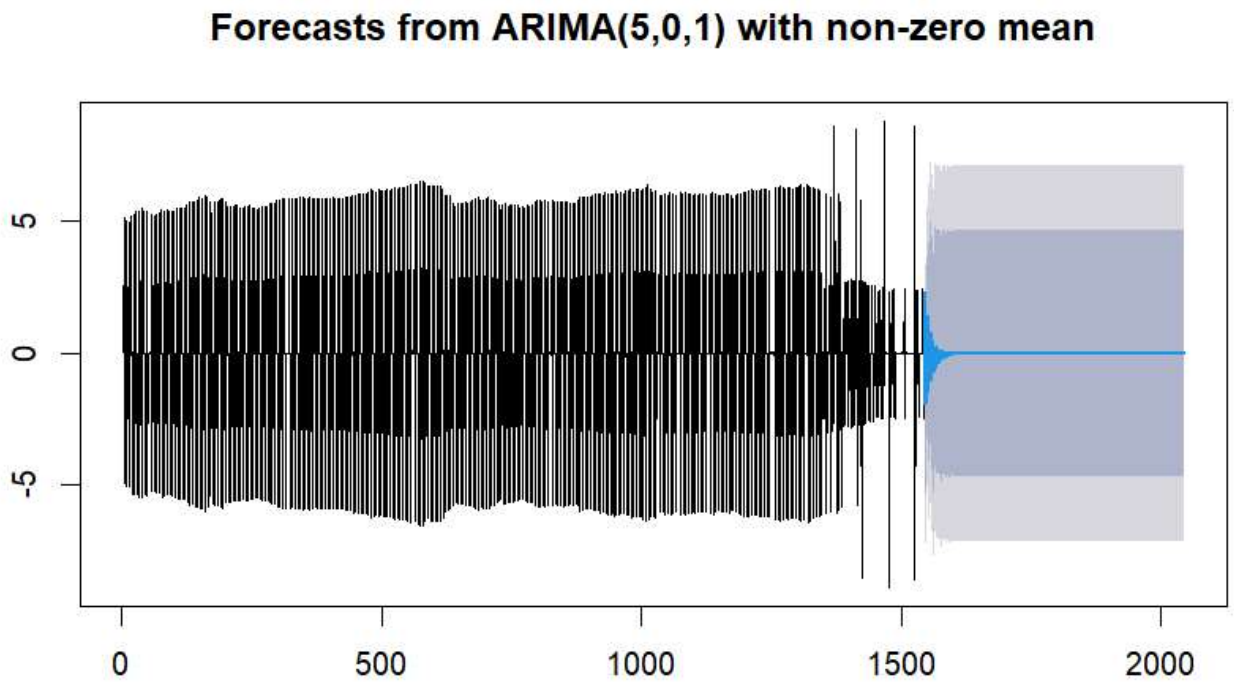
```
#Forecast of Arima model
ds_fpq = forecast(arma_pq, h = 500)
plot(ds_fpq)
```



Report:

Objective: To forecast the prices using arima model.

Analysis: For this, the forecast function of R is used.

Result: Plot shows the prediction of next 500 steps, which means as we had daily data. It shows prediction for next 500 days.

Implication: This plot shows that data will be steadily constant over time as it is reflected in historical data.

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```
#Checking for Volatility Clustering or Heteroskedasticity: Arch test

data_ret_sq = arma_pq$residuals^2
data_ret_arch_test = ArchTest(data_ret_sq, lags = 10)
data_ret_arch_test
```

```

    ARCH LM-test; Null hypothesis: no ARCH effects

data:  data_ret_sq
Chi-squared = 366.75, df = 10, p-value < 2.2e-16
```

Report:

Objective: To test for volatility clustering or heteroskedasticity in the residuals of the ARIMA(5, 0, 4) model.

Analysis: Conducted Box ARCH test on the squared residuals to assess the presence of volatility clustering.

Results: Arch test yields the p value of 2.2e-16, with null hypothesis that there is no arch effect and alternate hypothesis tells presence of Arch effect.

Implications: It means we can reject null hypothesis and it means data contains Volatility Clustering or Heteroskedasticity, which mean we need to do garch modelling to transform data to white noise.

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```
#Garch Modelling
garch_model1 = ugarchspec(variance.model = list(model = 'sGARCH', garchOrder = c(1,1)), mean.
model = list(armaOrder = c(5,4), include.mean = TRUE))
ret_garch1 = ugarchfit(garch_model1, data = data_ret_sq); ret_garch1
```

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

Conditional Variance Dynamics
-----------------------------------
GARCH Model : sGARCH(1,1)
Mean Model  : ARFIMA(5,0,4)
Distribution    : norm

Optimal Parameters
------------------------------------
        Estimate  Std. Error    t value Pr(>|t|)
mu      3.113731    0.542055     5.7443    0e+00
ar1     1.227295    0.019688    62.3381    0e+00
ar2    -0.829260    0.027878   -29.7466    0e+00
ar3     0.195697    0.037517     5.2162    0e+00
ar4     0.603925    0.033656    17.9440    0e+00
ar5    -0.203403    0.026077    -7.8002    0e+00
ma1    -0.975572    0.000253 -3860.1791    0e+00
ma2     0.559059    0.000806   693.9601    0e+00
ma3     0.019858    0.003972     4.9996    1e-06
ma4    -0.580741    0.000764  -759.9526    0e+00
omega   0.300585    0.035587     8.4465    0e+00
alpha1  0.016328    0.001152    14.1774    0e+00
beta1   0.978817    0.001034   947.0808    0e+00

Robust Standard Errors:
        Estimate  Std. Error    t value Pr(>|t|)
mu      3.113731    0.465634     6.6871 0.000000
ar1     1.227295    0.026725    45.9232 0.000000
ar2    -0.829260    0.023014   -36.0331 0.000000
ar3     0.195697    0.033131     5.9068 0.000000
ar4     0.603925    0.035503    17.0105 0.000000
ar5    -0.203403    0.035293    -5.7632 0.000000
ma1    -0.975572    0.000160 -6094.6838 0.000000
ma2     0.559059    0.000125  4460.9669 0.000000
ma3     0.019858    0.007640     2.5993 0.009341
ma4    -0.580741    0.000202 -2876.5214 0.000000
omega   0.300585    0.108854     2.7614 0.005756
alpha1  0.016328    0.003908     4.1780 0.000029
beta1   0.978817    0.000706  1386.6874 0.000000

LogLikelihood : -5172.173

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

Akaike       6.7079
Bayes        6.7528
Shibata      6.7077
Hannan-Quinn 6.7246

Weighted Ljung-Box Test on Standardized Residuals
```

```
-----------------------------------
                          statistic   p-value
Lag[1]                    7.125e-04 0.9787043
Lag[2*(p+q)+(p+q)-1][26] 1.556e+01 0.0003996
Lag[4*(p+q)+(p+q)-1][44] 3.004e+01 0.0230502
d.o.f=9
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
-----------------------------------
                         statistic p-value
Lag[1]                       5.486 0.01917
Lag[2*(p+q)+(p+q)-1][5]      9.535 0.01210
Lag[4*(p+q)+(p+q)-1][9]     14.627 0.00440
d.o.f=2

Weighted ARCH LM Tests
-----------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]  0.009642 0.500 2.000 0.92178
ARCH Lag[5]  7.878589 1.440 1.667 0.02147
ARCH Lag[7] 10.865795 2.315 1.543 0.01154

Nyblom stability test
-----------------------------------
Joint Statistic:  4.0134
Individual Statistics:
mu     0.09347
ar1    0.14187
ar2    0.10153
ar3    0.05196
ar4    0.04741
ar5    0.06430
ma1    0.67094
ma2    0.51359
ma3    0.12390
ma4    0.10908
omega  0.16852
alpha1 0.66506
beta1  0.28363

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:          2.89 3.15 3.69
Individual Statistic:     0.35 0.47 0.75

Sign Bias Test
-----------------------------------
```

	t-value <dbl>	prob <dbl>	sig <chr>
Sign Bias	2.4628779	1.389136e-02	**
Negative Sign Bias	0.4037908	6.864226e-01	
Positive Sign Bias	4.5236680	6.543338e-06	***

	t-value <dbl>	prob <dbl>	sig <chr>
Joint Effect	20.7276940	1.199128e-04	***

4 rows

```
Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20      1987            0
2    30      2050            0
3    40      2124            0
4    50      2170            0


Elapsed time : 1.124363
```

Report:

Objective: To transform the data to remove volatility clustering or heteroskedasticity.

Analysis: We used ugarchfit and ugarchspec to do this.

Result: We found the data with following characterstics: Sign Bias: 2.4628779 , Negative Sign Bias: 0.4037908 Positive Sign Bias 4.5236680, Joint Effect 20.7276940

Implication: Now, we can ue this data forecasting.

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```
stk_ret_garch_forecast1 = ugarchforecast(ret_garch1, n.ahead = 500); stk_ret_garch_forecast1
```

```
*-----------------------------------*
*       GARCH Model Forecast        *
*-----------------------------------*
Model: sGARCH
Horizon: 500
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=1546-01-01]:
      Series  Sigma
T+1   0.8637 12.166
T+2   5.8113 12.148
T+3   9.5128 12.131
T+4   7.1496 12.114
T+5   2.4146 12.097
T+6   2.2481 12.080
T+7   6.7367 12.063
T+8   9.2770 12.047
T+9   6.2610 12.030
T+10  2.1938 12.013
T+11  2.9450 11.996
T+12  7.2707 11.980
T+13  8.8225 11.963
T+14  5.4441 11.947
T+15  2.1385 11.930
T+16  3.6463 11.914
T+17  7.6343 11.898
T+18  8.2754 11.881
T+19  4.7412 11.865
T+20  2.2354 11.849
T+21  4.3180 11.833
T+22  7.8364 11.817
T+23  7.6722 11.801
T+24  4.1662 11.785
T+25  2.4554 11.769
T+26  4.9323 11.753
T+27  7.8899 11.738
T+28  7.0470 11.722
T+29  3.7246 11.706
T+30  2.7686 11.691
T+31  5.4678 11.675
T+32  7.8126 11.660
T+33  6.4298 11.644
T+34  3.4149 11.629
T+35  3.1450 11.613
T+36  5.9102 11.598
T+37  7.6257 11.583
T+38  5.8458 11.568
T+39  3.2300 11.553
T+40  3.5563 11.538
T+41  6.2512 11.523
T+42  7.3523 11.508
T+43  5.3151 11.493
T+44  3.1582 11.478
```

```
T+45  3.9770 11.463
T+46  6.4888 11.449
T+47  7.0161 11.434
T+48  4.8522 11.419
T+49  3.1842 11.405
T+50  4.3849 11.390
T+51  6.6258 11.376
T+52  6.6400 11.361
T+53  4.4667 11.347
T+54  3.2907 11.333
T+55  4.7615 11.318
T+56  6.6693 11.304
T+57  6.2455 11.290
T+58  4.1629 11.276
T+59  3.4594 11.262
T+60  5.0929 11.248
T+61  6.6295 11.234
T+62  5.8517 11.220
T+63  3.9412 11.206
T+64  3.6717 11.192
T+65  5.3689 11.179
T+66  6.5191 11.165
T+67  5.4750 11.151
T+68  3.7978 11.138
T+69  3.9100 11.124
T+70  5.5838 11.111
T+71  6.3521 11.097
T+72  5.1285 11.084
T+73  3.7262 11.070
T+74  4.1581 11.057
T+75  5.7352 11.044
T+76  6.1429 11.031
T+77  4.8220 11.017
T+78  3.7174 11.004
T+79  4.4016 10.991
T+80  5.8242 10.978
T+81  5.9059 10.965
T+82  4.5621 10.952
T+83  3.7612 10.940
T+84  4.6287 10.927
T+85  5.8545 10.914
T+86  5.6546 10.901
T+87  4.3523 10.889
T+88  3.8463 10.876
T+89  4.8301 10.863
T+90  5.8321 10.851
T+91  5.4012 10.838
T+92  4.1933 10.826
T+93  3.9612 10.813
T+94  4.9989 10.801
T+95  5.7644 10.789
T+96  5.1561 10.776
T+97  4.0834 10.764
T+98  4.0950 10.752
T+99  5.1309 10.740
T+100 5.6598 10.728
```

```
T+101 4.9279 10.716
T+102 4.0190 10.704
T+103 4.2373 10.692
T+104 5.2243 10.680
T+105 5.5272 10.668
T+106 4.7232 10.656
T+107 3.9950 10.645
T+108 4.3791 10.633
T+109 5.2791 10.621
T+110 5.3755 10.609
T+111 4.5464 10.598
T+112 4.0052 10.586
T+113 4.5127 10.575
T+114 5.2972 10.563
T+115 5.2131 10.552
T+116 4.4003 10.541
T+117 4.0426 10.529
T+118 4.6318 10.518
T+119 5.2821 10.507
T+120 5.0478 10.495
T+121 4.2857 10.484
T+122 4.1004 10.473
T+123 4.7321 10.462
T+124 5.2380 10.451
T+125 4.8863 10.440
T+126 4.2018 10.429
T+127 4.1716 10.418
T+128 4.8104 10.407
T+129 5.1701 10.397
T+130 4.7342 10.386
T+131 4.1468 10.375
T+132 4.2497 10.364
T+133 4.8652 10.354
T+134 5.0837 10.343
T+135 4.5957 10.332
T+136 4.1176 10.322
T+137 4.3290 10.311
T+138 4.8963 10.301
T+139 4.9844 10.290
T+140 4.4740 10.280
T+141 4.1105 10.270
T+142 4.4045 10.259
T+143 4.9046 10.249
T+144 4.8774 10.239
T+145 4.3711 10.229
T+146 4.1215 10.219
T+147 4.4721 10.209
T+148 4.8921 10.198
T+149 4.7676 10.188
T+150 4.2876 10.178
T+151 4.1463 10.169
T+152 4.5289 10.159
T+153 4.8611 10.149
T+154 4.6593 10.139
T+155 4.2234 10.129
T+156 4.1804 10.119
```

```
T+157 4.5726 10.110
T+158 4.8148 10.100
T+159 4.5562 10.090
T+160 4.1774 10.081
T+161 4.2200 10.071
T+162 4.6022 10.062
T+163 4.7565 10.052
T+164 4.4610 10.043
T+165 4.1479 10.033
T+166 4.2612 10.024
T+167 4.6174 10.015
T+168 4.6895 10.005
T+169 4.3758  9.996
T+170 4.1329  9.987
T+171 4.3010  9.978
T+172 4.6185  9.968
T+173 4.6171  9.959
T+174 4.3021  9.950
T+175 4.1297  9.941
T+176 4.3367  9.932
T+177 4.6065  9.923
T+178 4.5424  9.914
T+179 4.2404  9.905
T+180 4.1358  9.896
T+181 4.3662  9.888
T+182 4.5829  9.879
T+183 4.4681  9.870
T+184 4.1908  9.861
T+185 4.1485  9.853
T+186 4.3881  9.844
T+187 4.5495  9.835
T+188 4.3966  9.827
T+189 4.1528  9.818
T+190 4.1652  9.810
T+191 4.4015  9.801
T+192 4.5084  9.793
T+193 4.3298  9.784
T+194 4.1253  9.776
T+195 4.1836  9.767
T+196 4.4062  9.759
T+197 4.4615  9.751
T+198 4.2689  9.743
T+199 4.1072  9.734
T+200 4.2018  9.726
T+201 4.4023  9.718
T+202 4.4109  9.710
T+203 4.2151  9.702
T+204 4.0969  9.694
T+205 4.2178  9.686
T+206 4.3903  9.678
T+207 4.3585  9.670
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Hide

```
plot(stk_ret_garch_forecast1)
```

```

Make a plot selection (or 0 to exit):

1:   Time Series Prediction (unconditional)
2:   Time Series Prediction (rolling)
3:   Sigma Prediction (unconditional)
4:   Sigma Prediction (rolling)
```

Hide

```
1
```

```

Make a plot selection (or 0 to exit):

1:   Time Series Prediction (unconditional)
2:   Time Series Prediction (rolling)
3:   Sigma Prediction (unconditional)
4:   Sigma Prediction (rolling)
```

Hide

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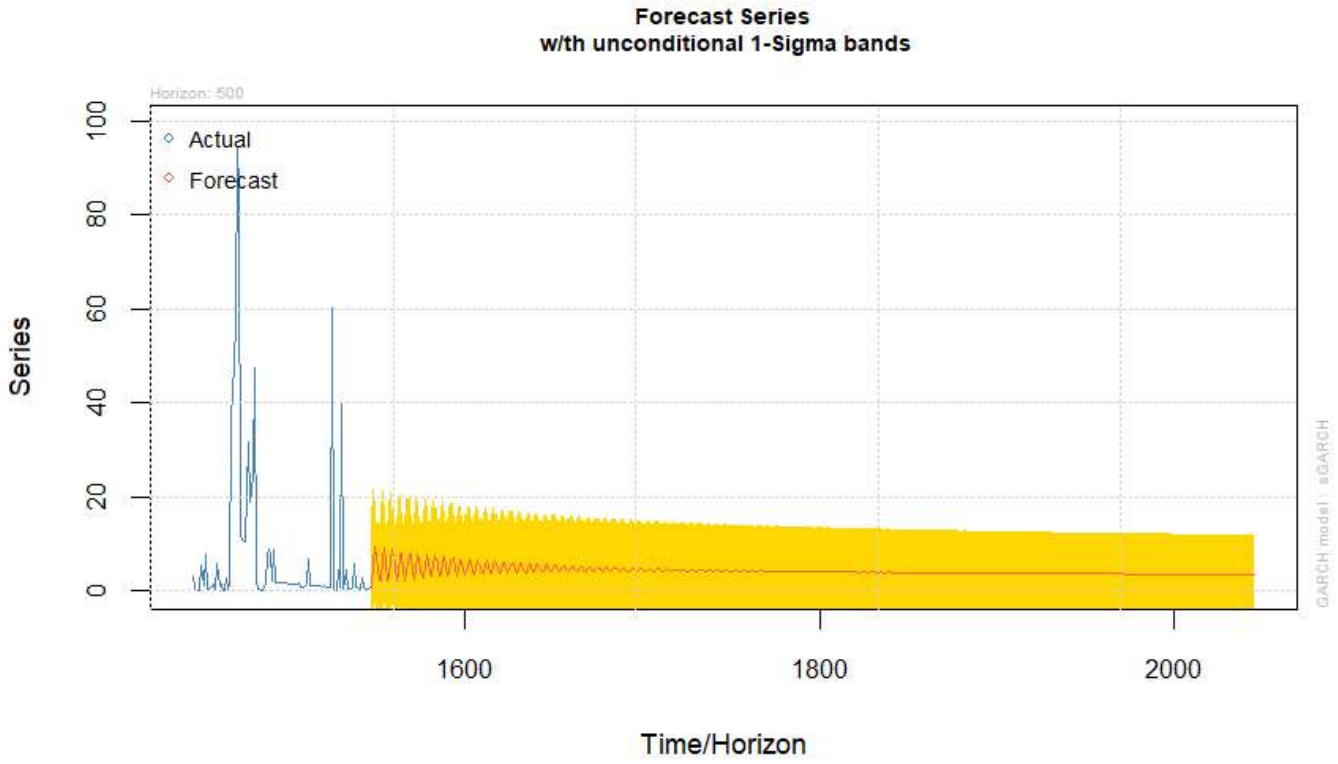

Report:

Objective: To predict future values using garch model

Analysis: We used “forecast” and “Plot” fuction of R.

Result: It predicts constant stock return in future.

Implication: It can be used to predict stock may not have growth prospects in future.

Add a new chunk by clicking the *Insert Chunk* button on the toolbar or by pressing *Ctrl+Alt+I*.

When you save the notebook, an HTML file containing the code and output will be saved alongside it (click the *Preview* button or press *Ctrl+Shift+K* to preview the HTML file).

The preview shows you a rendered HTML copy of the contents of the editor. Consequently, unlike *Knit*, *Preview* does not run any R code chunks. Instead, the output of the chunk when it was last run in the editor is displayed.