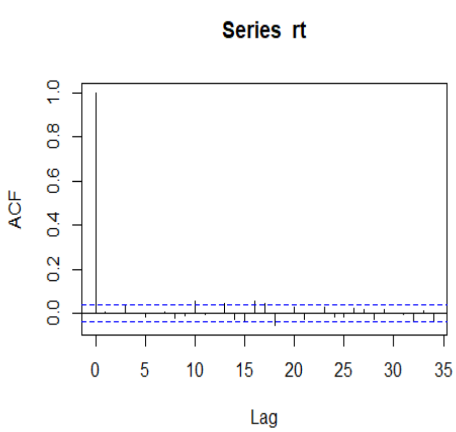
Assignment-5.R

Jidapa

2021-04-29

```
setwd("D:/uni year 3/EE435")
#install.packages("quantmod")
#install.packages("fBasics")
#install.packages("sn")
#install.packages("PerformanceAnalytics")
#install.packages("car")
#install.packages("tseries")
#install.packages("forecast")
#install.packages("fGarch")
library(fGarch)
library(quantmod)
library(fBasics)
library(sn)
library(PerformanceAnalytics)
library(car)
library(tseries)
library(forecast)
require(quantmod)

## Question 1
getSymbols("CAT",from="2006-01-03",to="2017-04-13")

## [1] "CAT"

rt <- diff(log(as.numeric(CAT[,6])))
#1a serial correlation
acf(rt)
```



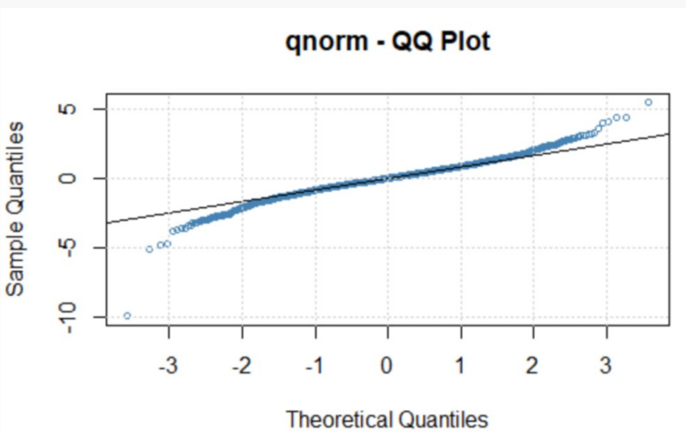
```
Box.test(rt,lag=15,type = 'Ljung')

##
##  Box-Ljung test
##
## data:  rt
## X-squared = 28.552, df = 15, p-value = 0.01836
```

H0: There is no serial correlation in rt dataset.
H1: There is serial correlation in rt.
Since p-value < 0.05, we can reject H0 and conclude that there is serial correlation in the data of rt.

```
#1b ARCH effect
Box.test(rt^2, lag = 15, type="Ljung")

##
##    Box-Ljung test
##
## data:  rt^2
## X-squared = 5528.4, df = 15, p-value < 2.2e-16
```

There is ARCH effect in log return series since the p-value < 0.05. Therefore, there is a serial correlation in squared of rt.

```
#1c ARMA(1,0)-GARCH(1,1)
m2 = garchFit(~arma(1,0)+garch(1,1),data = rt, include.mean = F, trace = F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

#plot
```




```
summary(m2)

##
## Title:
##  GARCH Modelling
##
```

```
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 1), data = rt, include.mean = F
,
##     trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 1)
## <environment: 0x00000000224ff680>
##  [data = rt]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##        ar1       omega      alpha1       beta1
## 1.8304e-02  4.4963e-06  4.9926e-02  9.3841e-01
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## ar1    1.830e-02   2.005e-02    0.913 0.361170
## omega  4.496e-06   1.296e-06    3.469 0.000522 ***
## alpha1 4.993e-02   8.332e-03    5.992 2.07e-09 ***
## beta1  9.384e-01   1.049e-02   89.442  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  7377.328    normalized:  2.599481
##
## Description:
##  Thu Apr 29 08:26:16 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  3263.302  0
##  Shapiro-Wilk Test  R    W      0.9664142 0
##  Ljung-Box Test     R    Q(10)  12.26756  0.267549
##  Ljung-Box Test     R    Q(15)  14.64152  0.477534
##  Ljung-Box Test     R    Q(20)  19.16095  0.5113875
##  Ljung-Box Test     R^2  Q(10)  0.9739135 0.9998476
##  Ljung-Box Test     R^2  Q(15)  3.707743  0.9985481
##  Ljung-Box Test     R^2  Q(20)  7.111337  0.9963036
##  LM Arch Test       R    TR^2   2.736133  0.9971375
##
## Information Criterion Statistics:
```

```
##       AIC       BIC       SIC      HQIC 
## -5.196143 -5.187756 -5.196147 -5.193118
```

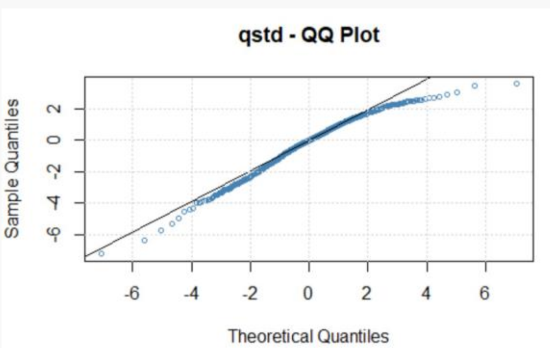
The model is adequate because all of the standardized residual tests show that there is no serial correlation between residuals and squared residuals left. All p-value > 0.05

Fitted model: $r_t = \underset{(2.005e-02)}{(1.830e-02)} r_{t-1}$

$$\sigma_a^2 = \underset{(1.296e-06)}{4.496e-06} + \underset{(8.332e-03)}{0.0499} a_{t-1}^2 + \underset{(1.049e-02)}{0.938} a_{t-2}^2 .$$

```
#1d GARCH(1,1)
m3 = garchFit(~garch(1,1),data=rt, cond.dist = "std",trace=F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m3)

## 
## Title:
##  GARCH Modelling 
## 
## Call:
##  garchFit(formula = ~garch(1, 1), data = rt, cond.dist = "std", 
##     trace = F) 
## 
## Mean and Variance Equation:
##  data ~ garch(1, 1)
## <environment: 0x000000001f640e50>
##  [data = rt]
## 
## Conditional Distribution:
##  std 
## 
## Coefficient(s):
##         mu       omega      alpha1       beta1       shape  
## 5.9780e-04  4.2035e-06  7.2376e-02  9.2033e-01  5.0958e+00  
## 
## Std. Errors:
##  based on Hessian 
## 
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)    
## mu     5.978e-04   2.702e-04    2.212  0.02695 *  
## omega  4.203e-06   1.571e-06    2.675  0.00747 ** 
## alpha1 7.238e-02   1.374e-02    5.267 1.39e-07 ***
## beta1  9.203e-01   1.472e-02   62.503  < 2e-16 ***
## shape  5.096e+00   4.825e-01   10.561  < 2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  7507.106    normalized:  2.64521
##
## Description:
##  Thu Apr 29 08:26:17 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  4056.502  0
##  Shapiro-Wilk Test  R    W      0.9639091 0
##  Ljung-Box Test     R    Q(10)  14.77968  0.140303
##  Ljung-Box Test     R    Q(15)  16.74279  0.3344718
##  Ljung-Box Test     R    Q(20)  20.39783  0.433304
##  Ljung-Box Test     R^2  Q(10)  2.953085  0.9825066
##  Ljung-Box Test     R^2  Q(15)  5.482428  0.9871938
##  Ljung-Box Test     R^2  Q(20)  9.458146  0.9769677
##  LM Arch Test       R    TR^2   4.273688  0.977976
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -5.286897 -5.276412 -5.286903 -5.283115
```



The model is adequate since all p-value from Ljung Box test exceeds 0.05 which means that there is no serial correlation left in the model.

```
#1e fitted model
```

Fitted model: GARCH(1,1) : $\sigma_t^2 = \underset{(1.571e-06)}{4.203e-06} + \underset{(1.374e-02)}{0.07238}\, a_{t-1}^2 + \underset{(1.472e-02)}{0.9203}\, \sigma_{t-1}^2$

```
#1f 1-step to 5-step using GARCH(1,1) --m3
predict(m3,5)
```

```
##   meanForecast  meanError standardDeviation
## 1 0.0005977987 0.01515760        0.01515760
## 2 0.0005977987 0.01524072        0.01524072
## 3 0.0005977987 0.01532280        0.01532280
```

```
## 4 0.0005977987 0.01540384        0.01540384
## 5 0.0005977987 0.01548387        0.01548387
```

```
#1g 95% interval prediction
```

1-step: [0.000598-1.96(0.01516), 0.000598+1.96(0.01516)] = [-0.0291, 0.0303]
2-step: [0.000598-1.96(0.01524), 0.000598+1.96(0.01524)] = [-0.0293, 0.0305]
3-step: [0.000598-1.96(0.01532), 0.000598+1.96(0.01532)] = [-0.0294, 0.0306]
4-step: [0.000598-1.96(0.01540), 0.000598+1.96(0.01540)] = [-0.0296, 0.0308]
5-step: [0.000598-1.96(0.01548), 0.000598+1.96(0.01548)] = [-0.0297, 0.0309]

```
#Question 2
da=read.table("m-kovw-5116.txt",header=T)
rt_ko = da[,3]
logrt_ko = log(1+rt_ko)

#2a

t.test(logrt_ko)

##
##  One Sample t-test
##
## data:  logrt_ko
## t = 4.9853, df = 779, p-value = 7.628e-07
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.00625636 0.01438347
## sample estimates:
##  mean of x
## 0.01031992
```

Mean of log return series is equal to zero according to t-test. P-value is less than 0.05 meaning that we cannot reject H0: mean = 0.

```
Box.test(logrt_ko, lag = 15, type = "Ljung")

##
##  Box-Ljung test
##
## data:  logrt_ko
## X-squared = 24.998, df = 15, p-value = 0.04997
```

Since p-value is less than 0.05(critical value), we reject H0: there is no serial correlation in the data. So, there is serial correlation in log return series.

```
#2b
m4 = garchFit(~arma(1,0)+garch(1,1),data = logrt_ko,include.mean = F,trace =
F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m4)
```

```
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 1), data = logrt_ko,
##     include.mean = F, trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 1)
## <environment: 0x0000000019113338>
##  [data = logrt_ko]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##        ar1       omega      alpha1       beta1
## 0.02082733  0.00019921  0.09207165  0.84792495
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## ar1    2.083e-02   3.878e-02    0.537  0.59124
## omega  1.992e-04   6.516e-05    3.057  0.00223 **
## alpha1 9.207e-02   1.908e-02    4.826  1.4e-06 ***
## beta1  8.479e-01   2.941e-02   28.836  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1153.42    normalized:  1.478744
##
## Description:
##  Thu Apr 29 08:26:17 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  132.9782  0
##  Shapiro-Wilk Test  R    W      0.9829456 6.88982e-08
##  Ljung-Box Test     R    Q(10)  7.876696  0.6408798
##  Ljung-Box Test     R    Q(15)  20.76337  0.1445616
##  Ljung-Box Test     R    Q(20)  25.62025  0.1787234
##  Ljung-Box Test     R^2  Q(10)  13.33177  0.2057091
##  Ljung-Box Test     R^2  Q(15)  14.23619  0.5076968
##  Ljung-Box Test     R^2  Q(20)  16.80256  0.6657545
##  LM Arch Test       R    TR^2   11.59286  0.4789064
```

```
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -2.947231 -2.923337 -2.947283 -2.938041
```

The model is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correlation among residual term and squared residuals.

Fitted model:

$$r_t = \underset{(3.878e-02)}{(2.083e-02)} r_{t-1}$$

$$\sigma_t^2 = \underset{(6.516e-05)}{1.992e-04} + \underset{(1.908e-02)}{(9.207e-02)} a_{t-1}^2 + \underset{(2.941e-02)}{(8.479e-01)} \sigma_{t-1}^2$$

```
#2c
m5 = garchFit(~arma(1,0)+garch(1,1),data = logrt_ko,cond.dist = "std",trace =
F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m5)
```

```
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 1), data = logrt_ko,
##     cond.dist = "std", trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 1)
## <environment: 0x000000001f7f7b70>
##  [data = logrt_ko]
##
## Conditional Distribution:
##  std
##
## Coefficient(s):
##          mu          ar1        omega       alpha1        beta1         sha
pe
##  0.01124020  -0.01887601   0.00017395   0.09642927   0.85044151   7.478777
80
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
```

```
##          Estimate  Std. Error  t value Pr(>|t|)
## mu      1.124e-02   1.810e-03    6.211 5.27e-10 ***
## ar1    -1.888e-02   3.691e-02   -0.511  0.60904
## omega   1.739e-04   6.596e-05    2.637  0.00836 **
## alpha1  9.643e-02   2.338e-02    4.124 3.72e-05 ***
## beta1   8.504e-01   3.267e-02   26.028  < 2e-16 ***
## shape   7.479e+00   1.840e+00    4.066 4.79e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1184.863    normalized:  1.519055
##
## Description:
##  Thu Apr 29 08:26:17 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  93.6433   0
##  Shapiro-Wilk Test  R    W      0.9857385 6.832848e-07
##  Ljung-Box Test     R    Q(10)  8.966733  0.5352637
##  Ljung-Box Test     R    Q(15)  22.44818  0.09657967
##  Ljung-Box Test     R    Q(20)  26.86769  0.1390276
##  Ljung-Box Test     R^2  Q(10)  12.48941  0.2536355
##  Ljung-Box Test     R^2  Q(15)  13.37442  0.5734021
##  Ljung-Box Test     R^2  Q(20)  14.90709  0.7816987
##  LM Arch Test       R    TR^2   10.48089  0.5738501
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.022725 -2.986885 -3.022843 -3.008941
```

The model is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correlation among residual term and squared residuals.

Fitted model:

$$r_t = \underset{(3.691e-02)}{(-1.888e-02)} r_{t-1}$$

$$\sigma_t^2 = \underset{(6.596e-05)}{(1.739e-04)} + \underset{(2.338e-02)}{(0.09643)} a_{t-1}^2 + \underset{(3.267e-02)}{(0.8504)} \sigma_{t-1}^2$$

```
#2d
m6 = garchFit(~garch(1,1), data = logrt_ko,trace = F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m6)

##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~garch(1, 1), data = logrt_ko, trace = F)
##
## Mean and Variance Equation:
##  data ~ garch(1, 1)
## <environment: 0x00000000214b7190>
##  [data = logrt_ko]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##         mu       omega      alpha1       beta1
## 0.01098417  0.00018497  0.09479925  0.84780406
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     1.098e-02   1.846e-03    5.950 2.68e-09 ***
## omega  1.850e-04   5.899e-05    3.135  0.00172 **
## alpha1 9.480e-02   1.912e-02    4.958 7.11e-07 ***
## beta1  8.478e-01   2.787e-02   30.416  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1170.393    normalized:  1.500504
##
## Description:
##  Thu Apr 29 08:26:17 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  95.07163  0
##  Shapiro-Wilk Test  R    W      0.9856773 6.481596e-07
##  Ljung-Box Test     R    Q(10)  8.125181  0.6166108
##  Ljung-Box Test     R    Q(15)  21.27199  0.128362
##  Ljung-Box Test     R    Q(20)  25.62765  0.1784646
##  Ljung-Box Test     R^2  Q(10)  12.90586  0.228983
##  Ljung-Box Test     R^2  Q(15)  13.87463  0.5350581
##  Ljung-Box Test     R^2  Q(20)  15.35522  0.755734
```

```
##  LM Arch Test       R    TR^2   10.96004  0.532346
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -2.990752 -2.966858 -2.990804 -2.981562
```

The model GARCH(1,1) under Gaussian innovation is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correla tion among residual term and squared residuals.

Fitted model: $\sigma_t^2 = \underset{(5.899e-05)}{1.850e-04} + \underset{(1.912e-02)}{0.0948}\, a_{t-1}^2 + \underset{(2.787e-02)}{0.8478}\, \sigma_{t-1}^2$

```
#2e
m7 = garchFit(~garch(1,1), data = logrt_ko,cond.dist = "std",trace = F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m7)
```

```
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~garch(1, 1), data = logrt_ko, cond.dist = "std",
##     trace = F)
##
## Mean and Variance Equation:
##  data ~ garch(1, 1)
## <environment: 0x0000000017f91290>
##  [data = logrt_ko]
##
## Conditional Distribution:
##  std
##
## Coefficient(s):
##         mu       omega      alpha1       beta1       shape
## 0.01105016  0.00017528  0.09632874  0.85006800  7.48604505
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     1.105e-02   1.757e-03    6.291 3.16e-10 ***
## omega  1.753e-04   6.627e-05    2.645  0.00817 **
## alpha1 9.633e-02   2.337e-02    4.123 3.75e-05 ***
```

```
## beta1  8.501e-01   3.277e-02   25.941  < 2e-16 ***
## shape  7.486e+00   1.840e+00    4.069 4.72e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1184.68    normalized:  1.518821
##
## Description:
##  Thu Apr 29 08:26:17 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  95.31715  0
##  Shapiro-Wilk Test  R    W      0.9857263 6.761141e-07
##  Ljung-Box Test     R    Q(10)  8.228765  0.6065024
##  Ljung-Box Test     R    Q(15)  21.34759  0.1260864
##  Ljung-Box Test     R    Q(20)  25.67699  0.1767469
##  Ljung-Box Test     R^2  Q(10)  12.61146  0.2462139
##  Ljung-Box Test     R^2  Q(15)  13.4693   0.5660982
##  Ljung-Box Test     R^2  Q(20)  14.93694  0.7800047
##  LM Arch Test       R    TR^2   10.62989  0.560875
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.024822 -2.994954 -3.024903 -3.013334
```

The model GARCH(1,1) is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correlation among residual term and squared residuals.

Fitted model: $\sigma_t^2 = \underset{(6.627e-05)}{0.00017528} + \underset{(0.02337)}{0.09630}\, a_{t-1}^2 + \underset{(0.03277)}{0.850}\, \sigma_{t-1}^2$

```
#2f
```

I will choose the model in (e) since it gives the lowest number of AIC which indicates that it is the most suitable model.

```
#Question 3
getSymbols("^GSPC",from="2005-01-02",to="2021-03-31")

## [1] "^GSPC"

rt = diff(log(as.numeric(GSPC[,6])))
#3a
t.test(rt)

##
##  One Sample t-test
```

Mean of log return series is not equal to zero according to t-test. P-value is larger than 0.05 meaning that we can reject H0: mean = 0.

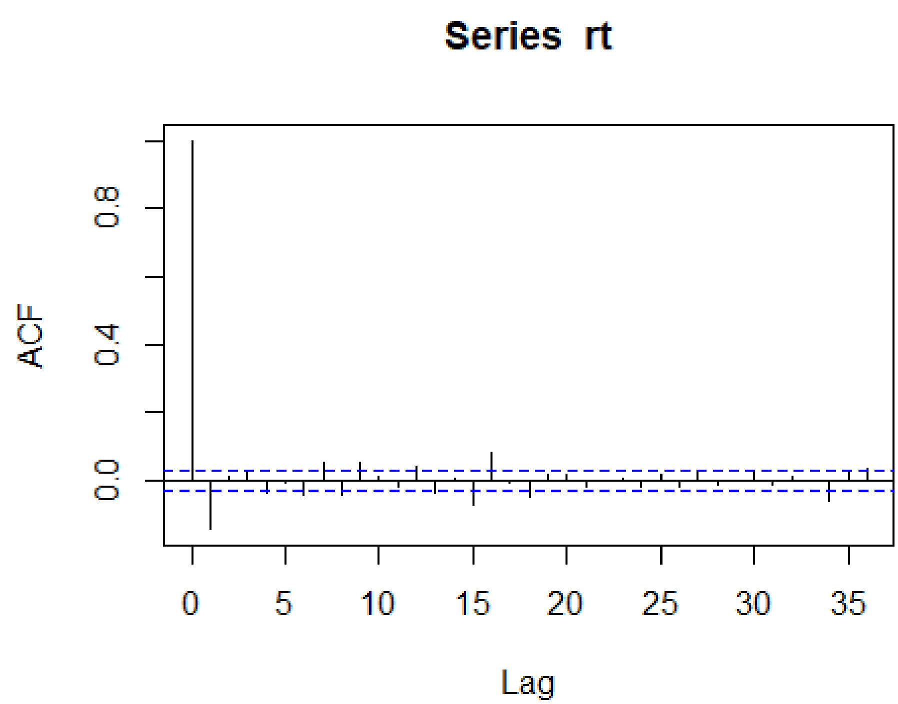
```
##
## data:  rt
## t = 1.4961, df = 4086, p-value = 0.1347
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -9.051939e-05  6.737464e-04
## sample estimates:
##    mean of x
## 0.0002916135
```

Since p-value is less than 0.05(critical value), we reject H0: there is no serial correlation in the data. So, there is serial correlation in log return series.

```
Box.test(rt, lag=12,type="Ljung")
```

```
##
##  Box-Ljung test
##
## data:  rt
## X-squared = 139.3, df = 12, p-value < 2.2e-16
```

```
acf(rt)
```



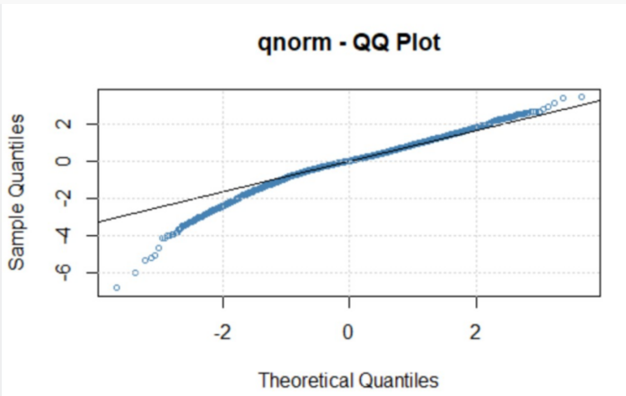

```
#3b
m13 = garchFit(~arma(2,0)+garch(1,1),data=rt,trace=F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m13)
```

```
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(2, 0) + garch(1, 1), data = rt, trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(2, 0) + garch(1, 1)
## <environment: 0x000000001f3ffbf8>
##  [data = rt]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##          mu          ar1          ar2        omega       alpha1        bet
a1
##  7.5186e-04  -7.6476e-02  -1.2861e-02   2.7177e-06   1.4176e-01   8.3745e-
01
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##          Estimate  Std. Error  t value Pr(>|t|)
## mu      7.519e-04   1.187e-04    6.337 2.35e-10 ***
## ar1    -7.648e-02   1.736e-02   -4.405 1.06e-05 ***
## ar2    -1.286e-02   1.703e-02   -0.755     0.45
## omega   2.718e-06   3.504e-07    7.756 8.66e-15 ***
## alpha1  1.418e-01   1.201e-02   11.802  < 2e-16 ***
## beta1   8.374e-01   1.195e-02   70.064  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  13428.63    normalized:  3.285694
##
## Description:
##  Thu Apr 29 13:49:56 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  1140.917  0
##  Shapiro-Wilk Test  R    W      0.9715901 0
##  Ljung-Box Test     R    Q(10)  17.77739  0.05883683
##  Ljung-Box Test     R    Q(15)  25.98913  0.03813713
##  Ljung-Box Test     R    Q(20)  31.54829  0.04835578
##  Ljung-Box Test     R^2  Q(10)  16.04715  0.09829068
```

```
##  Ljung-Box Test     R^2  Q(15)  18.28693  0.2478816
##  Ljung-Box Test     R^2  Q(20)  19.68465  0.4778056
##  LM Arch Test       R    TR^2   16.81055  0.156864
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -6.568452 -6.559180 -6.568456 -6.565169
```



The model is inadequate. According to standardized residual test, one of the computed p-value is less than 0.05 which means that there still be serial correlation in residuals.

Fitted model:

$$r_t = \underset{(0.001736)}{-0.007648}\, r_{t-1} \underset{(0.001703)}{-0.01286}\, r_{t-2}$$

$$\sigma_t^2 = \underset{(3.504e-07)}{2.718e-06} + \underset{(1.201e-02)}{0.1418}\, a_{t-1}^2 + \underset{(1.195e-02)}{0.8374}\, \sigma_{t-1}^2$$

```
#3c
m14 = garchFit(~arma(2,0)+garch(1,1),data=rt, cond.dist = "std", trace = F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m14)

##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(2, 0) + garch(1, 1), data = rt, cond.dist = "std
",
##     trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(2, 0) + garch(1, 1)
## <environment: 0x000000001f01c5f0>
##  [data = rt]
##
## Conditional Distribution:
```

```
##  std
##
## Coefficient(s):
##          mu          ar1          ar2        omega       alpha1        bet
a1
##  9.4148e-04  -7.1765e-02  -2.3816e-02   1.6919e-06   1.4127e-01   8.5671e-
01
##       shape
##  5.0636e+00
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##          Estimate  Std. Error  t value Pr(>|t|)
## mu      9.415e-04   1.077e-04    8.742  < 2e-16 ***
## ar1    -7.176e-02   1.575e-02   -4.558 5.18e-06 ***
## ar2    -2.382e-02   1.601e-02   -1.487    0.137
## omega   1.692e-06   3.620e-07    4.674 2.95e-06 ***
## alpha1  1.413e-01   1.460e-02    9.679  < 2e-16 ***
## beta1   8.567e-01   1.283e-02   66.778  < 2e-16 ***
## shape   5.064e+00   4.257e-01   11.894  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  13564.81    normalized:  3.319014
##
## Description:
##  Thu Apr 29 13:49:57 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  1452.851  0
##  Shapiro-Wilk Test  R    W      0.9691759 0
##  Ljung-Box Test     R    Q(10)  18.55203  0.04633557
##  Ljung-Box Test     R    Q(15)  26.72239  0.03108129
##  Ljung-Box Test     R    Q(20)  31.89353  0.0444461
##  Ljung-Box Test     R^2  Q(10)  13.10229  0.2180087
##  Ljung-Box Test     R^2  Q(15)  17.71551  0.2779175
##  Ljung-Box Test     R^2  Q(20)  20.48015  0.428277
##  LM Arch Test       R    TR^2   14.71893  0.2571685
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -6.634602 -6.623786 -6.634608 -6.630772
```

The model is inadequate. According to standardized residual test, one of the computed p-va lue is less than 0.05 which means that there still be serial correlation in residuals.

Fitted model:

$$r_t = (-7.176e\text{-}02)\, r_{t-1} + (-2.382e\text{-}02)\, r_{t-2}$$
$$\qquad (1.575e\text{-}02) \qquad\qquad (1.601e\text{-}02)$$

$$\sigma_t^2 = 1.692e\text{-}06 + 0.1413\, a_{t-1}^2 + 0.8567\, \sigma_{t-1}^2$$
$$\qquad (3.62e\text{-}07) \qquad (1.46e\text{-}02) \qquad (1.283e\text{-}02)$$

```
#3d
predict(m14,5)

##   meanForecast   meanError standardDeviation
## 1 0.0011891361 0.008985692       0.008985692
## 2 0.0009314628 0.009093242       0.009070348
## 3 0.0008463096 0.009178700       0.009154053
## 4 0.0008585573 0.009261720       0.009236833
## 5 0.0008597063 0.009343829       0.009318712

#Question 4
da2 = read.table("m-deciles.txt",header = TRUE)
crsp = da2[,10]
logreturn_crsp = log(1+crsp)
#4a
t.test(logreturn_crsp)

##
##  One Sample t-test
##
## data:  logreturn_crsp
## t = 5.1808, df = 719, p-value = 2.873e-07
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.005946562 0.013203545
## sample estimates:
##   mean of x
## 0.009575054
```

Mean of log return series is equal to zero according to t-test. P-value is less than 0.05 meaning that we cannot reject H0: mean = 0.

```
Box.test(logreturn_crsp, lag=12, type = 'Ljung')
##
##    Box-Ljung test
##
## data:  logreturn_crsp
## X-squared = 24.768, df = 12, p-value = 0.01596
```

Since p-value is less than 0.05(critical value), we reject H0: there is no serial correlation in the data. So, there is serial correlation in log return series.

```
#4b ARCH effect

Box.test(logreturn_crsp^2, lag = 12, type='Ljung')

##
##    Box-Ljung test
##
## data:  logreturn_crsp^2
## X-squared = 20.605, df = 12, p-value = 0.05648
```

There is no ARCH effect in this log return series since `p-value is larger than 0.05.`

```
#4c
m9 = garchFit(~arma(1,0)+garch(1,0),data = logreturn_crsp, trace=F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m9)

##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 0), data = logreturn_crsp,
##     trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 0)
## <environment: 0x00000000207e2288>
##  [data = logreturn_crsp]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##       mu       ar1     omega    alpha1
## 0.01053  0.14707  0.00200  0.18152
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     0.0105300   0.0019275    5.463 4.68e-08 ***
## ar1    0.1470670   0.0424301    3.466 0.000528 ***
## omega  0.0020000   0.0001482   13.493  < 2e-16 ***
## alpha1 0.1815182   0.0651142    2.788 0.005309 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1158.628    normalized:  1.609206
##
## Description:
##  Thu Apr 29 08:26:18 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
```

```
##                                    Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  647.6357  0
##  Shapiro-Wilk Test  R    W      0.962804  1.502752e-12
##  Ljung-Box Test     R    Q(10)  8.582995  0.572082
##  Ljung-Box Test     R    Q(15)  12.95811  0.6055337
##  Ljung-Box Test     R    Q(20)  15.77362  0.7305655
##  Ljung-Box Test     R^2  Q(10)  8.153476  0.6138486
##  Ljung-Box Test     R^2  Q(15)  12.29206  0.6568012
##  Ljung-Box Test     R^2  Q(20)  13.57787  0.851238
##  LM Arch Test       R    TR^2   8.24593   0.7656286
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.207301 -3.181861 -3.207363 -3.197480
```

The model is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correlation among residual term and squared residuals.

Fitted model: $r_t = \underset{(0.0424)}{0.147} r_{t-1}$

$$\sigma_t^2 = \underset{(0.00014)}{0.002} + \underset{(0.065)}{0.1815} a_{t-1}^2$$

```
#4d
m10 = garchFit(~arma(1,0)+garch(1,0),data = logreturn_crsp, cond.dist = "std"
,trace=F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m10)

##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~arma(1, 0) + garch(1, 0), data = logreturn_crsp,
##     cond.dist = "std", trace = F)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 0)
## <environment: 0x0000000021947020>
##  [data = logreturn_crsp]
##
## Conditional Distribution:
##  std
##
```

```
## Coefficient(s):
##        mu        ar1      omega     alpha1      shape
## 0.0116189  0.1076982  0.0019203  0.1900830  6.4225253
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     0.0116189   0.0017710    6.561 5.35e-11 ***
## ar1    0.1076982   0.0403169    2.671  0.00756 **
## omega  0.0019203   0.0001818   10.564  < 2e-16 ***
## alpha1 0.1900830   0.0713692    2.663  0.00774 **
## shape  6.4225253   1.3115905    4.897 9.74e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1187.516    normalized:  1.649328
##
## Description:
##  Thu Apr 29 08:26:18 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  680.4834  0
##  Shapiro-Wilk Test  R    W      0.9612945 7.49198e-13
##  Ljung-Box Test     R    Q(10)  9.486455  0.4866411
##  Ljung-Box Test     R    Q(15)  13.8214   0.5391158
##  Ljung-Box Test     R    Q(20)  17.0087   0.6524086
##  Ljung-Box Test     R^2  Q(10)  7.567444  0.671006
##  Ljung-Box Test     R^2  Q(15)  11.42176  0.7221637
##  Ljung-Box Test     R^2  Q(20)  12.79422  0.8860373
##  LM Arch Test       R    TR^2   7.723697  0.8063327
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.284768 -3.252967 -3.284863 -3.272491
```

The model is adequate. According to standardized residual test, all computed p-value exceeds 0.05 which means that there is no serial correlation among residual term and squared residuals.

Fitted model: $r_t = \underset{(0.0403)}{0.108} r_{t-1}$

$$\sigma_t^2 = \underset{(0.00018)}{0.0019203} + \underset{(0.0713)}{0.19} a_{t-1}$$

```r
#4e
m11 = garchFit(~garch(1,0),data = logreturn_crsp,trace=F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.
```

```r
summary(m11)
```

```
##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~garch(1, 0), data = logreturn_crsp, trace = F)
##
## Mean and Variance Equation:
##  data ~ garch(1, 0)
## <environment: 0x000000001f1f29c8>
##  [data = logreturn_crsp]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##       mu     omega    alpha1
## 0.012346  0.002016  0.194126
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu      0.012346    0.001923    6.421 1.35e-10 ***
## omega   0.002016    0.000145   13.900  < 2e-16 ***
## alpha1  0.194126    0.062209    3.121  0.00181 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1152.289    normalized:  1.600401
##
## Description:
##  Thu Apr 29 08:26:18 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  746.8024  0
##  Shapiro-Wilk Test  R    W      0.9570702 1.171061e-13
```

```
##  Ljung-Box Test     R    Q(10)  18.72223  0.04393591
##  Ljung-Box Test     R    Q(15)  23.27998  0.07837365
##  Ljung-Box Test     R    Q(20)  27.61004  0.1189566
##  Ljung-Box Test     R^2  Q(10)  7.012055  0.7243064
##  Ljung-Box Test     R^2  Q(15)  10.3604   0.7964784
##  Ljung-Box Test     R^2  Q(20)  11.97825  0.9168225
##  LM Arch Test       R    TR^2   7.047101  0.8544853
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.192468 -3.173388 -3.192503 -3.185102
```

The model is inadequate. According to standardized residual test, one of the computed p-value is less than 0.05 which means that there still be serial correlation in residuals.

Fitted model: $\sigma_t^2 = \underset{(0.000745)}{0.002} + \underset{(0.0622)}{0.1941}\, a_{t-1}^2$

```
#4f
m12 = garchFit(~garch(1,0),data = logreturn_crsp, cond.dist = "std",trace=F)

## Warning: Using formula(x) is deprecated when x is a character vector of le
ngth > 1.
##   Consider formula(paste(x, collapse = " ")) instead.

summary(m12)

##
## Title:
##  GARCH Modelling
##
## Call:
##  garchFit(formula = ~garch(1, 0), data = logreturn_crsp, cond.dist = "std"
,
##     trace = F)
##
## Mean and Variance Equation:
##  data ~ garch(1, 0)
## <environment: 0x000000001fca0f48>
##  [data = logreturn_crsp]
##
## Conditional Distribution:
##  std
##
## Coefficient(s):
##       mu     omega    alpha1     shape
## 0.013356  0.001928  0.204163  6.220222
##
## Std. Errors:
##  based on Hessian
```

```
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu      0.013356    0.001685    7.927 2.22e-15 ***
## omega   0.001928    0.000185   10.421  < 2e-16 ***
## alpha1  0.204163    0.072375    2.821  0.00479 **
## shape   6.220223    1.236608    5.030 4.90e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  1183.349    normalized:  1.64354
##
## Description:
##  Thu Apr 29 08:26:18 2021 by user: Jidapa
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  746.3878  0
##  Shapiro-Wilk Test  R    W      0.9574271 1.363165e-13
##  Ljung-Box Test     R    Q(10)  18.51406  0.04688705
##  Ljung-Box Test     R    Q(15)  22.99926  0.08415548
##  Ljung-Box Test     R    Q(20)  27.3947   0.1245202
##  Ljung-Box Test     R^2  Q(10)  6.667871  0.7563837
##  Ljung-Box Test     R^2  Q(15)  10.0157   0.8187514
##  Ljung-Box Test     R^2  Q(20)  11.63085  0.928196
##  LM Arch Test       R    TR^2   6.819315  0.8693193
##
## Information Criterion Statistics:
##       AIC       BIC       SIC      HQIC
## -3.275969 -3.250529 -3.276031 -3.266148
```

The model is inadequate. According to standardized residual test, one of the p-value is less than 0.05 which means that there is serial correlation left in the residual terms when consi dering 10 lags.

Fitted model: $\sigma_t^2 = \underset{(0.00018)}{0.0019} + \underset{(0.0723)}{0.204}\, a_{t-1}^2$

#4g

I will select model in (d) which is arma(1, 0) + garch(1, 0) with standardized student t-distr ibution because based on AIC criteria, it gives the lowest AIC.