

EE-435-assignment-5.R

Windows 10

2021-04-29

#EE435 Kittinan Prasertgrueang 6004641699 #Assignment5
setwd("C:/Users/Windows 10/Desktop/homework 5 ee435")

```
library(timeDate)
library(timeSeries)
library(fGarch)
```

```
## Warning: package 'fGarch' was built under R version 4.0.5
```

```
## Loading required package: fBasics
```

```
## Warning: package 'fBasics' was built under R version 4.0.5
```

```
library(quantmod)
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 4.0.5
```

```
## Loading required package: zoo
```

```
## Warning: package 'zoo' was built under R version 4.0.5
```

```
##
```

```
## Attaching package: 'zoo'
```

```
## The following object is masked from 'package:timeSeries':
```

```
##
```

```
##   time<-
```

```
## The following objects are masked from 'package:base':
```

```
##
```

```
##   as.Date, as.Date.numeric
```

```
## Loading required package: TTR
```

```
##
```

```
## Attaching package: 'TTR'
```

```
## The following object is masked from 'package:fBasics':
```

```
##
```

```
##   volatility
```

```
## Registered S3 method overwritten by 'quantmod':
```

```
##   method      from
```

```
##   as.zoo.data.frame zoo
```

```
cat(rep("\n",50))
```

```
getSymbols("CAT",from="2006-01-03",to="2017-04-14")
```

```
## 'getSymbols' currently uses auto.assign=TRUE by default, but will
## use auto.assign=FALSE in 0.5-0. You will still be able to use
## 'loadSymbols' to automatically load data. getOption("getSymbols.env")
## and getOption("getSymbols.auto.assign") will still be checked for
## alternate defaults.
##
## This message is shown once per session and may be disabled by setting
## options("getSymbols.warning4.0"=FALSE). See ?getSymbols for details.
```

```
## [1] "CAT"
```

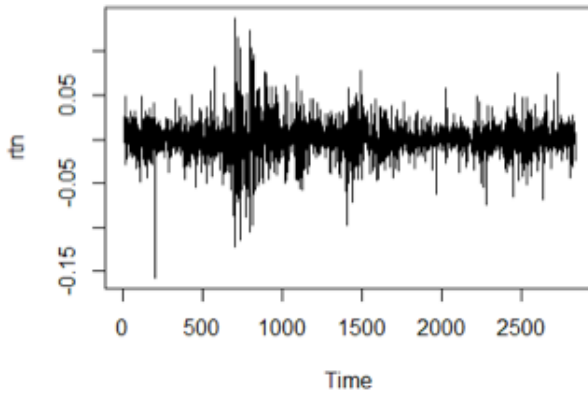
```
head(CAT)
```

```
##      CAT.Open CAT.High CAT.Low CAT.Close CAT.Volume CAT.Adjusted
## 2006-01-03  57.87  58.11  57.05  57.80  3697500  38.08682
## 2006-01-04  57.95  59.43  57.55  59.27  4577200  39.05544
## 2006-01-05  59.02  59.86  59.00  59.27  4590700  39.05544
## 2006-01-06  59.47  60.76  59.38  60.45  5692300  39.83300
## 2006-01-09  60.45  61.68  60.45  61.55  4408800  40.55783
## 2006-01-10  61.35  61.52  60.64  61.30  3188100  40.39312
```

```
tail(CAT)
```

```
##      CAT.Open CAT.High CAT.Low CAT.Close CAT.Volume CAT.Adjusted
## 2017-04-06  94.42  96.42  94.26  95.82  5421600  85.75500
## 2017-04-07  95.87  96.62  95.42  95.52  4463800  85.48653
## 2017-04-10  96.31  97.89  96.10  97.14  5168300  86.93636
## 2017-04-11  97.30  97.31  95.67  97.10  4250400  86.90057
## 2017-04-12  96.69  96.77  94.66  94.86  4773900  84.89585
## 2017-04-13  94.60  94.86  93.09  93.10  4706000  83.32072
```

```
rtn =diff(log(as.numeric(CAT[,6])))
ts.plot(rtn)
```



```
Box.test(rtn,lag=10,type="Ljung")
```

```
##
## Box-Ljung test
##
## data: rtn
## X-squared = 16.229, df = 10, p-value = 0.09325
```

```
t.test(rtn)
```

```
##
## One Sample t-test
##
## data: rtn
## t = 0.7159, df = 2838, p-value = 0.4741
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -0.0004794893 0.0010309714
## sample estimates:
## mean of x
## 0.0002757411
```

```
Box.test(rtn^2,lag=10,type="Ljung")
```

```
##
## Box-Ljung test
##
## data: rtn^2
## X-squared = 917.58, df = 10, p-value < 2.2e-16
```

```
m1 = garchFit(formula = ~garch(1,1),data=rtn,trace=F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of length > 1.
```

a) No, the Ljung box statistic give $Q(10) = 16.229$ with p-value 0.093

b) Yes, the Ljung box of r_t^2 give $Q(10) = 917.58$ with p-value close to 0

```
## Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m1)
```

```
##
```

```
## Title:
```

```
## GARCH Modelling
```

```
##
```

```
## Call:
```

```
## garchFit(formula = ~garch(1, 1), data = rtn, trace = F)
```

```
##
```

```
## Mean and Variance Equation:
```

```
## data ~ garch(1, 1)
```

```
## <environment: 0x00000000154dab20>
```

```
## [data = rtn]
```

```
##
```

```
## Conditional Distribution:
```

```
## norm
```

```
##
```

```
## Coefficient(s):
```

```
## mu omega alpha1 beta1
```

```
## 4.9258e-04 4.4243e-06 4.9485e-02 9.3903e-01
```

```
##
```

```
## Std. Errors:
```

```
## based on Hessian
```

```
##
```

```
## Error Analysis:
```

```
## Estimate Std. Error t value Pr(>|t|)
```

```
## mu 4.926e-04 3.075e-04 1.602 0.109167
```

```
## omega 4.424e-06 1.259e-06 3.514 0.000441 ***
```

```
## alpha1 4.949e-02 8.096e-03 6.112 9.83e-10 ***
```

```
## beta1 9.390e-01 1.016e-02 92.407 < 2e-16 ***
```

```
## ---
```

```
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Log Likelihood:
```

```
## 7379.812 normalized: 2.599441
```

```
##
```

```
## Description:
```

```
## Thu Apr 29 13:29:42 2021 by user: Windows 10
```

```
##
```

```
##
```

```
## Standardised Residuals Tests:
```

```
##
```

```
Statistic p-Value
```

```
## Jarque-Bera Test R Chi^2 3249.183 0
```

```
## Shapiro-Wilk Test R W 0.9666933 0
```

```
## Ljung-Box Test R Q(10) 13.769 0.1837915
```

```
## Ljung-Box Test R Q(15) 16.04338 0.3791746
```

```
## Ljung-Box Test R Q(20) 20.59485 0.4213143
```

```
## Ljung-Box Test R^2 Q(10) 1.013167 0.9998172
```

```
## Ljung-Box Test R^2 Q(15) 3.722275 0.9985142
```

```
## Ljung-Box Test R^2 Q(20) 7.0086 0.9966568
```

```
## LM Arch Test R TR^2 2.756883 0.9970306
```

```
##
```

Mean equation $\rightarrow$

$$\hat{r}_t = 4.9258 \times 10^{-4} + (3.075 \times 10^{-4}) \varepsilon_t, \quad \varepsilon_t \stackrel{iid}{\sim} N(0, 1)$$

Volatility equation

$$\sigma_t^2 = 4.424 \times 10^{-6} + 0.04949 \varepsilon_t^2 + 0.93956 \sigma_{t-1}^2$$
$$(1.259 \times 10^{-6}) \quad (0.000441) \quad (0.010)$$

```
## Information Criterion Statistics:
##   AIC   BIC   SIC   HQIC
## -5.196063 -5.187679 -5.196067 -5.193039
```

cannot run this garchfit

```
m2 = garchFit(formula = ~garch(1,1),data=rtn,cond.dist="std",trace=F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of length > 1.
```

```
## Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m2)
```

```
##
```

```
## Title:
```

```
## GARCH Modelling
```

```
##
```

```
## Call:
```

```
## garchFit(formula = ~garch(1, 1), data = rtn, cond.dist = "std",
## trace = F)
```

```
##
```

```
## Mean and Variance Equation:
```

```
## data ~ garch(1, 1)
```

```
## <environment: 0x0000000017bcd450>
```

```
## [data = rtn]
```

```
##
```

```
## Conditional Distribution:
```

```
## std
```

```
##
```

```
## Coefficient(s):
```

```
## mu omega alpha1 beta1 shape
## 5.9008e-04 4.2138e-06 7.2389e-02 9.2028e-01 5.1049e+00
```

```
##
```

```
## Std. Errors:
```

```
## based on Hessian
```

```
##
```

```
## Error Analysis:
```

```
## Estimate Std. Error t value Pr(>|t|)
```

```
## mu 5.901e-04 2.703e-04 2.183 0.02904 *
```

```
## omega 4.214e-06 1.574e-06 2.678 0.00741 **
```

```
## alpha1 7.239e-02 1.375e-02 5.265 1.4e-07 ***
```

```
## beta1 9.203e-01 1.474e-02 62.448 < 2e-16 ***
```

```
## shape 5.105e+00 4.839e-01 10.549 < 2e-16 ***
```

```
## ---
```

```
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Log Likelihood:
```

```
## 7509.292 normalized: 2.645048
```

```
##
```

```
## Description:
```

```
## Thu Apr 29 13:29:42 2021 by user: Windows 10
```

```
##
```

```
##
```

```
## Standardised Residuals Tests:
```

```
## Statistic p-Value
```

d) with QQ-plot the model is not adequate, the normality assumption is rejected

e) fitted model

$$\hat{\mu} = 5.90 \times 10^{-4}$$

$$(2.70 \times 10^{-4})$$

$$\hat{\omega} = 4.21 \times 10^{-6} + 0.072 \hat{\alpha}_1^2$$

$$(1.57 \times 10^{-6}) \quad (0.010)$$

$$+ 0.92 \hat{\beta}_1^2$$

$$(0.014)$$

```
## Jarque-Bera Test R Chi^2 4047.363 0
## Shapiro-Wilk Test R W 0.9639883 0
## Ljung-Box Test R Q(10) 14.87685 0.1366167
## Ljung-Box Test R Q(15) 16.83467 0.3288433
## Ljung-Box Test R Q(20) 20.67317 0.4165887
## Ljung-Box Test R^2 Q(10) 2.955969 0.9824413
## Ljung-Box Test R^2 Q(15) 5.488358 0.9871219
## Ljung-Box Test R^2 Q(20) 9.459063 0.9769545
## LM Arch Test R TR^2 4.275692 0.9779321
##
## Information Criterion Statistics:
## AIC BIC SIC HQIC
## -5.286574 -5.276093 -5.286580 -5.282793
```

```
pm2 = predict(m2,5)
pm2
```

```
## meanForecast meanError standardDeviation
## 1 0.0005900796 0.01557857 0.01557857
## 2 0.0005900796 0.01565654 0.01565654
## 3 0.0005900796 0.01573356 0.01573356
## 4 0.0005900796 0.01580965 0.01580965
## 5 0.0005900796 0.01588481 0.01588481
```

```
qstd(0.975,nu=5.1)
```

```
## [1] 1.992374
```

```
lcl = pm2$meanForecast-1.99*pm2$standardDeviation
ucl = pm2$meanForecast+1.99*pm2$standardDeviation
CI = cbind(lcl,ucl)
CI
```

```
## lcl ucl
## [1,] -0.03041128 0.03159144
## [2,] -0.03056644 0.03174660
## [3,] -0.03071971 0.03189987
## [4,] -0.03087112 0.03205128
## [5,] -0.03102070 0.03220086
```

#Question2

```
da = read.table("m-kovw-5116.txt",header=T)
dim(da)
```

```
## [1] 780 4
```

```
ko = log(da$ko+1)
t.test(ko)
```

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

```
## data: ko
## t = 4.9853, df = 779, p-value = 7.628e-07
## alternative hypothesis: true mean is not equal to 0
```

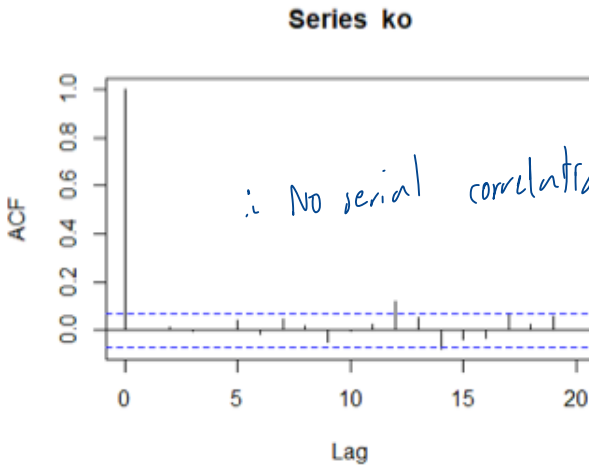
a) $H_0: E(r_f) = 0$
 $H_a: E(r_f) \neq 0$
 since p-value $\approx 7.62 \times 10^{-7}$
 which is nearly zero

```
## 95 percent confidence interval:
## 0.00625636 0.01438347
## sample estimates:
## mean of x
## 0.01031992
```

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

```
##
## Box-Ljung test
##
## data: ko
## X-squared = 17.06, df = 12, p-value = 0.1474
```

```
acf(ko,lag.max = 20)
```



```
at = ko-mean(ko)
Box.test(at^2,lag=12,type="Ljung")
##
## Box-Ljung test
##
## data: at^2
## X-squared = 255.99, df = 12, p-value < 2.2e-16
```

```
m1 = garchFit(~arma(1,0)+garch(1,1),data=ko,trace=F)
```

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

```
summary(m1)
```

```
##
## Title:
```

we can conclude that the expected return is different from zero. $E(r_t) \neq 0$

→ p-value = 0.1474
∴ No, there is no serial correlation in the returns

∴ No serial correlation shown in ACF

Mun equation

$$r_t = c_0 + a_t$$

$$\therefore a_t^2 = r_t - c_0$$

b) →

```
## GARCH Modelling
##
## Call:
## garchFit(formula = ~arma(1, 0) + garch(1, 1), data = ko, trace = F)
##
## Mean and Variance Equation:
## data ~ arma(1, 0) + garch(1, 1)
## <environment: 0x0000000023894678>
## [data = ko]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      ar1      omega      alpha1      beta1
## 0.01124544 -0.02633742 0.00018112 0.09535029 0.84861593
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      1.125e-02 1.897e-03 5.929 3.05e-09 ***
## ar1     -2.634e-02 3.881e-02 -0.679 0.49740
## omega   1.811e-04 5.852e-05 3.095 0.00197 **
## alpha1  9.535e-02 1.915e-02 4.978 6.42e-07 ***
## beta1   8.486e-01 2.766e-02 30.675 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1170.664 normalized: 1.500852
##
## Description:
## Thu Apr 29 13:29:43 2021 by user: Windows 10
##
## Standardised Residuals Tests:
##      Statistic p-Value
## Jarque-Bera Test R Chi^2 92.91946 0
## Shapiro-Wilk Test R W 0.9857081 6.655604e-07
## Ljung-Box Test R Q(10) 9.306169 0.5033144
## Ljung-Box Test R Q(15) 22.9901 0.0843502
## Ljung-Box Test R Q(20) 27.44814 0.1231201
## Ljung-Box Test R^2 Q(10) 12.63377 0.2448749
## Ljung-Box Test R^2 Q(15) 13.62088 0.5544545
## Ljung-Box Test R^2 Q(20) 15.19817 0.7649584
## LM Arch Test R TR^2 10.65102 0.5590389
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -2.988883 -2.959016 -2.988965 -2.977396
m2 = garchFit(~arma(1,0)+garch(1,1),data=ko,cond.dist="std",trace=F)
```

ARCH effect

H_0 : there is no ARCH effect

H_1 : there is ARCH effect

since p-value $\approx 2.2e-16$
(nearly zero) there is

ARCH effect at the
95% confident interval

← Ljung-Box test
mean and volatility equation

are adequate

but in the qq-plot,

the normality assumption is
violated, therefore model

is not adequate

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

summary(m2)

##

Title:

GARCH Modelling

##

Call:

garchFit(formula = ~arma(1, 0) + garch(1, 1), data = ko, cond.dist = "std",
 ## trace = F)

##

Mean and Variance Equation:

data ~ arma(1, 0) + garch(1, 1)

<environment: 0x000000002668b8d0>

[data = ko]

##

Conditional Distribution:

std

##

Coefficient(s):

mu	ar1	omega	alpha1	beta1	shape
0.01124020	-0.01887601	0.00017395	0.09642927	0.85044151	7.47877780

##

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 13:29:43 2021 by user: Windows 10

##

##

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

fitted model

mean eq. :
$$\hat{r}_t = 0.011 - 0.019 r_{t-1}$$

 (0.002) (0.037)

var :
$$\sigma_t^2 = \epsilon_t^2 \epsilon_t^2, \epsilon_t^2 \sim 7.479$$

$$\sigma_t^2 = 1.739 \times 10^{-4} + 0.096 a_{t-1}^2$$

 (0.051 $\times 10^{-4}$) (2.34 $\times 10^{-2}$)

$$+ 0.85 \sigma_{t-1}^2$$

 (7.27 $\times 10^{-2}$)

① ✓
 ② ✓

```
## 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
```

}
 ③ with QQ plot, the model seems to be adequate

```
m3 = garchFit(~garch(1,1),data=ko,trace=F)
```

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

```
summary(m3)
```

d) since the normality assumption is violated we can conclude that model is not adequate (qq-plot)

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 1), data = ko, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 1)
## <environment: 0x0000000019534db8>
## [data = 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 13:29:43 2021 by user: Windows 10
##
## 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
```

```
m4 = garchFit(~garch(1,1),data=ko,cond.dist="std",trace=F)
```

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

```
summary(m4)
```

(m4) model is adequate

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 1), data = ko, cond.dist = "std",
## trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 1)
## <environment: 0x0000000014eb9340>
## [data = 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:
```

*with m_1, m_2, m_3 and m_4
we will choose m_4 with BIC
criteria (smallest BIC) and
the model is adequate*

```
## 1184.68   normalized: 1.518821
##
## Description:
## Thu Apr 29 13:29:43 2021 by user: Windows 10
##
## 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
```

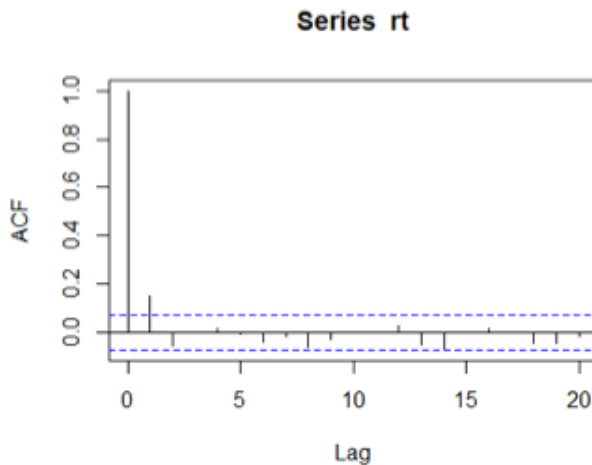
#Question 4

```
da=read.table("m-deciles.txt",header=T)
```

```
simple_return = da$CAP9RET
```

```
rt=log(1+simple_return)
```

```
acf(rt,lag.max = 20)
```



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

```

##
## Box-Ljung test
##
## data: rt
## X-squared = 24.768, df = 12, p-value = 0.01596

at = rt-mean(rt)
Box.test(at^2,lag=10,type="Ljung")

##
## Box-Ljung test
##
## data: at^2
## X-squared = 20.53, df = 10, p-value = 0.02462

m1 = garchFit(~arma(1,0)+garch(1,0),data=rt,trace=F)

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

summary(m1)

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~arma(1, 0) + garch(1, 0), data = rt, trace = F)
##
## Mean and Variance Equation:
## data ~ arma(1, 0) + garch(1, 0)
## <environment: 0x0000000025735dc0>
## [data = rt]
##
## 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 13:29:43 2021 by user: Windows 10
##
##
## 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

m2 = garchFit(~arma(1,0)+garch(1,0),data=rt,cond.dist="std",trace=F)

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

summary(m2)

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~arma(1, 0) + garch(1, 0), data = rt, cond.dist = "std",
## trace = F)
##
## Mean and Variance Equation:
## data ~ arma(1, 0) + garch(1, 0)
## <environment: 0x0000000026c337a0>
## [data = rt]
##
## 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 13:29:43 2021 by user: Windows 10
##
##
## 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
```

```
m3 = garchFit(formula = ~garch(1,0),data=rt,trace=F)
```

```
## Warning: Using formula(x) is deprecated when x is a character vector of length > 1.
```

```
## Consider formula(paste(x, collapse = " ")) instead.
```

```
summary(m3)
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 0), data = rt, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 0)
## <environment: 0x000000001951ba60>
## [data = rt]
##
## 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 13:29:43 2021 by user: Windows 10
##
##
## 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

m4 = garchFit(formula = ~garch(1,1),data=rt,cond.dist="std",trace=F)

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

summary(m4)

##
## 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: 0x0000000017adb020>
## [data = rt]
##
## Conditional Distribution:

```

```

## std
##
## Coefficient(s):
##      mu      omega      alpha1      beta1      shape
## 0.01253321 0.00013013 0.11435407 0.83665662 6.46000315
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      1.253e-02 1.538e-03  8.150 4.44e-16 ***
## omega   1.301e-04 5.817e-05  2.237 0.02528 *
## alpha1  1.144e-01 3.494e-02  3.273 0.00107 **
## beta1   8.367e-01 4.591e-02 18.225 < 2e-16 ***
## shape   6.460e+00 1.315e+00  4.913 8.97e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1201.367 normalized: 1.668565
##
## Description:
## Thu Apr 29 13:29:43 2021 by user: Windows 10
##
##
## Standardised Residuals Tests:
##              Statistic p-Value
## Jarque-Bera Test R  Chi^2 1171.213 0
## Shapiro-Wilk Test R  W    0.9457868 1.420853e-15
## Ljung-Box Test R    Q(10) 16.52228 0.08562605
## Ljung-Box Test R    Q(15) 20.6328 0.1489773
## Ljung-Box Test R    Q(20) 25.48915 0.183354
## Ljung-Box Test R^2 Q(10) 2.235555 0.9941952
## Ljung-Box Test R^2 Q(15) 4.909806 0.9928629
## Ljung-Box Test R^2 Q(20) 5.757538 0.9991875
## LM Arch Test R    TR^2 2.506995 0.9981363
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -3.323241 -3.291441 -3.323337 -3.310964

```