VaR Prediction

Code

Casey Tirshfield

The file `intel_d_logret.txt` contains daily log returns of Intel stock from July 9, 1986 to June 29, 2007. Compute the 99% 1-day and 10-day VaR for a long position of $1 million using the following methods (as internal models in Section 12.1.2 of the textbook):

Hide

```
df <- read.table('intel_d_logret.txt', header=FALSE)
colnames(df) <- c('Date', 'logret')
# make dates column into rownames
df$Date <- as.Date(df$Date, '%m/%d/%Y')
row.names(df) <- df$Date
df[1] <- NULL
```

(a) GARCH(1,1) model with standard normal ϵ_t;

Hide

```
# first we fit the GARCH(1,1) model to our return series
# including mean
model <- ugarchspec(variance.model=list(model='sGARCH', garchOrder=c(1, 1)), mean.mod
el=list(armaOrder=c(0, 0), include.mean=TRUE), distribution.model='norm')
model_fit <- ugarchfit(spec=model, data=df, solver='hybrid')
print(model_fit)
```

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

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

```
Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001159    0.000321   3.6132 0.000302
omega   0.000009    0.000004   2.3628 0.018136
alpha1  0.055866    0.000545 102.5766 0.000000
beta1   0.933970    0.005115 182.5816 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001159    0.000330  3.50979 0.000448
omega   0.000009    0.000024  0.36556 0.714690
alpha1  0.055866    0.028248  1.97767 0.047965
beta1   0.933970    0.021394 43.65549 0.000000

LogLikelihood : 11906.77

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

Akaike       -4.4984
Bayes        -4.4934
Shibata      -4.4984
Hannan-Quinn -4.4967

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      3.460 0.06289
Lag[2*(p+q)+(p+q)-1][2]     3.668 0.09261
Lag[4*(p+q)+(p+q)-1][5]     4.693 0.17938
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.01313  0.9088
Lag[2*(p+q)+(p+q)-1][5]   2.12384  0.5895
Lag[4*(p+q)+(p+q)-1][9]   3.81544  0.6203
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     3.179 0.500 2.000 0.07457
ARCH Lag[5]     3.703 1.440 1.667 0.20279
ARCH Lag[7]     4.727 2.315 1.543 0.25358

Nyblom stability test
```

```
-----------------------------------
Joint Statistic:  3.5335
Individual Statistics:
mu     0.5698
omega  1.0057
alpha1 0.1989
beta1  0.2134

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           0.5675 0.5704
Negative Sign Bias  0.8468 0.3972
Positive Sign Bias  0.4907 0.6237
Joint Effect        4.1733 0.2433


Adjusted Pearson Goodness-of-Fit Test:
-----------------------------------
  group statistic p-value(g-1)
1    20     303.5    3.802e-53
2    30     523.1    5.113e-92
3    40     657.5   2.334e-113
4    50     502.2    1.905e-76


Elapsed time : 0.389076
```

Hide

```
# next we forecast the conditional mean and conditional variance of the assumed param
etric density 10 days ahead
forc <- ugarchforecast(model_fit, n.ahead = 10, include.mean=TRUE)
print(forc)
```

```
*-----------------------------------*
*       GARCH Model Forecast        *
*-----------------------------------*
Model: sGARCH
Horizon: 10
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2007-07-02]:
       Series   Sigma
T+1  0.001159 0.01833
T+2  0.001159 0.01847
T+3  0.001159 0.01861
T+4  0.001159 0.01874
T+5  0.001159 0.01888
T+6  0.001159 0.01901
T+7  0.001159 0.01914
T+8  0.001159 0.01927
T+9  0.001159 0.01939
T+10 0.001159 0.01951
```

Hide

```
# set 1 and 10 day ahead means and standard deviations from forecast
sigma1 <- 0.01833
sigma10 <- (0.01833^2 + 0.01847^2 + 0.01861^2 + 0.01874^2 + 0.01888^2 + 0.01901^2 + 0
.01914^2 + 0.01927^2 + 0.01939^2 + 0.01951^2) ^ (1 / 2)
mu <- 0.001159
long <- 1000000
# compute the 1-day VaR
VaR1 <- (mu - qnorm(0.99) * sigma1) * long
# compute the 10-day VaR
VaR10 <- (10 * mu - qnorm(0.99) * sigma10) * long
# formating for printing
VaR <- matrix(c(VaR1, VaR10), nrow=1, ncol=2)
rownames(VaR) <- 'VaR'
colnames(VaR) <- c('1-day', '10-day')
print('The 99% 1-day and 10-day VaR for a long position of $1 million using a GARCH(1
,1) model with a standard normal residual is:')
```

```
[1] "The 99% 1-day and 10-day VaR for a long position of $1 million using a GARCH(1,1
) model with a standard normal residual is:"
```

Hide

```
print(VaR)
```

```
        1-day    10-day
VaR -41482.96 -127734.1
```

Hide

```
# excluding mean
model_nomean <- ugarchspec(variance.model=list(model='sGARCH', garchOrder=c(1, 1)), m
ean.model=list(armaOrder=c(0, 0), include.mean=FALSE), distribution.model='norm')
model_fit_nomean <- ugarchfit(spec=model_nomean, data=df, solver='hybrid')
print(model_fit)
```

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

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

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001159    0.000321   3.6132 0.000302
omega   0.000009    0.000004   2.3628 0.018136
alpha1  0.055866    0.000545 102.5766 0.000000
beta1   0.933970    0.005115 182.5816 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001159    0.000330  3.50979 0.000448
omega   0.000009    0.000024  0.36556 0.714690
alpha1  0.055866    0.028248  1.97767 0.047965
beta1   0.933970    0.021394 43.65549 0.000000

LogLikelihood : 11906.77

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

Akaike       -4.4984
Bayes        -4.4934
Shibata      -4.4984
Hannan-Quinn -4.4967

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
```

```
                        statistic p-value
Lag[1]                      3.460 0.06289
Lag[2*(p+q)+(p+q)-1][2]     3.668 0.09261
Lag[4*(p+q)+(p+q)-1][5]     4.693 0.17938
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.01313  0.9088
Lag[2*(p+q)+(p+q)-1][5]   2.12384  0.5895
Lag[4*(p+q)+(p+q)-1][9]   3.81544  0.6203
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     3.179 0.500 2.000 0.07457
ARCH Lag[5]     3.703 1.440 1.667 0.20279
ARCH Lag[7]     4.727 2.315 1.543 0.25358

Nyblom stability test
------------------------------------
Joint Statistic:  3.5335
Individual Statistics:
mu     0.5698
omega  1.0057
alpha1 0.1989
beta1  0.2134

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           0.5675 0.5704
Negative Sign Bias  0.8468 0.3972
Positive Sign Bias  0.4907 0.6237
Joint Effect        4.1733 0.2433


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     303.5    3.802e-53
2    30     523.1    5.113e-92
3    40     657.5   2.334e-113
```

```
4    50     502.2    1.905e-76


Elapsed time : 0.389076
```

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```
# next we forecast the conditional mean and conditional variance of the assumed param
etric density 10 days ahead
forc_nomean <- ugarchforecast(model_fit_nomean, n.ahead = 10, include.mean=FALSE)
print(forc_nomean)
```

```
*----------------------------------*
*       GARCH Model Forecast       *
*----------------------------------*
Model: sGARCH
Horizon: 10
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2007-07-02]:
     Series   Sigma
T+1       0 0.01839
T+2       0 0.01852
T+3       0 0.01864
T+4       0 0.01877
T+5       0 0.01889
T+6       0 0.01901
T+7       0 0.01913
T+8       0 0.01925
T+9       0 0.01936
T+10      0 0.01948
```

Hide

```
# set 1 and 10 day ahead means and standard deviations from forecast
sigma1_nomean <- 0.01839
sigma10_nomean <- (0.01839^2 + 0.01852^2 + 0.01864^2 + 0.01877^2 + 0.01889^2 + 0.0190
1^2 + 0.01913^2 + 0.01925^2 + 0.01936^2 + 0.01948^2) ^ (1 / 2)
mu <- 0
long <- 1000000
# compute the 1-day VaR
VaR1_nomean <- (mu - qnorm(0.99) * sigma1_nomean) * long
# compute the 10-day VaR
VaR10_nomean <- (10 * mu - qnorm(0.99) * sigma10_nomean) * long
# formating for printing
VaR_nomean <- matrix(c(VaR1_nomean, VaR10_nomean), nrow=1, ncol=2)
rownames(VaR_nomean) <- 'VaR'
colnames(VaR_nomean) <- c('1-day', '10-day')
print('The 99% 1-day and 10-day VaR for a long position of $1 million using a GARCH(1
,1) model (no mean) with a standard normal residual is:')
```

```
[1] "The 99% 1-day and 10-day VaR for a long position of $1 million using a GARCH(1,1
) model (no mean) with a standard normal residual is:"
```

Hide

```
print(VaR_nomean)
```

```
        1-day  10-day
VaR -42781.54 -139386
```

(b) EGARCH(1, 1) model with standard normal ϵ_t;

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```
# first we fit the EGARCH(1,1) model to our return series
# including mean
model_e <- ugarchspec(variance.model=list(model='eGARCH', garchOrder=c(1, 1)), mean.m
odel=list(armaOrder=c(0, 0), include.mean=TRUE), distribution.model='norm')
model_fit_e <- ugarchfit(spec=model_e, data=df, solver='hybrid')
print(model_fit_e)
```

```


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

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

```
Distribution    : norm

Optimal Parameters
------------------------------------
        Estimate  Std. Error   t value Pr(>|t|)
mu      0.001051    0.000256    4.1066    4e-05
omega  -0.120069    0.007587  -15.8253    0e+00
alpha1 -0.039050    0.006599   -5.9173    0e+00
beta1   0.983048    0.000979 1003.7206    0e+00
gamma1  0.130575    0.012778   10.2189    0e+00

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001051    0.000221   4.7635 0.000002
omega  -0.120069    0.015158  -7.9211 0.000000
alpha1 -0.039050    0.012456  -3.1350 0.001718
beta1   0.983048    0.001869 525.9191 0.000000
gamma1  0.130575    0.035564   3.6715 0.000241

LogLikelihood : 11941.21

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

Akaike       -4.5110
Bayes        -4.5048
Shibata      -4.5110
Hannan-Quinn -4.5089

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic p-value
Lag[1]                      4.280 0.03856
Lag[2*(p+q)+(p+q)-1][2]     4.532 0.05428
Lag[4*(p+q)+(p+q)-1][5]     5.848 0.09763
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                     0.1203  0.7287
Lag[2*(p+q)+(p+q)-1][5]    2.0842  0.5987
Lag[4*(p+q)+(p+q)-1][9]    3.7439  0.6325
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     3.019 0.500 2.000  0.0823
```

```
ARCH Lag[5]     3.461 1.440 1.667  0.2295
ARCH Lag[7]     4.481 2.315 1.543  0.2824

Nyblom stability test
------------------------------------
Joint Statistic:  1.9286
Individual Statistics:
mu     0.9913
omega  0.4006
alpha1 0.2223
beta1  0.4529
gamma1 0.1430

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          0.68740 0.4919
Negative Sign Bias 0.13314 0.8941
Positive Sign Bias 0.05792 0.9538
Joint Effect       1.31774 0.7249


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     274.8    2.806e-47
2    30     481.5    1.840e-83
3    40     677.1   2.250e-117
4    50     576.3    3.854e-91


Elapsed time : 0.5143549
```

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```
# next we forecast the conditional mean and conditional variance of the assumed param
etric density 10 days ahead
forc_e <- ugarchforecast(model_fit_e, n.ahead = 10, include.mean=TRUE)
print(forc_e)
```

```
*-----------------------------------*
*       GARCH Model Forecast        *
*-----------------------------------*
Model: eGARCH
Horizon: 10
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2007-07-02]:
       Series   Sigma
T+1  0.001051 0.01800
T+2  0.001051 0.01815
T+3  0.001051 0.01829
T+4  0.001051 0.01844
T+5  0.001051 0.01858
T+6  0.001051 0.01872
T+7  0.001051 0.01886
T+8  0.001051 0.01899
T+9  0.001051 0.01913
T+10 0.001051 0.01927
```

Hide

```
# set 1 and 10 day ahead means and standard deviations from forecast
sigma1_e <- 0.01800
sigma10_e <- (0.01800^2 + 0.01815^2 + 0.01829^2 + 0.01844^2 + 0.01858^2 + 0.01872^2 +
0.01886^2 + 0.01899^2 + 0.01913^2 + 0.01927^2) ^ (1 / 2)
mu_e <- 0.001051
long <- 1000000
# compute the 1-day VaR
VaR1_e <- (mu_e - qnorm(0.99) * sigma1_e) * long
# compute the 10-day VaR
VaR10_e <- (10 * mu_e - qnorm(0.99) * sigma10_e) * long
# formating for printing
VaR_e <- matrix(c(VaR1_e, VaR10_e), nrow=1, ncol=2)
rownames(VaR_e) <- 'VaR'
colnames(VaR_e) <- c('1-day', '10-day')
print('The 99% 1-day and 10-day VaR for a long position of $1 million using a EGARCH(
1,1) model with a standard normal residual is:')
```

```
[1] "The 99% 1-day and 10-day VaR for a long position of $1 million using a EGARCH(1,
1) model with a standard normal residual is:"
```

Hide

```
print(VaR_e)
```

```
       1-day    10-day
VaR -40823.26 -126670.5
```

Hide

```
# excluding mean
model_e_nomean <- ugarchspec(variance.model=list(model='eGARCH', garchOrder=c(1, 1)),
mean.model=list(armaOrder=c(0, 0), include.mean=FALSE), distribution.model='norm')
model_fit_e_nomean <- ugarchfit(spec=model_e_nomean, data=df, solver='hybrid')
print(model_fit_e_nomean)
```

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

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

Optimal Parameters
------------------------------------
        Estimate  Std. Error   t value Pr(>|t|)
omega  -0.122277    0.001901  -64.3318        0
alpha1 -0.042214    0.006285   -6.7169        0
beta1   0.982470    0.000442 2222.2968        0
gamma1  0.127764    0.008345   15.3099        0

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
omega  -0.122277    0.008244 -14.8314 0.000000
alpha1 -0.042214    0.012193  -3.4623 0.000536
beta1   0.982470    0.001157 849.0387 0.000000
gamma1  0.127764    0.013423   9.5181 0.000000

LogLikelihood : 11935.96

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

Akaike       -4.5094
Bayes        -4.5045
Shibata      -4.5094
Hannan-Quinn -4.5077

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
```

```
                        statistic p-value
Lag[1]                      4.558 0.03277
Lag[2*(p+q)+(p+q)-1][2]     4.761 0.04714
Lag[4*(p+q)+(p+q)-1][5]     5.838 0.09817
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.07924  0.7783
Lag[2*(p+q)+(p+q)-1][5]   2.20551  0.5707
Lag[4*(p+q)+(p+q)-1][9]   3.98333  0.5917
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     3.248 0.500 2.000 0.07153
ARCH Lag[5]     3.774 1.440 1.667 0.19546
ARCH Lag[7]     4.818 2.315 1.543 0.24358

Nyblom stability test
------------------------------------
Joint Statistic:  1.5477
Individual Statistics:
omega  0.4879
alpha1 0.1662
beta1  0.5486
gamma1 0.1720

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           0.1892 0.8500
Negative Sign Bias  0.3380 0.7354
Positive Sign Bias  0.3378 0.7355
Joint Effect        0.8146 0.8460


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     370.4    6.139e-67
2    30     534.7    2.047e-94
3    40     748.6   4.290e-132
```

```
4    50     972.9   6.397e-172


Elapsed time : 0.750628
```

Hide

```
# next we forecast the conditional mean and conditional variance of the assumed param
etric density 10 days ahead
forc_e_nomean <- ugarchforecast(model_fit_e_nomean, n.ahead = 10, include.mean=FALSE)
print(forc_e_nomean)
```

```


*-----------------------------------*
*       GARCH Model Forecast        *
*-----------------------------------*
Model: eGARCH
Horizon: 10
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2007-07-02]:
     Series   Sigma
T+1       0 0.01800
T+2       0 0.01817
T+3       0 0.01833
T+4       0 0.01850
T+5       0 0.01866
T+6       0 0.01883
T+7       0 0.01899
T+8       0 0.01915
T+9       0 0.01930
T+10      0 0.01946
```

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```
# set 1 and 10 day ahead means and standard deviations from forecast
sigma1_e_nomean <- 0.01800
sigma10_e_nomean <- (0.01800^2 + 0.01817^2 + 0.01833^2 + 0.01850^2 + 0.01866^2 + 0.01
883^2 + 0.01899^2 + 0.01915^2 + 0.01930^2 + 0.01946^2) ^ (1 / 2)
mu_e_nomean <- 0
long <- 1000000
# compute the 1-day VaR
VaR1_e_nomean <- (mu_e_nomean - qnorm(0.99) * sigma1_e_nomean) * long
# compute the 10-day VaR
VaR10_e_nomean <- (10 * mu_e_nomean - qnorm(0.99) * sigma10_e_nomean) * long
# formating for printing
VaR_e_nomean <- matrix(c(VaR1_e_nomean, VaR10_e_nomean), nrow=1, ncol=2)
rownames(VaR_e_nomean) <- 'VaR'
colnames(VaR_e_nomean) <- c('1-day', '10-day')
print('The 99% 1-day and 10-day VaR for a long position of $1 million using a EGARCH(
1,1) model (nomean) with a standard normal residual is:')
```

```
[1] "The 99% 1-day and 10-day VaR for a long position of $1 million using a EGARCH(1,
1) model (nomean) with a standard normal residual is:"
```

Hide

```
print(VaR_e_nomean)
```

```
        1-day    10-day
VaR -41874.26 -137897.2
```

(c) ARMA(1, 1)-GARCH(1, 1) model with ϵ_t having the standardized Student t-distribution whose degrees of freedom are to be estimated from the data;

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```
# first we fit the ARMA(1,1)-GARCH(1,1) model to our return series
model_ag <- ugarchspec(variance.model=list(model='sGARCH', garchOrder=c(1, 1)), mean.
model=list(armaOrder=c(1, 1), include.mean=TRUE), distribution.model='std')
model_fit_ag <- ugarchfit(spec=model_ag, data=df, solver='hybrid')
print(model_fit_ag)
```

```


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

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

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

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001099    0.000281   3.9070 0.000093
ar1     0.799277    0.103296   7.7377 0.000000
ma1    -0.811452    0.100288  -8.0912 0.000000
omega   0.000003    0.000001   2.8625 0.004204
alpha1  0.033806    0.001632  20.7113 0.000000
beta1   0.961630    0.001157 831.1905 0.000000
shape   6.828087    0.547981  12.4604 0.000000

Robust Standard Errors:
        Estimate  Std. Error   t value Pr(>|t|)
mu      0.001099    0.000303    3.6221 0.000292
ar1     0.799277    0.041144   19.4261 0.000000
ma1    -0.811452    0.039850  -20.3626 0.000000
omega   0.000003    0.000002    1.5951 0.110698
alpha1  0.033806    0.001274   26.5300 0.000000
beta1   0.961630    0.000672 1430.4572 0.000000
shape   6.828087    0.711653    9.5947 0.000000

LogLikelihood : 12100.3

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

Akaike       -4.5704
Bayes        -4.5617
Shibata      -4.5704
Hannan-Quinn -4.5674

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic   p-value
Lag[1]                      7.556 5.982e-03
Lag[2*(p+q)+(p+q)-1][5]     7.728 3.572e-08
Lag[4*(p+q)+(p+q)-1][9]     8.054 5.509e-02
d.o.f=2
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                     0.7687 0.38061
Lag[2*(p+q)+(p+q)-1][5]    7.4459 0.04038
Lag[4*(p+q)+(p+q)-1][9]   11.5639 0.02276
```

```
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale  P-Value
ARCH Lag[3]     8.087 0.500 2.000 0.004459
ARCH Lag[5]    11.175 1.440 1.667 0.003390
ARCH Lag[7]    12.141 2.315 1.543 0.005742

Nyblom stability test
------------------------------------
Joint Statistic:  20.6986
Individual Statistics:
mu     0.6192
ar1    0.1401
ma1    0.1460
omega  1.9415
alpha1 0.3869
beta1  0.3951
shape  0.1659

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:          1.69 1.9 2.35
Individual Statistic:     0.35 0.47 0.75

Sign Bias Test
------------------------------------
                   t-value   prob sig
Sign Bias          0.57448 0.5657
Negative Sign Bias 1.56242 0.1182
Positive Sign Bias 0.03635 0.9710
Joint Effect       5.99544 0.1118


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     263.9    4.724e-45
2    30     430.4    4.977e-73
3    40     420.9    1.520e-65
4    50     422.8    5.945e-61


Elapsed time : 0.740963
```

Hide

```
# next we forecast the conditional mean and conditional variance of the assumed param
etric density 10 days ahead
forc_ag <- ugarchforecast(model_fit_ag, n.ahead = 10, include.mean=TRUE)
print(forc_ag)
```

```
*----------------------------------*
*       GARCH Model Forecast       *
*----------------------------------*
Model: sGARCH
Horizon: 10
Roll Steps: 0
Out of Sample: 0

0-roll forecast [T0=2007-07-02]:
        Series   Sigma
T+1  0.0008492 0.01671
T+2  0.0008993 0.01676
T+3  0.0009393 0.01682
T+4  0.0009713 0.01687
T+5  0.0009968 0.01692
T+6  0.0010173 0.01698
T+7  0.0010336 0.01703
T+8  0.0010467 0.01708
T+9  0.0010571 0.01713
T+10 0.0010654 0.01718
```

Hide

```
# set 1 and 10 day ahead means and standard deviations from forecast
sigma1_ag <- 0.01671
sigma10_ag <- (0.01671^2 + 0.01676^2 + 0.01682^2 + 0.01687^2 + 0.01692^2 + 0.01698^2
+ 0.01703^2 + 0.01708^2 + 0.01713^2 + 0.01718^2) ^ (1 / 2)
mu1 <- 0.0008492
mu10 <- 0.0008492 + 0.0008993 + 0.0009393 + 0.0009713 + 0.0009968 + 0.0010173 + 0.001
0336 + 0.0010467 + 0.0010571 + 0.0010654
long <- 1000000
dof <- 6.828087
# compute the 1-day VaR
# we use the formula for VaR of a student-t found at the following link http://www.qu
antatrisk.com/2015/12/02/student-t-distributed-linear-value-at-risk/
VaR1_ag <- (mu1 - qt(0.99, dof) / sqrt(dof / (dof - 2)) * sigma1_ag) * long
# compute the 10-day VaR
VaR10_ag <- (mu10 - qt(0.99, dof) / sqrt(dof / (dof - 2)) * sigma10_ag) * long
# formating for printing
VaR_ag <- matrix(c(VaR1_ag, VaR10_ag), nrow=1, ncol=2)
rownames(VaR_ag) <- 'VaR'
colnames(VaR_ag) <- c('1-day', '10-day')
print('The 99% 1-day and 10-day VaR for a long position of $1 million using a ARMA(1,
1)-GARCH(1,1) model with a standard normal residual is:')
```

```
[1] "The 99% 1-day and 10-day VaR for a long position of $1 million using a ARMA(1,1)
-GARCH(1,1) model with a standard normal residual is:"
```

Hide

```
print(VaR_ag)
```

```
        1-day    10-day
VaR -41572.99 -126190.8
```

(d) the GEV distribution for extreme (negative) returns with subperiod length of 20 trading days.

Hide

```
# we fit the GEV distribution
GEV_fit <- gevFit(data.matrix(df), block=20, type='mle')
print(GEV_fit)
```

```
Title:
 GEV Parameter Estimation

Call:
 gevFit(x = data.matrix(df), block = 20, type = "mle")

Estimation Type:
  gev mle

Estimated Parameters:
        xi         mu       beta
0.10355161 0.03837724 0.01666132

Description
  Mon Jul 16 23:29:49 2018
```

Hide

```
GEV_model <- gev(data.matrix(df), block=20)
print(GEV_model)
```

```
$n.all
[1] 5292

$n
[1] 265

$data
  [1] 0.05884011 0.08701080 0.05406686 0.05406686 0.07598540 0.02409739
  [7] 0.07847109 0.11211655 0.07197302 0.06291341 0.02381049 0.06371539
 [13] 0.06136854 0.02272810 0.02927019 0.05358389 0.23638720 0.08829202
 [19] 0.05635256 0.06062422 0.05195939 0.05588009 0.04546207 0.02325671
 [25] 0.04495109 0.04167242 0.04546207 0.06453809 0.06805301 0.03125233
 [31] 0.06453809 0.03125233 0.05884011 0.02777938 0.04445147 0.02469245
 [37] 0.03390133 0.03593177 0.04598481 0.03550645 0.03468533 0.04348482
 [43] 0.05715803 0.05406686 0.05770793 0.04566973 0.05129295 0.01785750
 [49] 0.03745731 0.02247271 0.03745731 0.05505941 0.08167748 0.05348833
 [55] 0.06385104 0.03846602 0.03846602 0.04317188 0.07095126 0.06952560
 [61] 0.09193688 0.05981810 0.04688327 0.03149846 0.05091975 0.02553313
 [67] 0.08777502 0.03419114 0.02553313 0.08438683 0.04598481 0.03815151
 [73] 0.05001009 0.03947855 0.03610476 0.06407843 0.04255933 0.02932742
 [79] 0.03409398 0.03815151 0.03580921 0.07864260 0.08152606 0.04985423
 [85] 0.03593177 0.05089127 0.04240890 0.06221277 0.03922045 0.07347888
 [91] 0.02739879 0.03182622 0.04220007 0.02597531 0.03922045 0.02590801
 [97] 0.02914094 0.02316690 0.04458361 0.03468533 0.02898734 0.03647797
[103] 0.03342907 0.02638658 0.02950047 0.03217414 0.05866746 0.03580921
[109] 0.04890348 0.03684032 0.04221704 0.03864300 0.02473062 0.06106507
[115] 0.06557489 0.04469988 0.04164249 0.03789332 0.06045370 0.05326667
```

```
[121] 0.05016692 0.03016800 0.04687146 0.06650605 0.03699534 0.05438656
[127] 0.02469245 0.04434194 0.06171827 0.05328921 0.04173454 0.05872489
[133] 0.05941023 0.03416287 0.03205201 0.05386125 0.03746637 0.03954360
[139] 0.02766835 0.08817124 0.03468012 0.04014353 0.12822664 0.05223534
[145] 0.04847091 0.05111210 0.04050295 0.03325164 0.06271939 0.03724507
[151] 0.04307160 0.05357851 0.03532466 0.07179816 0.06615701 0.04764998
[157] 0.06647049 0.04964190 0.07484579 0.04352670 0.05327595 0.05120046
[163] 0.03714295 0.06969065 0.07192052 0.05760946 0.04577144 0.07135555
[169] 0.07046747 0.08591731 0.12382262 0.05125850 0.04659167 0.05263059
[175] 0.10713557 0.06742487 0.07959439 0.03336085 0.04801682 0.07856953
[181] 0.09374225 0.06978261 0.09634664 0.09716953 0.05082789 0.11571905
[187] 0.18321636 0.05240219 0.06221783 0.07001516 0.04317188 0.09920599
[193] 0.08291839 0.06070199 0.05196353 0.07347888 0.03555619 0.08163321
[199] 0.04849855 0.10293389 0.06477040 0.09624404 0.07608427 0.09080361
[205] 0.05811327 0.08961156 0.05856973 0.03532220 0.06977210 0.03919394
[211] 0.07027109 0.06498616 0.04987150 0.05375336 0.05318583 0.04461832
[217] 0.03694537 0.03957872 0.03899818 0.03440758 0.03255931 0.03494537
[223] 0.02204028 0.04672065 0.03748688 0.04507886 0.01877797 0.03258468
[229] 0.03256645 0.02350576 0.03844604 0.02218777 0.05143306 0.02692809
[235] 0.02794574 0.02609961 0.03031907 0.01497156 0.02191959 0.02661588
[241] 0.01702472 0.01664326 0.02169268 0.03150205 0.03543414 0.02403747
[247] 0.01323864 0.01550408 0.01216616 0.03002576 0.03035273 0.03511197
[253] 0.04013306 0.02629406 0.02477224 0.02821180 0.04115386 0.01411550
[259] 0.03953057 0.01783096 0.01957204 0.02852313 0.02175012 0.02476890
[265] 0.04234087

$block
[1] 20

$par.ests
       xi     sigma        mu
0.1032800 0.0166641 0.0383838

$par.ses
          xi        sigma           mu
0.0450268716 0.0008512921 0.0011510560

$varcov
              [,1]          [,2]          [,3]
[1,]  2.027419e-03 -5.652355e-06 -1.630883e-05
[2,] -5.652355e-06  7.246983e-07  4.725179e-07
[3,] -1.630883e-05  4.725179e-07  1.324930e-06

$converged
[1] 0

$nllh.final
[1] -651.7594

attr(,"class")
```

```
[1] "gev"
```

Hide

```
long <- 1000000
VaR_GEV <- VaR(data.matrix(df), alpha=0.01, type='sample', tail='lower') * long
print(VaR_GEV)
```

```
       1%
-75348.93
```