

Untitled

me

7/26/2020

```
5+5
```

```
## [1] 10
```

```
library(zoo)
```

```
##
```

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

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

```
##
```

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

```
library(tseries)
```

```
## Warning: package 'tseries' was built under R version 4.0.2
```

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

```
##   method          from
```

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

```
library(FinTS)
```

```
## Warning: package 'FinTS' was built under R version 4.0.2
```

```
library(rugarch)
```

```
## Warning: package 'rugarch' was built under R version 4.0.2
```

```
## Loading required package: parallel
```

```
##
```

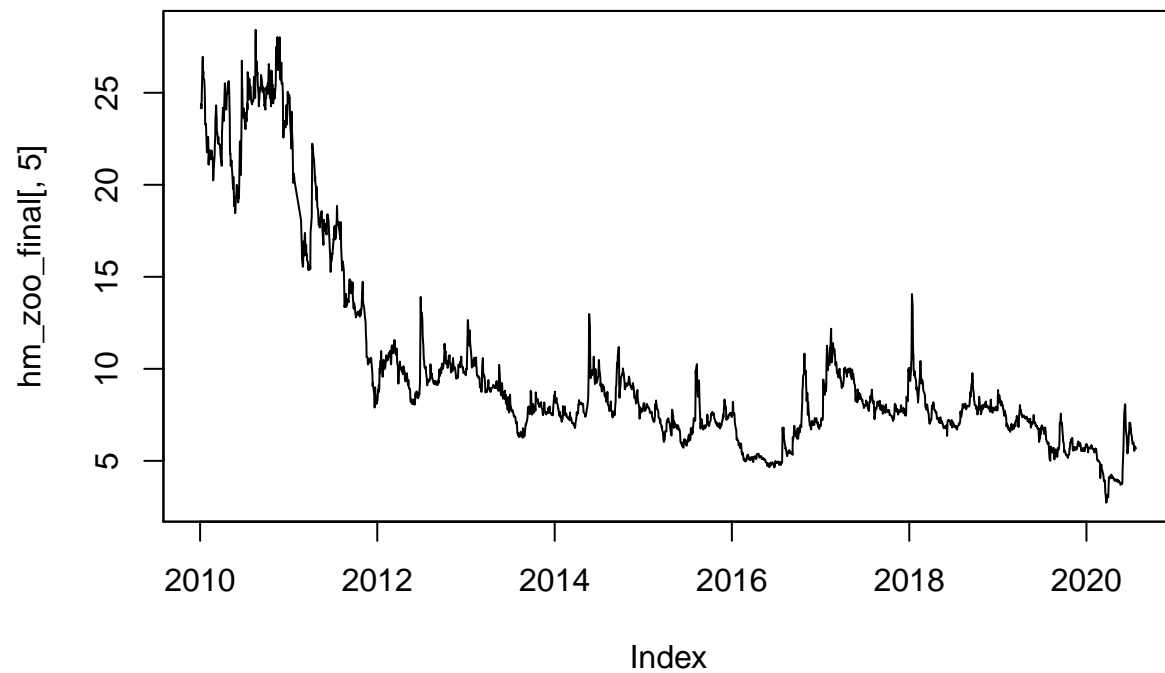
```
## Attaching package: 'rugarch'
```

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

```
##
```

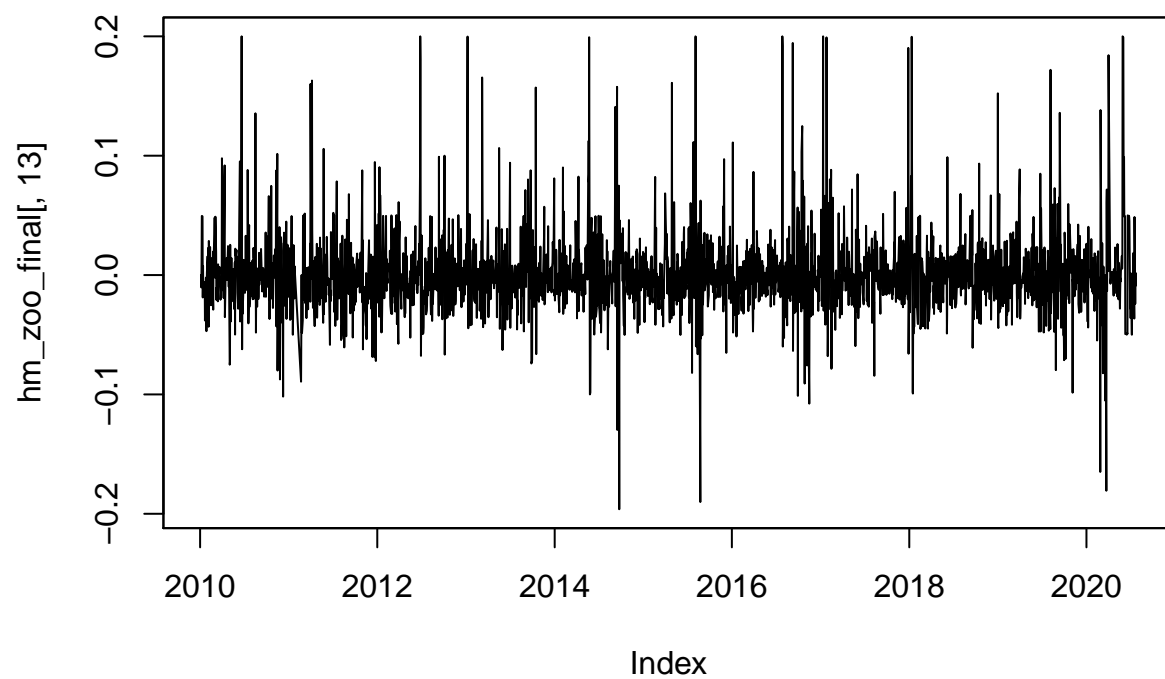
```
##      sigma
```

```
hm_zoo_final<-read.zoo("hindustan motors.csv",header=TRUE,sep=",",format="%d-%b-%y",FUN = as.Date)
plot(hm_zoo_final[,5])
```



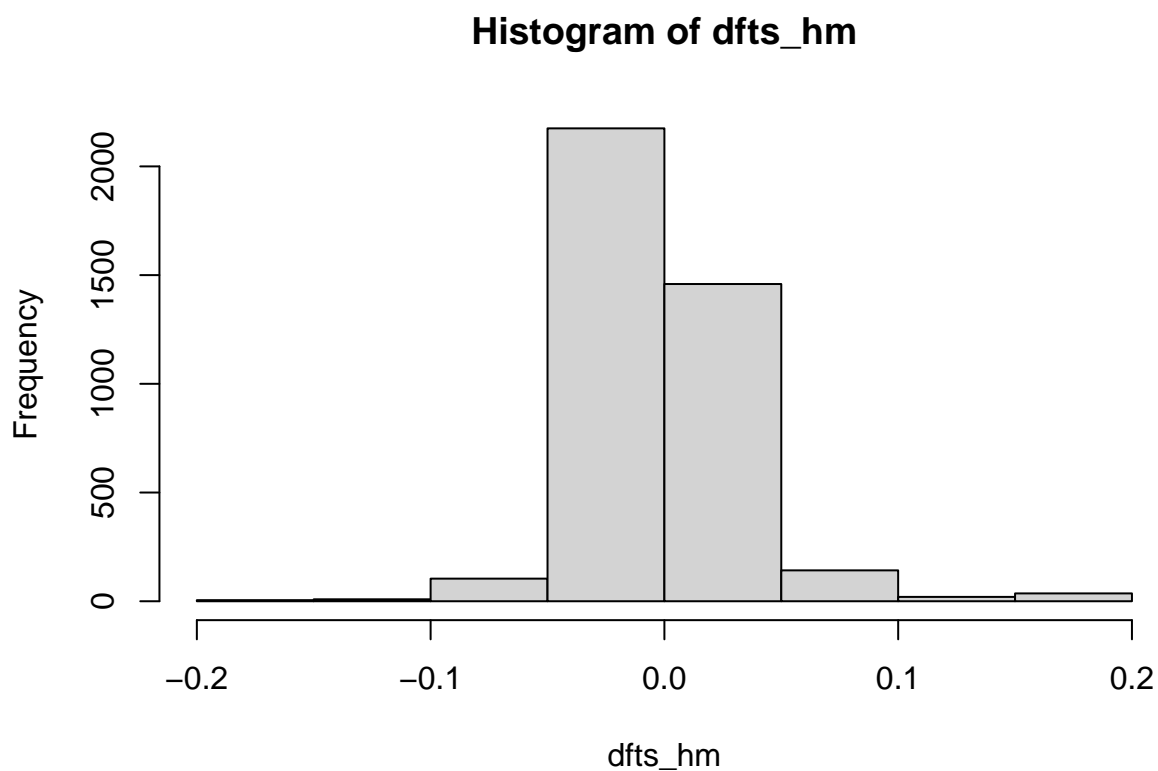
there is a trend in the closing price hence i am taking the difference and considering the log return.

```
plot(hm_zoo_final[,13])
```



the return series seems to be constant at mean zero and volatility clustering is visible in graph

```
ret_hm<-hm_zoo_final[-1,13]
dfts_hm<- ts(ret_hm,start=c(2010,1),end=c(2020,300),frequency = 365)
hist(dfts_hm)
```



the return appears to be noormally distributed.

```
shapiro.test(dfts_hm)
```

```
##  
## Shapiro-Wilk normality test  
##  
## data:  dfts_hm  
## W = 0.85846, p-value < 2.2e-16
```

the series is staionary.

```
mean(dfts_hm)
```

```
## [1] -0.0001571083
```

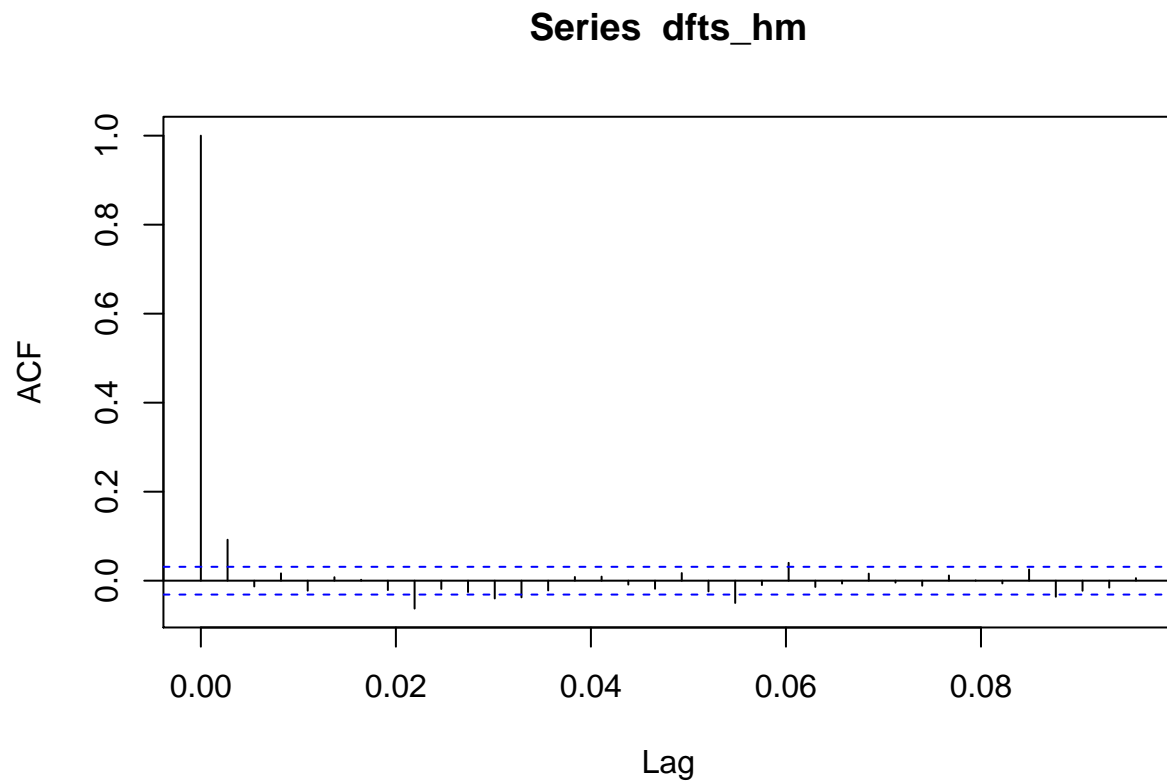
```
adf.test(ret_hm)
```

```
## Warning in adf.test(ret_hm): p-value smaller than printed p-value
```

```
##  
## Augmented Dickey-Fuller Test  
##  
## data:  ret_hm  
## Dickey-Fuller = -15.391, Lag order = 13, p-value = 0.01  
## alternative hypothesis: stationary
```

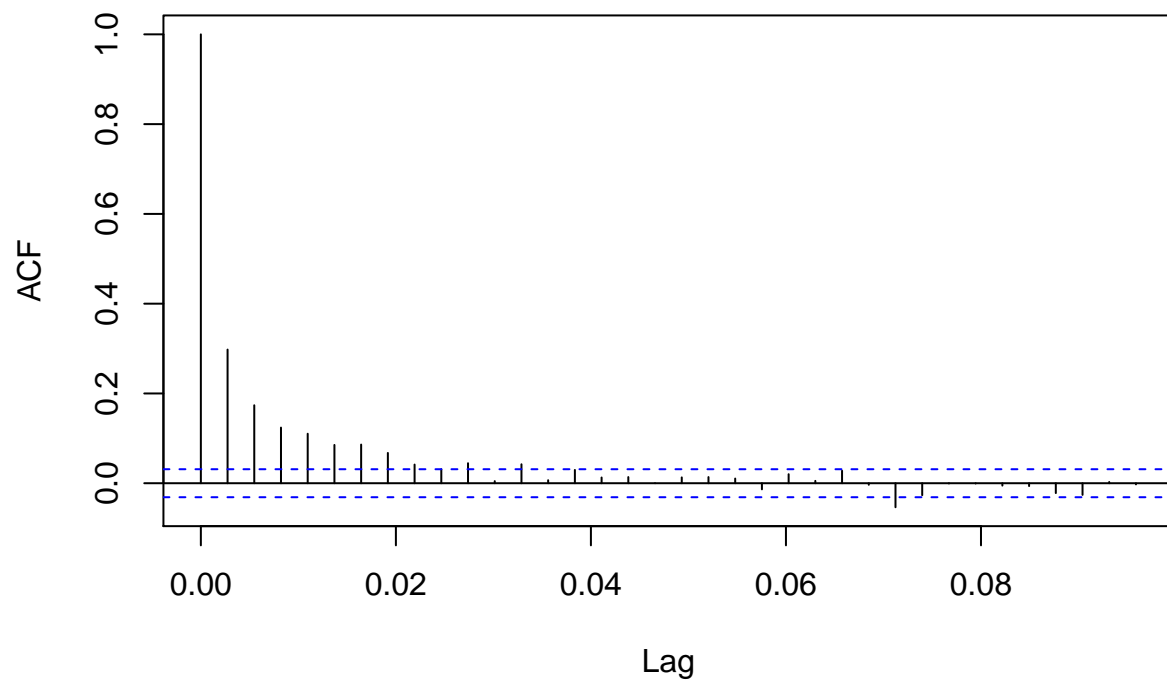
since p value is smaller than 0.05 hence we are rejecting the null hypothesis hence the series is stationary.
also the series is normal around mean 0.

```
acf(dfts_hm)
```



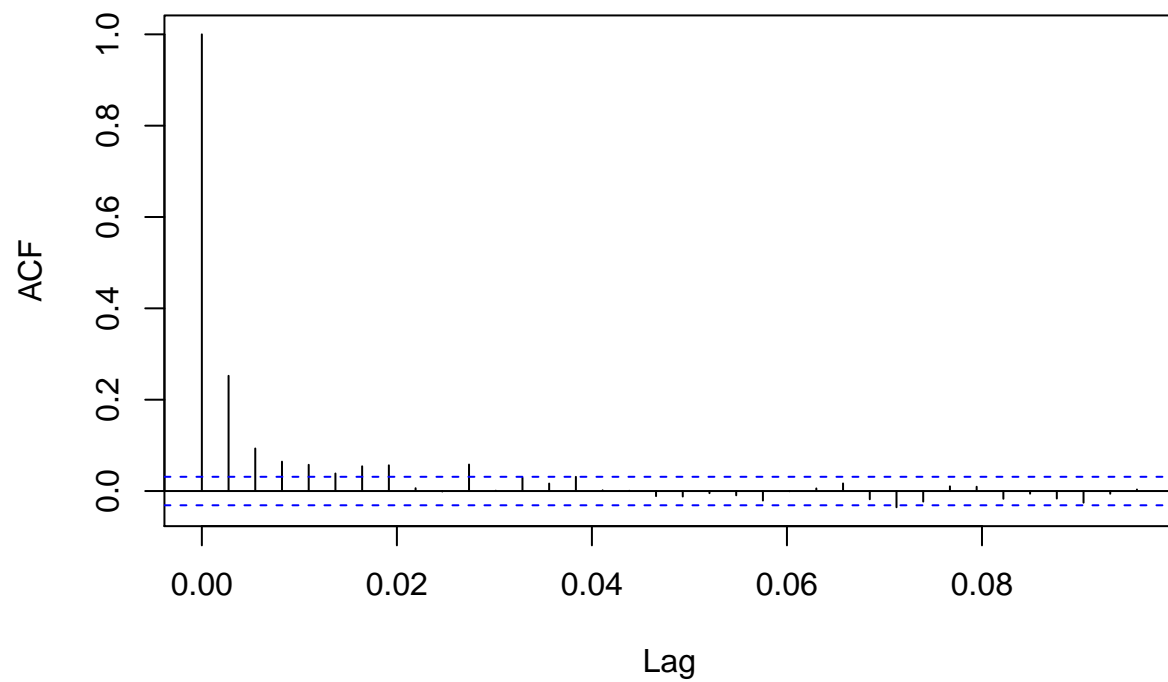
```
acf(abs(dfts_hm))
```

Series abs(dfts_hm)



```
acf(dfts_hm^2)
```

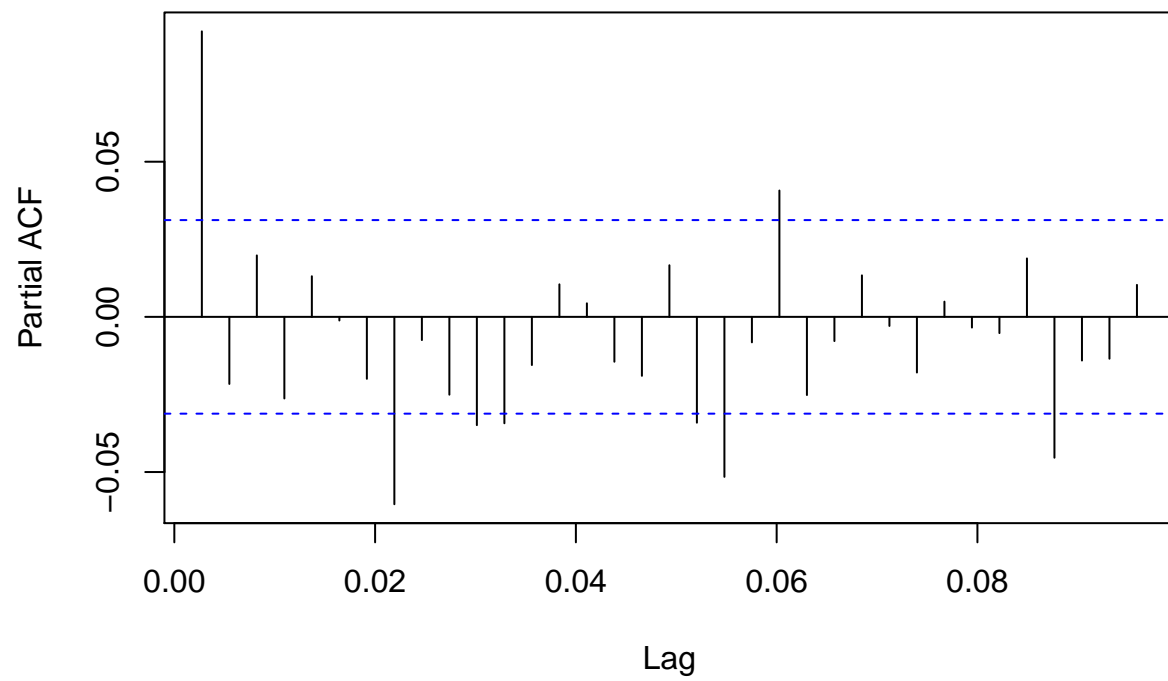
Series dfts_hm^2



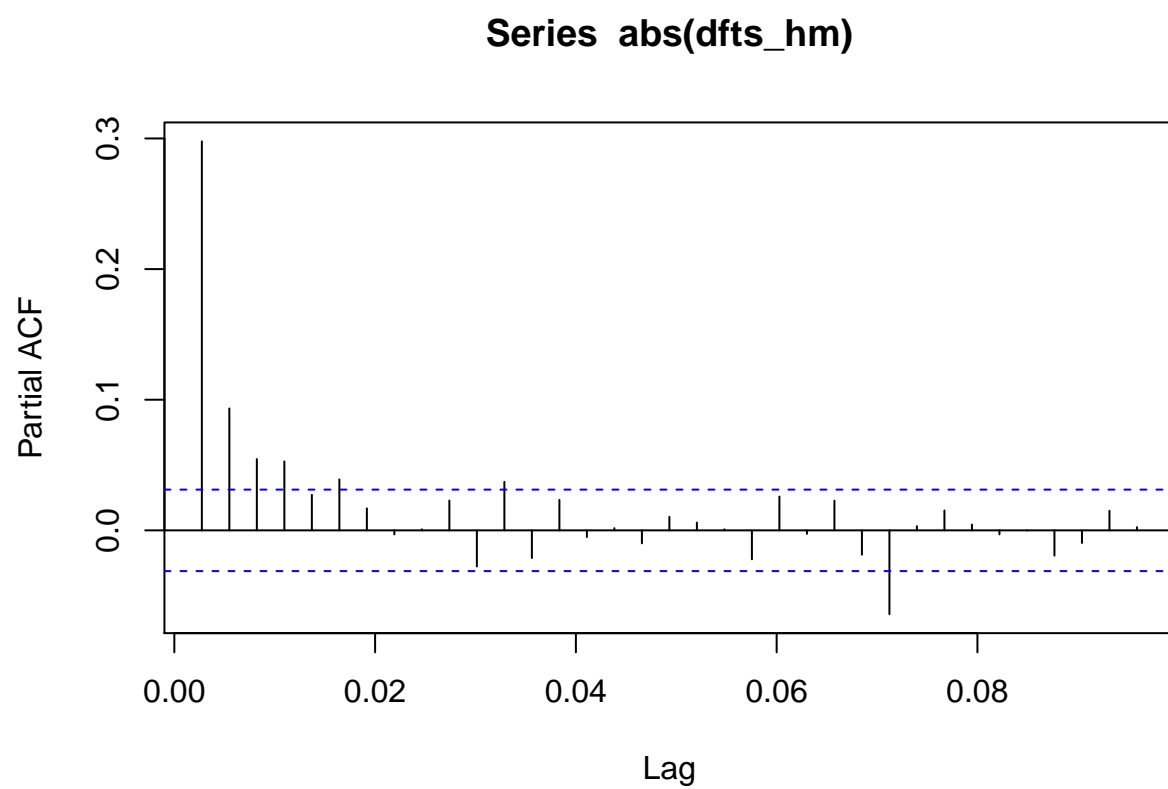
by acf function of return we can say there is no auto correlation and there will be no need of MA model
also by looking at the acf of absolute return we can say that the large return are followed by large returns
regardless of sign

```
pacf(dfts_hm)
```

Series dfts_hm

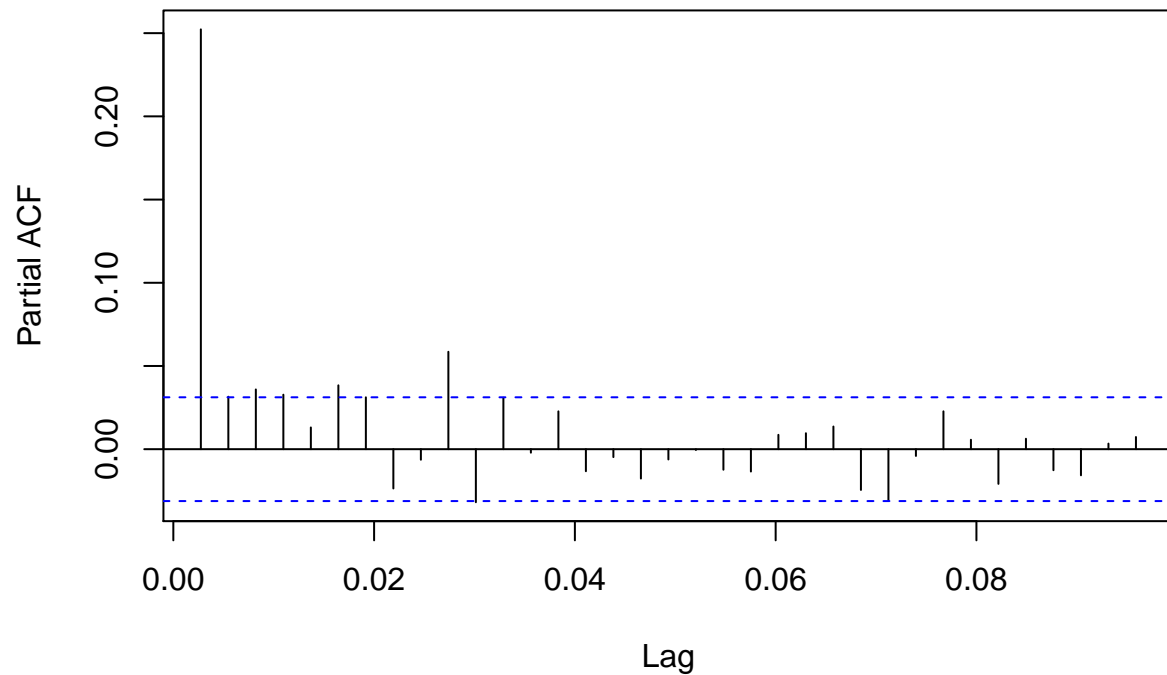


```
pacf(abs(dfts_hm))
```

```
pacf(dfts_hm2)
```

Series dfts_hm^2



there may need arise of an AR model

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

```
##  
## Box-Ljung test  
##  
## data:  ret_hm  
## X-squared = 57.374, df = 12, p-value = 6.767e-08
```

```
ArchTest(ret_hm)
```

```
##  
## ARCH LM-test; Null hypothesis: no ARCH effects  
##  
## data:  ret_hm  
## Chi-squared = 217.35, df = 12, p-value < 2.2e-16
```

since p value is less than 0.05 we are rejecting the null hypothesis and thus we can say there is arch effect in the series.

```
arima010=arima(ret_hm,order=c(0,1,0))  
AIC(arima010)
```

```
## [1] -8327.755
```

```
arima110=arima(ret_hm,order=c(1,1,0))  
AIC(arima110)
```

```
## [1] -9025.426
```

```
arima011=arima(ret_hm,order=c(0,1,1))  
AIC(arima011)
```

```
## [1] -10097.98
```

```
arima111=arima(ret_hm,order=c(1,1,1))  
AIC(arima111)
```

```
## [1] -10111.63
```

```
arima012=arima(ret_hm,order=c(0,1,2))  
AIC(arima012)
```

```
## [1] -10111.46
```

```
arima210=arima(ret_hm,order=c(2,1,0))  
AIC(arima210)
```

```
## [1] -9408.992
```

```
arima112=arima(ret_hm,order=c(1,1,2))  
AIC(arima112)
```

```
## [1] -10110.4
```

```
arima211=arima(ret_hm,order=c(2,1,1))  
AIC(arima211)
```

```
## [1] -10109.79
```

```
arima212=arima(ret_hm,order=c(2,1,2))  
AIC(arima212)
```

```
## [1] -10111.82
```

```
arima020=arima(ret_hm,order=c(0,2,0))  
AIC(arima020)
```

```
## [1] -4899.385
```

```
arima120=arima(ret_hm,order=c(1,2,0))  
AIC(arima120)
```

```
## [1] -6454.954
```

```
arima021=arima(ret_hm,order=c(0,2,1))  
AIC(arima021)
```

```
## [1] -8313.035
```

```
arima121=arima(ret_hm,order=c(1,2,1))  
AIC(arima121)
```

```
## [1] -9009.657
```

```
arima022=arima(ret_hm,order=c(0,2,2))  
AIC(arima022)
```

```
## [1] -9983.073
```

```
arima220=arima(ret_hm,order=c(2,2,0))  
AIC(arima220)
```

```
## [1] -7443.981
```

```
arima122=arima(ret_hm,order=c(1,2,2))  
AIC(arima122)
```

```
## [1] -10056.46
```

```
arima221=arima(ret_hm,order=c(2,2,1))  
AIC(arima221)
```

```
## [1] -9392.478
```

```
arima222=arima(ret_hm,order=c(2,2,2))  
AIC(arima222)
```

```
## [1] -10041.97
```

```
arima002=arima(ret_hm,order=c(0,0,2))  
AIC(arima002)
```

```
## [1] -10122.1
```

```
arima001=arima(ret_hm,order=c(0,0,1))
AIC(arima001)
```

```
## [1] -10124.09
```

```
arima100=arima(ret_hm,order=c(1,0,0))
AIC(arima100)
```

```
## [1] -10124.25
```

```
arima001=arima(ret_hm,order=c(1,0,0))
AIC(arima100)
```

```
## [1] -10124.25
```

(2,1,2) and (1,1,1) we may ignore these since the acf and pacf function didnt recommended any also there is no need to make the model more complex.

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,0)),mean.model =list(armaOrder=c(0,0))
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(1,0)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : norm
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000614    0.000613  -1.0023  0.3162
## omega    0.000845    0.000030  27.8692  0.0000
## alpha1   0.314338    0.038859   8.0892  0.0000
##
## Robust Standard Errors:
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000614    0.000643 -0.95542 0.339365
## omega    0.000845    0.000085  9.90138 0.000000
## alpha1   0.314338    0.068704  4.57528 0.000005
##
## LogLikelihood : 5214.172
##
## Information Criteria
## -----
##
```

```

## Akaike          -4.0086
## Bayes           -4.0018
## Shibata         -4.0086
## Hannan-Quinn   -4.0061
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##               statistic  p-value
## Lag[1]                8.621 0.003323
## Lag[2*(p+q)+(p+q)-1][2] 8.715 0.004181
## Lag[4*(p+q)+(p+q)-1][5] 10.018 0.009108
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic  p-value
## Lag[1]                0.1205 0.7285
## Lag[2*(p+q)+(p+q)-1][2] 0.2122 0.8467
## Lag[4*(p+q)+(p+q)-1][5] 2.5254 0.5005
## d.o.f=1
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[2]    0.1831 0.500 2.000 0.6687
## ARCH Lag[4]    2.7094 1.397 1.611 0.3058
## ARCH Lag[6]    4.3851 2.222 1.500 0.2582
##
## Nyblom stability test
## -----
## Joint Statistic: 0.4867
## Individual Statistics:
## mu      0.07616
## omega   0.09277
## alpha1  0.23295
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      0.846 1.01 1.35
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##           t-value    prob sig
## Sign Bias      2.1093 0.03501 **
## Negative Sign Bias 0.5128 0.60813
## Positive Sign Bias 0.7466 0.45540
## Joint Effect    5.0259 0.16991
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      445.8    1.235e-82

```

```
## 2    30    460.3    4.040e-79
## 3    40    488.6    4.774e-79
## 4    50    506.8    2.396e-77
##
##
## Elapsed time : 0.3822222
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(0,1)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(0,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : norm
##
## Optimal Parameters
## -----
##      Estimate Std. Error   t value Pr(>|t|)
## mu      0.000017  0.000677 2.5072e-02   0.98
## omega   0.000001  0.000000 4.4583e+01   0.00
## beta1   0.999000  0.000012 8.1291e+04   0.00
##
## Robust Standard Errors:
##      Estimate Std. Error   t value Pr(>|t|)
## mu      0.000017  0.000657 2.5841e-02  0.97938
## omega   0.000001  0.000000 1.0805e+01  0.00000
## beta1   0.999000  0.000127 7.8354e+03  0.00000
##
## LogLikelihood : 5058.001
##
## Information Criteria
## -----
##
## Akaike          -3.8885
## Bayes           -3.8817
## Shibata         -3.8885
## Hannan-Quinn    -3.8860
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##              statistic   p-value
## Lag[1]                25.29 4.941e-07
## Lag[2*(p+q)+(p+q)-1] [2] 25.34 1.766e-07
## Lag[4*(p+q)+(p+q)-1] [5] 26.80 2.505e-07
## d.o.f=0
## H0 : No serial correlation
##
```

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

```
## -----
```

```
##               statistic p-value
```

```
## Lag[1]                181.9      0
```

```
## Lag[2*(p+q)+(p+q)-1][2] 191.2      0
```

```
## Lag[4*(p+q)+(p+q)-1][5] 205.9      0
```

```
## d.o.f=1
```

```
##
```

```
## Weighted ARCH LM Tests
```

```
## -----
```

```
##           Statistic Shape Scale  P-Value
```

```
## ARCH Lag[2]      18.57 0.500 2.000 1.641e-05
```

```
## ARCH Lag[4]      29.41 1.397 1.611 4.307e-08
```

```
## ARCH Lag[6]      34.41 2.222 1.500 4.748e-09
```

```
##
```

```
## Nyblom stability test
```

```
## -----
```

```
## Joint Statistic: 6.1311
```

```
## Individual Statistics:
```

```
## mu      0.06183
```

```
## omega 0.75330
```

```
## beta1 0.17709
```

```
##
```

```
## Asymptotic Critical Values (10% 5% 1%)
```

```
## Joint Statistic:      0.846 1.01 1.35
```

```
## Individual Statistic: 0.35 0.47 0.75
```

```
##
```

```
## Sign Bias Test
```

```
## -----
```

```
##               t-value      prob sig
```

```
## Sign Bias      0.2677 7.890e-01
```

```
## Negative Sign Bias 4.9577 7.594e-07 ***
```

```
## Positive Sign Bias 11.4503 1.192e-29 ***
```

```
## Joint Effect    171.4625 6.151e-37 ***
```

```
##
```

```
##
```

```
## Adjusted Pearson Goodness-of-Fit Test:
```

```
## -----
```

```
##   group statistic p-value(g-1)
```

```
## 1    20      586.7 3.190e-112
```

```
## 2    30      639.7 3.575e-116
```

```
## 3    40      657.5 2.302e-113
```

```
## 4    50      679.6 7.012e-112
```

```
##
```

```
##
```

```
## Elapsed time : 0.4278071
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,1)),mean.model =list(armaOrder=c(0,0),
```

```
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
```

```
my_model_hm
```

```
##
```

```
## *-----*
```

```
## *           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        -0.000552   0.000603 -0.91485 0.36027
## omega      0.000225   0.000030  7.44504 0.00000
## alpha1     0.159197   0.022238  7.15875 0.00000
## beta1      0.657757   0.038145 17.24349 0.00000
##
## Robust Standard Errors:
##           Estimate Std. Error  t value Pr(>|t|)
## mu        -0.000552   0.000577 -0.95549 0.339328
## omega      0.000225   0.000080  2.81468 0.004883
## alpha1     0.159197   0.040695  3.91197 0.000092
## beta1      0.657757   0.092723  7.09380 0.000000
##
## LogLikelihood : 5242.235
##
## Information Criteria
## -----
##
## Akaike          -4.0294
## Bayes            -4.0204
## Shibata          -4.0294
## Hannan-Quinn    -4.0261
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##                               statistic p-value
## Lag[1]                               8.024 0.004617
## Lag[2*(p+q)+(p+q)-1] [2]          8.037 0.006326
## Lag[4*(p+q)+(p+q)-1] [5]          8.839 0.018171
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##                               statistic p-value
## Lag[1]                               1.296 0.2549
## Lag[2*(p+q)+(p+q)-1] [5]          2.259 0.5586
## Lag[4*(p+q)+(p+q)-1] [9]          2.648 0.8154
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[3]    0.3664 0.500 2.000 0.5450

```

```

## ARCH Lag[5]      0.5075 1.440 1.667 0.8814
## ARCH Lag[7]      0.5443 2.315 1.543 0.9742
##
## Nyblom stability test
## -----
## Joint Statistic: 0.3636
## Individual Statistics:
## mu      0.01862
## omega   0.04597
## alpha1  0.12434
## beta1   0.08184
##
## 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      2.0499 0.04047 **
## Negative Sign Bias 0.6458 0.51846
## Positive Sign Bias 0.1415 0.88746
## Joint Effect      6.1153 0.10613
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      422.6    8.701e-78
## 2    30      460.6    3.359e-79
## 3    40      485.5    1.924e-78
## 4    50      497.2    1.842e-75
##
##
## Elapsed time : 0.5473549

```

```

spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,0)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

```

```

##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(2,0)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : norm
##
## Optimal Parameters
## -----
##           Estimate Std. Error   t value Pr(>|t|)

```

```

## mu      2.1e-05      6.9e-05      0.31123 0.755626
## omega   1.0e-06      0.0e+00      4.66329 0.000003
## alpha1  2.5e-02      2.7e-05     930.66806 0.000000
## alpha2  2.5e-02      1.2e-05    2133.70221 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      2.1e-05    0.016853 0.001273 0.998984
## omega   1.0e-06    0.000072 0.016574 0.986777
## alpha1  2.5e-02    0.007329 3.411008 0.000647
## alpha2  2.5e-02    0.004466 5.598294 0.000000
##
## LogLikelihood : -53282.89
##
## Information Criteria
## -----
##
## Akaike      40.990
## Bayes      40.999
## Shibata    40.990
## Hannan-Quinn 40.993
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]              2.555 0.1099
## Lag[2*(p+q)+(p+q)-1] [2] 2.624 0.1775
## Lag[4*(p+q)+(p+q)-1] [5] 3.292 0.3563
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##              statistic p-value
## Lag[1]              1.140 0.2856
## Lag[2*(p+q)+(p+q)-1] [5] 2.534 0.4987
## Lag[4*(p+q)+(p+q)-1] [9] 2.829 0.7868
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[3]    0.3599 0.500 2.000 0.5485
## ARCH Lag[5]    0.4041 1.440 1.667 0.9115
## ARCH Lag[7]    0.4616 2.315 1.543 0.9817
##
## Nyblom stability test
## -----
## Joint Statistic: 123.5262
## Individual Statistics:
## mu      0.1919
## omega   53.7989
## alpha1  76.3994
## alpha2  80.6063

```

```
##
## 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      1.705 8.836e-02  *
## Negative Sign Bias  2.695 7.079e-03 ***
## Positive Sign Bias  3.561 3.763e-04 ***
## Joint Effect      23.583 3.052e-05 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      11685          0
## 2    30      17157          0
## 3    40      22056          0
## 4    50      27016          0
##
##
## Elapsed time : 0.08400297
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(0,2)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(0,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : norm
##
## Optimal Parameters
## -----
##      Estimate Std. Error   t value Pr(>|t|)
## mu      0.000023  0.000678 3.4249e-02  0.97268
## omega    0.000001  0.000000 7.6185e+01  0.00000
## beta1    0.000404  0.000060 6.7675e+00  0.00000
## beta2    0.998596  0.000005 1.9383e+05  0.00000
##
## Robust Standard Errors:
##      Estimate Std. Error   t value Pr(>|t|)
## mu      0.000023  0.000648 3.5831e-02  0.971417
## omega    0.000001  0.000000 2.0857e+01  0.000000
## beta1    0.000404  0.000179 2.2602e+00  0.023812
## beta2    0.998596  0.000055 1.8307e+04  0.000000
```

```

##
## LogLikelihood : 5058.314
##
## Information Criteria
## -----
##
## Akaike      -3.8879
## Bayes      -3.8789
## Shibata    -3.8879
## Hannan-Quinn -3.8847
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic  p-value
## Lag[1]                25.18 5.235e-07
## Lag[2*(p+q)+(p+q)-1] [2] 25.23 1.884e-07
## Lag[4*(p+q)+(p+q)-1] [5] 26.68 2.708e-07
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                181.2      0
## Lag[2*(p+q)+(p+q)-1] [5] 205.1      0
## Lag[4*(p+q)+(p+q)-1] [9] 217.0      0
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale  P-Value
## ARCH Lag[3]      10.19 0.500 2.000 1.415e-03
## ARCH Lag[5]      16.54 1.440 1.667 1.580e-04
## ARCH Lag[7]      24.75 2.315 1.543 3.819e-06
##
## Nyblom stability test
## -----
## Joint Statistic: 135.2244
## Individual Statistics:
## mu      0.06419
## omega 3.17938
## beta1 0.18254
## beta2 0.18254
##
## 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      0.2662 7.901e-01
## Negative Sign Bias 4.9517 7.831e-07 ***
## Positive Sign Bias 11.4431 1.290e-29 ***

```

```
## Joint Effect          171.1982 7.014e-37 ***
```

```
##
```

```
##
```

```
## Adjusted Pearson Goodness-of-Fit Test:
```

```
## -----
```

```
##   group statistic p-value(g-1)
```

```
## 1    20      592.4  2.025e-113
```

```
## 2    30      639.3  4.460e-116
```

```
## 3    40      665.0  6.745e-115
```

```
## 4    50      678.5  1.178e-111
```

```
##
```

```
##
```

```
## Elapsed time : 0.4849632
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,2)),mean.model =list(armaOrder=c(0,0),
```

```
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
```

```
my_model_hm
```

```
##
```

```
## *-----*
```

```
## *          GARCH Model Fit          *
```

```
## *-----*
```

```
##
```

```
## Conditional Variance Dynamics
```

```
## -----
```

```
## GARCH Model   : sGARCH(2,2)
```

```
## Mean Model    : ARFIMA(0,0,0)
```

```
## Distribution   : norm
```

```
##
```

```
## Optimal Parameters
```

```
## -----
```

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

```
## mu      -0.000484   0.000602 -0.805285 0.420655
```

```
## omega    0.000290   0.000061  4.791537 0.000002
```

```
## alpha1   0.202246   0.029480  6.860471 0.000000
```

```
## alpha2   0.000000   0.047878  0.000002 0.999999
```

```
## beta1    0.212046   0.142375  1.489344 0.136397
```

```
## beta2    0.345850   0.077568  4.458657 0.000008
```

```
##
```

```
## Robust Standard Errors:
```

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

```
## mu      -0.000484   0.000582 -0.833061 0.404810
```

```
## omega    0.000290   0.000132  2.203845 0.027535
```

```
## alpha1   0.202246   0.049369  4.096613 0.000042
```

```
## alpha2   0.000000   0.088477  0.000001 0.999999
```

```
## beta1    0.212046   0.249739  0.849071 0.395842
```

```
## beta2    0.345850   0.109771  3.150636 0.001629
```

```
##
```

```
## LogLikelihood : 5249.53
```

```
##
```

```
## Information Criteria
```

```
## -----
```

```
##
```

```
## Akaike      -4.0335
```

```

## Bayes          -4.0200
## Shibata        -4.0335
## Hannan-Quinn  -4.0286
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##               statistic  p-value
## Lag[1]                7.463 0.006297
## Lag[2*(p+q)+(p+q)-1][2] 7.464 0.008977
## Lag[4*(p+q)+(p+q)-1][5] 8.318 0.024555
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic  p-value
## Lag[1]                0.3072 0.5794
## Lag[2*(p+q)+(p+q)-1][11] 2.4052 0.9300
## Lag[4*(p+q)+(p+q)-1][19] 6.4889 0.8322
## d.o.f=4
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[5]    0.1947 0.500 2.000 0.6590
## ARCH Lag[7]    0.2191 1.473 1.746 0.9665
## ARCH Lag[9]    0.8876 2.402 1.619 0.9460
##
## Nyblom stability test
## -----
## Joint Statistic: 1.5067
## Individual Statistics:
## mu      0.01951
## omega   0.04316
## alpha1  0.13032
## alpha2  0.13782
## beta1   0.05696
## beta2   0.08128
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.49 1.68 2.12
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##           t-value   prob sig
## Sign Bias      2.0756 0.03803 **
## Negative Sign Bias 0.5143 0.60712
## Positive Sign Bias 0.2657 0.79051
## Joint Effect     5.5250 0.13715
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----

```

```
##      group statistic p-value(g-1)
## 1      20      422.6      8.765e-78
## 2      30      457.4      1.520e-78
## 3      40      478.8      4.321e-77
## 4      50      498.5      1.055e-75
```

```
##
##
```

```
## Elapsed time : 1.055024
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,2)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
```

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

```
##
```

```
## Conditional Variance Dynamics
```

```
## -----
```

```
## GARCH Model   : sGARCH(1,2)
```

```
## Mean Model    : ARFIMA(0,0,0)
```

```
## Distribution : norm
```

```
##
```

```
## Optimal Parameters
```

```
## -----
```

	Estimate	Std. Error	t value	Pr(> t)
## mu	-0.000484	0.000601	-0.80606	0.420211
## omega	0.000290	0.000037	7.79368	0.000000
## alpha1	0.202245	0.027417	7.37666	0.000000
## beta1	0.212046	0.066862	3.17138	0.001517
## beta2	0.345850	0.057166	6.04995	0.000000

```
##
```

```
## Robust Standard Errors:
```

	Estimate	Std. Error	t value	Pr(> t)
## mu	-0.000484	0.000573	-0.84476	0.398245
## omega	0.000290	0.000089	3.25101	0.001150
## alpha1	0.202245	0.048266	4.19022	0.000028
## beta1	0.212046	0.102512	2.06850	0.038593
## beta2	0.345850	0.089089	3.88209	0.000104

```
##
```

```
## LogLikelihood : 5249.53
```

```
##
```

```
## Information Criteria
```

```
## -----
```

```
##
```

```
## Akaike          -4.0343
```

```
## Bayes           -4.0230
```

```
## Shibata         -4.0343
```

```
## Hannan-Quinn    -4.0302
```

```
##
```

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

```
## -----
```

```
##                                statistic  p-value
```



```

## Lag[1] 7.463 0.006296
## Lag[2*(p+q)+(p+q)-1][2] 7.464 0.008977
## Lag[4*(p+q)+(p+q)-1][5] 8.318 0.024554
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##          statistic p-value
## Lag[1] 0.3073 0.5794
## Lag[2*(p+q)+(p+q)-1][8] 0.9251 0.9789
## Lag[4*(p+q)+(p+q)-1][14] 4.0162 0.8787
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##          Statistic Shape Scale P-Value
## ARCH Lag[4] 0.003164 0.500 2.000 0.9551
## ARCH Lag[6] 0.184123 1.461 1.711 0.9721
## ARCH Lag[8] 0.384186 2.368 1.583 0.9898
##
## Nyblom stability test
## -----
## Joint Statistic: 0.665
## Individual Statistics:
## mu 0.01951
## omega 0.04316
## alpha1 0.13032
## beta1 0.05696
## beta2 0.08128
##
## 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 2.0756 0.03803 **
## Negative Sign Bias 0.5143 0.60711
## Positive Sign Bias 0.2657 0.79052
## Joint Effect 5.5250 0.13715
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
## group statistic p-value(g-1)
## 1 20 422.6 8.765e-78
## 2 30 457.4 1.520e-78
## 3 40 478.8 4.321e-77
## 4 50 498.5 1.055e-75
##
##
## Elapsed time : 0.563163

```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,1)),mean.model =list(armaOrder=c(0,0))
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(2,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : norm
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000553    0.000607  -0.91202 0.361758
## omega    0.000224    0.000049   4.61934 0.000004
## alpha1   0.159147    0.023637   6.73302 0.000000
## alpha2   0.000000    0.042884   0.00000 1.000000
## beta1    0.657837    0.070170   9.37494 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000553    0.000624  -0.88601 0.375614
## omega    0.000224    0.000129   1.74167 0.081566
## alpha1   0.159147    0.037289   4.26798 0.000020
## alpha2   0.000000    0.092549   0.00000 1.000000
## beta1    0.657837    0.186151   3.53389 0.000409
##
## LogLikelihood : 5242.176
##
## Information Criteria
## -----
##
## Akaike          -4.0286
## Bayes           -4.0173
## Shibata         -4.0286
## Hannan-Quinn   -4.0245
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic  p-value
## Lag[1]              8.005 0.004666
## Lag[2*(p+q)+(p+q)-1][2] 8.018 0.006398
## Lag[4*(p+q)+(p+q)-1][5] 8.822 0.018352
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
```

```

##                                statistic p-value
## Lag[1]                        1.298  0.2546
## Lag[2*(p+q)+(p+q)-1][8]      2.499  0.7761
## Lag[4*(p+q)+(p+q)-1][14]     6.104  0.6248
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[4]   0.06946 0.500 2.000  0.7921
## ARCH Lag[6]   0.19900 1.461 1.711  0.9689
## ARCH Lag[8]   0.42808 2.368 1.583  0.9870
##
## Nyblom stability test
## -----
## Joint Statistic:  1.9671
## Individual Statistics:
## mu      0.01857
## omega   0.04597
## alpha1  0.12457
## alpha2  0.41416
## beta1   0.08186
##
## 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      2.0482 0.04064 **
## Negative Sign Bias 0.6462 0.51819
## Positive Sign Bias 0.1426 0.88665
## Joint Effect    6.1066 0.10654
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      422.6   8.701e-78
## 2    30      460.6   3.359e-79
## 3    40      485.1   2.314e-78
## 4    50      497.2   1.874e-75
##
##
## Elapsed time : 0.449388

```

```

spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(0,1)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

```

```

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

```

```

## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model : sGARCH(0,1)
## Mean Model : ARFIMA(0,0,0)
## Distribution : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error   t value Pr(>|t|)
## mu    -0.000456   0.000646   -0.70624  0.48004
## omega  0.000027   0.000005    5.86996  0.00000
## beta1  0.984486   0.000343 2869.34191  0.00000
## skew   1.189873   0.030812  38.61744  0.00000
## shape  2.511569   0.125716  19.97815  0.00000
##
## Robust Standard Errors:
##      Estimate Std. Error   t value Pr(>|t|)
## mu    -0.000456   0.000635   -0.71866  0.47235
## omega  0.000027   0.000005    5.05107  0.00000
## beta1  0.984486   0.000119 8298.71590  0.00000
## skew   1.189873   0.028916  41.14864  0.00000
## shape  2.511569   0.131867  19.04617  0.00000
##
## LogLikelihood : 5594.417
##
## Information Criteria
## -----
##
## Akaike      -4.2996
## Bayes       -4.2883
## Shibata     -4.2996
## Hannan-Quinn -4.2955
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##              statistic  p-value
## Lag[1]              25.51 4.393e-07
## Lag[2*(p+q)+(p+q)-1] [2] 25.57 1.542e-07
## Lag[4*(p+q)+(p+q)-1] [5] 27.07 2.102e-07
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##              statistic  p-value
## Lag[1]              181.6    0
## Lag[2*(p+q)+(p+q)-1] [2] 190.8    0
## Lag[4*(p+q)+(p+q)-1] [5] 205.2    0
## d.o.f=1
##
## Weighted ARCH LM Tests
## -----

```

```

##          Statistic Shape Scale   P-Value
## ARCH Lag[2]      18.28 0.500 2.000 1.910e-05
## ARCH Lag[4]      28.92 1.397 1.611 5.800e-08
## ARCH Lag[6]      33.89 2.222 1.500 6.598e-09
##
## Nyblom stability test
## -----
## Joint Statistic:  0.5297
## Individual Statistics:
## mu      0.1209
## omega 0.1891
## beta1 0.1917
## skew  0.1009
## shape 0.1836
##
## 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      0.2807 7.790e-01
## Negative Sign Bias  4.8843 1.101e-06 ***
## Positive Sign Bias 11.6008 2.261e-30 ***
## Joint Effect      170.8591 8.302e-37 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      8.646   9.789e-01
## 2    30     72.585   1.332e-05
## 3    40     45.231   2.279e-01
## 4    50     66.346   4.994e-02
##
##
## Elapsed time : 1.407672

```

```

spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,0)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

```

```

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

```

```

## Optimal Parameters
## -----
##           Estimate   Std. Error   t value   Pr(>|t|)
## mu       -0.000239    0.000568  -0.42122   0.67359
## omega     0.000851    0.000114   7.45631   0.00000
## alpha1    0.690368    0.121578   5.67841   0.00000
## skew      1.252926    0.034898  35.90250   0.00000
## shape     2.831086    0.178200  15.88715   0.00000
##
## Robust Standard Errors:
##           Estimate   Std. Error   t value   Pr(>|t|)
## mu       -0.000239    0.000592  -0.40448   0.68586
## omega     0.000851    0.000124   6.87921   0.00000
## alpha1    0.690368    0.125707   5.49188   0.00000
## skew      1.252926    0.039121  32.02688   0.00000
## shape     2.831086    0.184006  15.38580   0.00000
##
## LogLikelihood : 5716.244
##
## Information Criteria
## -----
##
## Akaike          -4.3933
## Bayes           -4.3820
## Shibata         -4.3933
## Hannan-Quinn   -4.3892
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##                               statistic p-value
## Lag[1]                                6.501 0.01078
## Lag[2*(p+q)+(p+q)-1] [2]          6.531 0.01588
## Lag[4*(p+q)+(p+q)-1] [5]          7.969 0.02999
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##                               statistic p-value
## Lag[1]                                1.789 0.1811
## Lag[2*(p+q)+(p+q)-1] [2]          1.800 0.2982
## Lag[4*(p+q)+(p+q)-1] [5]          3.070 0.3945
## d.o.f=1
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[2]    0.02226 0.500 2.000 0.8814
## ARCH Lag[4]    1.44103 1.397 1.611 0.5779
## ARCH Lag[6]    2.60748 2.222 1.500 0.5486
##
## Nyblom stability test
## -----
## Joint Statistic: 1.0512

```

```
## Individual Statistics:
## mu      0.07334
## omega   0.19854
## alpha1  0.33958
## skew    0.15166
## shape   0.10358
##
## 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      2.0596 0.03954 **
## Negative Sign Bias 0.6744 0.50009
## Positive Sign Bias 2.1711 0.03001 **
## Joint Effect     9.2816 0.02577 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      19.51   0.4247298
## 2    30      59.43   0.0007267
## 3    40      42.00   0.3422059
## 4    50      53.69   0.2992545
##
##
## Elapsed time : 1.450274
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,1)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(1,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error  t value Pr(>|t|)
## mu      0.000020   0.000540  0.037577 0.970025
## omega    0.000226   0.000049  4.597995 0.000004
## alpha1   0.357891   0.071134  5.031214 0.000000
## beta1    0.582941   0.056504 10.316793 0.000000
## skew     1.298620   0.036983 35.113558 0.000000
```

```

## shape    2.983342    0.192455 15.501508 0.000000
##
## Robust Standard Errors:
##      Estimate   Std. Error   t value Pr(>|t|)
## mu          0.000020    0.000548  0.037023 0.970466
## omega       0.000226    0.000067  3.361324 0.000776
## alpha1     0.357891    0.080518  4.444866 0.000009
## beta1      0.582941    0.083813  6.955246 0.000000
## skew       1.298620    0.043492 29.858543 0.000000
## shape     2.983342    0.194355 15.349939 0.000000
##
## LogLikelihood : 5754.14
##
## Information Criteria
## -----
##
## Akaike          -4.4216
## Bayes           -4.4081
## Shibata         -4.4217
## Hannan-Quinn   -4.4167
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]              6.300 0.01208
## Lag[2*(p+q)+(p+q)-1] [2] 6.399 0.01722
## Lag[4*(p+q)+(p+q)-1] [5] 7.336 0.04296
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##              statistic p-value
## Lag[1]              0.111 0.7390
## Lag[2*(p+q)+(p+q)-1] [5] 2.205 0.5709
## Lag[4*(p+q)+(p+q)-1] [9] 2.926 0.7712
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[3]    0.9329 0.500 2.000 0.3341
## ARCH Lag[5]    1.4712 1.440 1.667 0.5999
## ARCH Lag[7]    1.5614 2.315 1.543 0.8090
##
## Nyblom stability test
## -----
## Joint Statistic: 0.6731
## Individual Statistics:
## mu          0.05038
## omega       0.14038
## alpha1     0.08650
## beta1      0.07352
## skew       0.16519

```



```
## shape 0.08780
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.49 1.68 2.12
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##          t-value   prob sig
## Sign Bias      2.5001 0.01248 **
## Negative Sign Bias 0.4062 0.68461
## Positive Sign Bias 1.8615 0.06279 *
## Joint Effect      9.8380 0.01999 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      24.86   0.1651505
## 2    30      63.79   0.0002037
## 3    40      46.25   0.1979377
## 4    50      60.77   0.1207402
##
##
## Elapsed time : 1.618748
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,0)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(2,0)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error t value Pr(>|t|)
## mu      -0.000115  0.000560 -0.20589 0.836876
## omega    0.000742  0.000100  7.43893 0.000000
## alpha1   0.560907  0.104208  5.38260 0.000000
## alpha2   0.218335  0.060340  3.61842 0.000296
## skew     1.270936  0.036083 35.22265 0.000000
## shape    2.860891  0.180668 15.83509 0.000000
##
## Robust Standard Errors:
##      Estimate Std. Error t value Pr(>|t|)
## mu      -0.000115  0.000590 -0.19522 0.845224
```

```

## omega    0.000742    0.000114    6.50996 0.000000
## alpha1   0.560907    0.100828    5.56302 0.000000
## alpha2   0.218335    0.053950    4.04702 0.000052
## skew     1.270936    0.043216   29.40865 0.000000
## shape    2.860891    0.190669   15.00450 0.000000
##
## LogLikelihood : 5735.569
##
## Information Criteria
## -----
##
## Akaike          -4.4074
## Bayes           -4.3938
## Shibata         -4.4074
## Hannan-Quinn   -4.4025
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                6.377 0.01156
## Lag[2*(p+q)+(p+q)-1] [2]    6.446 0.01673
## Lag[4*(p+q)+(p+q)-1] [5]    7.614 0.03671
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.9859 0.3207
## Lag[2*(p+q)+(p+q)-1] [5]    3.1535 0.3797
## Lag[4*(p+q)+(p+q)-1] [9]    4.9587 0.4355
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##                Statistic Shape Scale P-Value
## ARCH Lag[3]    0.02221 0.500 2.000 0.8815
## ARCH Lag[5]    1.04637 1.440 1.667 0.7192
## ARCH Lag[7]    2.63340 2.315 1.543 0.5853
##
## Nyblom stability test
## -----
## Joint Statistic: 0.8797
## Individual Statistics:
## mu      0.04586
## omega   0.16980
## alpha1  0.19041
## alpha2  0.09935
## skew    0.18499
## shape   0.09122
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.49 1.68 2.12
## Individual Statistic: 0.35 0.47 0.75

```

```
##
## Sign Bias Test
## -----
##          t-value    prob sig
## Sign Bias      1.9766 0.04819 **
## Negative Sign Bias 0.7867 0.43155
## Positive Sign Bias 2.0537 0.04011 **
## Joint Effect      9.1317 0.02759 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      21.23    0.324191
## 2    30      58.05    0.001074
## 3    40      48.37    0.144504
## 4    50      55.42    0.245358
##
##
## Elapsed time : 1.710994
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(0,2)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(0,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error   t value Pr(>|t|)
## mu    -0.000452  0.000648   -0.69759 0.485433
## omega  0.000026  0.000005    5.00256 0.000001
## beta1  0.985380  0.000059 16606.95416 0.000000
## beta2  0.000000  0.002294    0.00000 1.000000
## skew   1.190096  0.030946   38.45700 0.000000
## shape  2.512737  0.125611   20.00413 0.000000
##
## Robust Standard Errors:
##      Estimate Std. Error   t value Pr(>|t|)
## mu    -0.000452  0.000642  -7.0327e-01 0.48189
## omega  0.000026  0.000004  5.9465e+00 0.000000
## beta1  0.985380  0.000038  2.5657e+04 0.000000
## beta2  0.000000  0.000996  1.0000e-06 1.000000
## skew   1.190096  0.029176  4.0790e+01 0.000000
## shape  2.512737  0.133282  1.8853e+01 0.000000
```

```

##
## LogLikelihood : 5594.406
##
## Information Criteria
## -----
##
## Akaike      -4.2988
## Bayes      -4.2852
## Shibata    -4.2988
## Hannan-Quinn -4.2939
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic    p-value
## Lag[1]                25.50 4.416e-07
## Lag[2*(p+q)+(p+q)-1] [2]    25.56 1.550e-07
## Lag[4*(p+q)+(p+q)-1] [5]    27.07 2.109e-07
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic    p-value
## Lag[1]                181.4      0
## Lag[2*(p+q)+(p+q)-1] [5]    205.0      0
## Lag[4*(p+q)+(p+q)-1] [9]    216.7      0
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale    P-Value
## ARCH Lag[3]      10.14 0.500 2.000 1.453e-03
## ARCH Lag[5]      16.32 1.440 1.667 1.792e-04
## ARCH Lag[7]      24.46 2.315 1.543 4.539e-06
##
## Nyblom stability test
## -----
## Joint Statistic: 0.4894
## Individual Statistics:
## mu      0.1242
## omega 0.1925
## beta1 0.1957
## beta2 0.1958
## skew 0.1006
## shape 0.1866
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.49 1.68 2.12
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##
##                t-value      prob sig
## Sign Bias      0.2797 7.797e-01

```

```
## Negative Sign Bias    4.8817 1.116e-06 ***
## Positive Sign Bias   11.5980 2.333e-30 ***
## Joint Effect         170.7463 8.781e-37 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      8.323   9.831e-01
## 2    30     74.846   6.405e-06
## 3    40     44.985   2.356e-01
## 4    50     64.731   6.541e-02
##
##
## Elapsed time : 1.533
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,2)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(2,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      0.000075   0.000541   0.138332 0.889978
## omega    0.000239   0.000143   1.666436 0.095627
## alpha1   0.394337   0.073812   5.342425 0.000000
## alpha2   0.000000   0.239444   0.000002 0.999999
## beta1    0.287611   0.510094   0.563840 0.572863
## beta2    0.255109   0.239515   1.065106 0.286828
## skew     1.305804   0.037387  34.926337 0.000000
## shape    2.993976   0.183234  16.339636 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      0.000075   0.000548   0.136469 0.89145
## omega    0.000239   0.000307   0.777875 0.43664
## alpha1   0.394337   0.069533   5.671253 0.00000
## alpha2   0.000000   0.523479   0.000001 1.00000
## beta1    0.287611   1.135802   0.253223 0.80010
## beta2    0.255109   0.604111   0.422288 0.67282
## skew     1.305804   0.045896  28.451198 0.00000
## shape    2.993976   0.238480  12.554424 0.00000
##
```

```

## LogLikelihood : 5757.812
##
## Information Criteria
## -----
##
## Akaike      -4.4229
## Bayes      -4.4049
## Shibata    -4.4230
## Hannan-Quinn -4.4164
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                5.799 0.01604
## Lag[2*(p+q)+(p+q)-1][2] 5.865 0.02390
## Lag[4*(p+q)+(p+q)-1][5] 6.722 0.06054
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.231 0.6308
## Lag[2*(p+q)+(p+q)-1][11] 3.305 0.8308
## Lag[4*(p+q)+(p+q)-1][19] 5.588 0.9041
## d.o.f=4
##
## Weighted ARCH LM Tests
## -----
##
##                Statistic Shape Scale P-Value
## ARCH Lag[5]      0.5054 0.500 2.000 0.4772
## ARCH Lag[7]      0.6870 1.473 1.746 0.8456
## ARCH Lag[9]      1.4805 2.402 1.619 0.8555
##
## Nyblom stability test
## -----
## Joint Statistic: 1.5524
## Individual Statistics:
## mu      0.05152
## omega   0.14094
## alpha1  0.07646
## alpha2  0.12909
## beta1   0.07355
## beta2   0.07702
## skew    0.15394
## shape   0.08681
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.89 2.11 2.59
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##                t-value    prob sig

```

```
## Sign Bias          2.5278 0.01154 **
## Negative Sign Bias 0.4456 0.65596
## Positive Sign Bias 1.9873 0.04699 **
## Joint Effect       10.3140 0.01608 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      17.22    0.5752786
## 2    30      60.08    0.0006042
## 3    40      49.05    0.1300010
## 4    50      61.96    0.1011570
##
##
## Elapsed time : 2.716993
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(1,2)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(1,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value  Pr(>|t|)
## mu          0.000075    0.000541  0.13812 0.890149
## omega        0.000239    0.000049  4.84768 0.000001
## alpha1       0.394397    0.074605  5.28649 0.000000
## beta1        0.287609    0.090345  3.18343 0.001455
## beta2        0.255060    0.081022  3.14802 0.001644
## skew         1.305789    0.037766 34.57558 0.000000
## shape        2.993875    0.194228 15.41426 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error  t value  Pr(>|t|)
## mu          0.000075    0.000549  0.13618 0.891678
## omega        0.000239    0.000063  3.78107 0.000156
## alpha1       0.394397    0.078003  5.05619 0.000000
## beta1        0.287609    0.067919  4.23455 0.000023
## beta2        0.255060    0.087266  2.92280 0.003469
## skew         1.305789    0.044963 29.04169 0.000000
## shape        2.993875    0.193670 15.45863 0.000000
##
## LogLikelihood : 5757.812
```

```

##
## Information Criteria
## -----
##
## Akaike      -4.4237
## Bayes      -4.4079
## Shibata    -4.4237
## Hannan-Quinn -4.4180
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                5.799 0.01604
## Lag[2*(p+q)+(p+q)-1][2] 5.865 0.02390
## Lag[4*(p+q)+(p+q)-1][5] 6.722 0.06053
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.2311 0.6307
## Lag[2*(p+q)+(p+q)-1][8] 2.3471 0.8024
## Lag[4*(p+q)+(p+q)-1][14] 4.1872 0.8618
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##
##                Statistic Shape Scale P-Value
## ARCH Lag[4]      0.2874 0.500 2.000 0.5919
## ARCH Lag[6]      0.7433 1.461 1.711 0.8222
## ARCH Lag[8]      1.0528 2.368 1.583 0.9164
##
## Nyblom stability test
## -----
## Joint Statistic: 0.7623
## Individual Statistics:
## mu      0.05153
## omega   0.14094
## alpha1  0.07645
## beta1   0.07352
## beta2   0.07697
## skew    0.15404
## shape   0.08679
##
## 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      2.5278 0.01154 **
## Negative Sign Bias 0.4456 0.65589

```



```
## Positive Sign Bias  1.9875 0.04698 **
## Joint Effect      10.3144 0.01607 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      17.22   0.5752786
## 2    30      60.08   0.0006042
## 3    40      49.05   0.1300010
## 4    50      61.85   0.1029340
##
##
## Elapsed time : 1.811992
```

```
spec_of_garch_hm<- ugarchspec(variance.model = list(garchOrder=c(2,1)),mean.model =list(armaOrder=c(0,0),
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(2,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      0.000019   0.000540   0.035509 0.971674
## omega    0.000226   0.000224   1.009946 0.312521
## alpha1   0.357251   0.056287   6.346931 0.000000
## alpha2   0.000000   0.274977   0.000000 1.000000
## beta1    0.583942   0.322237   1.812154 0.069962
## skew     1.298275   0.030926  41.979635 0.000000
## shape    2.981740   0.213429  13.970636 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      0.000019   0.000552   0.034766 0.972266
## omega    0.000226   0.001263   0.178851 0.858055
## alpha1   0.357251   0.465623   0.767254 0.442931
## alpha2   0.000000   1.568333   0.000000 1.000000
## beta1    0.583942   1.800795   0.324269 0.745734
## skew     1.298275   0.119602  10.854983 0.000000
## shape    2.981740   1.638870   1.819387 0.068852
##
## LogLikelihood : 5754.062
##
## Information Criteria
```

```

## -----
##
## Akaike          -4.4208
## Bayes           -4.4050
## Shibata         -4.4208
## Hannan-Quinn   -4.4151
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]          6.278 0.01223
## Lag[2*(p+q)+(p+q)-1][2] 6.378 0.01745
## Lag[4*(p+q)+(p+q)-1][5] 7.316 0.04345
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]          0.1083 0.7421
## Lag[2*(p+q)+(p+q)-1][8] 2.7159 0.7373
## Lag[4*(p+q)+(p+q)-1][14] 4.8828 0.7839
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[4]    0.3924 0.500 2.000 0.5311
## ARCH Lag[6]    0.7082 1.461 1.711 0.8324
## ARCH Lag[8]    0.9146 2.368 1.583 0.9365
##
## Nyblom stability test
## -----
## Joint Statistic: 3.8548
## Individual Statistics:
## mu      0.05012
## omega   0.14029
## alpha1  0.08666
## alpha2  0.58290
## beta1   0.07364
## skew    0.16354
## shape   0.08786
##
## 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      2.4981 0.01255 **
## Negative Sign Bias 0.4035 0.68664
## Positive Sign Bias 1.8563 0.06352 *
## Joint Effect    9.8093 0.02026 **

```

```

##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##      group statistic p-value(g-1)
## 1      20      25.00    0.1605422
## 2      30      65.11    0.0001373
## 3      40      46.49    0.1911055
## 4      50      60.58    0.1241588
##
##
## Elapsed time : 1.552002

spec_of_garch_hm<-ugarchspec(variance.model =list(model="eGARCH",garchOrder=c(1,1)),mean.model = list(a
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : eGARCH(1,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000257   0.000536 -0.47998 0.631243
## omega   -1.109089   0.238498 -4.65030 0.000003
## alpha1  -0.011527   0.027812 -0.41446 0.678533
## beta1    0.837270   0.034864 24.01507 0.000000
## gamma1   0.472441   0.056943  8.29681 0.000000
## skew     1.289988   0.036823 35.03198 0.000000
## shape    3.045425   0.196872 15.46904 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000257   0.000565 -0.45487 0.649204
## omega   -1.109089   0.361619 -3.06700 0.002162
## alpha1  -0.011527   0.030894 -0.37312 0.709062
## beta1    0.837270   0.052974 15.80527 0.000000
## gamma1   0.472441   0.070278  6.72245 0.000000
## skew     1.289988   0.043528 29.63564 0.000000
## shape    3.045425   0.199407 15.27240 0.000000
##
## LogLikelihood : 5756.141
##
## Information Criteria
## -----
##

```

```

## Akaike          -4.4224
## Bayes           -4.4066
## Shibata         -4.4224
## Hannan-Quinn   -4.4167
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##               statistic p-value
## Lag[1]                6.203 0.01275
## Lag[2*(p+q)+(p+q)-1][2] 6.286 0.01846
## Lag[4*(p+q)+(p+q)-1][5] 7.179 0.04691
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic p-value
## Lag[1]                0.0919 0.7618
## Lag[2*(p+q)+(p+q)-1][5] 1.4895 0.7425
## Lag[4*(p+q)+(p+q)-1][9] 1.9581 0.9100
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[3]    0.6805 0.500 2.000 0.4094
## ARCH Lag[5]    0.9045 1.440 1.667 0.7615
## ARCH Lag[7]    0.9434 2.315 1.543 0.9226
##
## Nyblom stability test
## -----
## Joint Statistic: 1.0447
## Individual Statistics:
## mu      0.02739
## omega   0.06910
## alpha1  0.30928
## beta1   0.07473
## gamma1  0.11247
## skew    0.13624
## shape   0.11201
##
## 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      2.2309 0.02577 **
## Negative Sign Bias 0.4485 0.65384
## Positive Sign Bias 1.4438 0.14892
## Joint Effect    8.5611 0.03573 **
##
##

```

```
## Adjusted Pearson Goodness-of-Fit Test:
```

```
## -----
```

```
##   group statistic p-value(g-1)
```

```
## 1    20      17.48    0.557591
```

```
## 2    30      52.30    0.005046
```

```
## 3    40      46.89    0.180364
```

```
## 4    50      69.54    0.028370
```

```
##
```

```
##
```

```
## Elapsed time : 1.609997
```

this model is rejected since there is no leverage effect.

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(1,1)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
```

```
## *-----*
```

```
## *          GARCH Model Fit          *
```

```
## *-----*
```

```
##
```

```
## Conditional Variance Dynamics
```

```
## -----
```

```
## GARCH Model   : gjrGARCH(1,1)
```

```
## Mean Model    : ARFIMA(0,0,0)
```

```
## Distribution   : sstd
```

```
##
```

```
## Optimal Parameters
```

```
## -----
```

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

```
## mu      -0.000093    0.000544   -0.1713  0.863990
```

```
## omega    0.000220    0.000048    4.5905  0.000004
```

```
## alpha1   0.325089    0.068840    4.7224  0.000002
```

```
## beta1    0.582269    0.055553   10.4814  0.000000
```

```
## gamma1   0.086331    0.073188    1.1796  0.238170
```

```
## skew     1.298861    0.037178   34.9366  0.000000
```

```
## shape    2.992478    0.192316   15.5602  0.000000
```

```
##
```

```
## Robust Standard Errors:
```

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

```
## mu      -0.000093    0.000566   -0.16458  0.869275
```

```
## omega    0.000220    0.000064    3.45118  0.000558
```

```
## alpha1   0.325089    0.075644    4.29764  0.000017
```

```
## beta1    0.582269    0.080180    7.26199  0.000000
```

```
## gamma1   0.086331    0.077849    1.10895  0.267451
```

```
## skew     1.298861    0.043929   29.56746  0.000000
```

```
## shape    2.992478    0.192750   15.52514  0.000000
```

```
##
```

```
## LogLikelihood : 5754.87
```

```
##
```

```
## Information Criteria
```

```
## -----
```

```

##
## Akaike          -4.4214
## Bayes           -4.4057
## Shibata         -4.4215
## Hannan-Quinn   -4.4157
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##               statistic p-value
## Lag[1]                6.408 0.01136
## Lag[2*(p+q)+(p+q)-1] [2]    6.505 0.01614
## Lag[4*(p+q)+(p+q)-1] [5]    7.403 0.04135
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic p-value
## Lag[1]                0.05588 0.8131
## Lag[2*(p+q)+(p+q)-1] [5]    2.01184 0.6156
## Lag[4*(p+q)+(p+q)-1] [9]    2.69260 0.8084
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[3]    0.8841 0.500 2.000 0.3471
## ARCH Lag[5]    1.3333 1.440 1.667 0.6372
## ARCH Lag[7]    1.4243 2.315 1.543 0.8364
##
## Nyblom stability test
## -----
## Joint Statistic: 0.941
## Individual Statistics:
## mu      0.05304
## omega   0.12890
## alpha1  0.07097
## beta1   0.06696
## gamma1  0.22608
## skew    0.16372
## shape   0.08189
##
## 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      2.1343 0.03291 **
## Negative Sign Bias 0.6246 0.53226
## Positive Sign Bias 1.4962 0.13472
## Joint Effect    8.7885 0.03224 **
##

```

```
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##      group statistic p-value(g-1)
## 1      20      23.40    0.2201825
## 2      30      58.65    0.0009075
## 3      40      55.08    0.0454688
## 4      50      63.77    0.0763960
##
##
## Elapsed time : 3.777005
```

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(1,2)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(1,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error  t value Pr(>|t|)
## mu      -0.000023  0.000546 -0.041742 0.966704
## omega    0.000232  0.000048  4.802533 0.000002
## alpha1   0.362014  0.074397  4.865945 0.000001
## beta1    0.300193  0.092835  3.233627 0.001222
## beta2    0.243230  0.082327  2.954441 0.003132
## gamma1   0.082775  0.082140  1.007736 0.313581
## skew     1.305833  0.037683 34.653328 0.000000
## shape    3.002980  0.194327 15.453204 0.000000
##
## Robust Standard Errors:
##      Estimate Std. Error  t value Pr(>|t|)
## mu      -0.000023  0.000571 -0.039858 0.968206
## omega    0.000232  0.000060  3.852563 0.000117
## alpha1   0.362014  0.076143  4.754405 0.000002
## beta1    0.300193  0.070311  4.269483 0.000020
## beta2    0.243230  0.087084  2.793047 0.005221
## gamma1   0.082775  0.089137  0.928634 0.353079
## skew     1.305833  0.044764 29.171484 0.000000
## shape    3.002980  0.192387 15.609059 0.000000
##
## LogLikelihood : 5758.332
##
## Information Criteria
## -----
```

```

##
## Akaike          -4.4233
## Bayes           -4.4053
## Shibata         -4.4234
## Hannan-Quinn   -4.4168
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##               statistic p-value
## Lag[1]                5.920 0.01497
## Lag[2*(p+q)+(p+q)-1][2] 5.991 0.02212
## Lag[4*(p+q)+(p+q)-1][5] 6.823 0.05724
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic p-value
## Lag[1]                0.1583 0.6907
## Lag[2*(p+q)+(p+q)-1][8] 2.1524 0.8348
## Lag[4*(p+q)+(p+q)-1][14] 4.0486 0.8756
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[4]    0.2544 0.500 2.000 0.6140
## ARCH Lag[6]    0.6405 1.461 1.711 0.8520
## ARCH Lag[8]    0.9668 2.368 1.583 0.9292
##
## Nyblom stability test
## -----
## Joint Statistic: 0.9656
## Individual Statistics:
## mu      0.05254
## omega   0.13075
## alpha1  0.06490
## beta1   0.06861
## beta2   0.06955
## gamma1  0.19658
## skew    0.15424
## shape   0.08244
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      1.89 2.11 2.59
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##           t-value   prob sig
## Sign Bias      2.1647 0.03050 **
## Negative Sign Bias 0.6426 0.52055
## Positive Sign Bias 1.6422 0.10066
## Joint Effect    9.1608 0.02723 **

```



```
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1     20      18.52    0.487791
## 2     30      55.23    0.002328
## 3     40      52.15    0.077459
## 4     50      56.96    0.203005
##
##
## Elapsed time : 3.951006
```

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(2,1)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(2,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      -0.000094   0.000539  -0.174208 0.861702
## omega    0.000219   0.000154   1.427241 0.153510
## alpha1   0.323861   0.030435  10.640952 0.000000
## alpha2   0.000000   0.191102   0.000000 1.000000
## beta1    0.584135   0.217373   2.687253 0.007204
## gamma1   0.088490   0.105166   0.841436 0.400104
## gamma2  -0.002779   0.095071  -0.029235 0.976677
## skew     1.298573   0.034519  37.619353 0.000000
## shape    2.991178   0.110955  26.958394 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      -0.000094   0.000656  -0.143249 0.886093
## omega    0.000219   0.000595   0.368175 0.712743
## alpha1   0.323861   0.204884   1.580707 0.113945
## alpha2   0.000000   0.754824   0.000000 1.000000
## beta1    0.584135   0.826356   0.706881 0.479640
## gamma1   0.088490   0.110012   0.804368 0.421184
## gamma2  -0.002779   0.121610  -0.022855 0.981766
## skew     1.298573   0.067969  19.105427 0.000000
## shape    2.991178   0.886839   3.372853 0.000744
##
## LogLikelihood : 5754.794
```

```

##
## Information Criteria
## -----
##
## Akaike      -4.4198
## Bayes      -4.3995
## Shibata    -4.4199
## Hannan-Quinn -4.4125
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                6.384 0.01151
## Lag[2*(p+q)+(p+q)-1] [2]    6.482 0.01637
## Lag[4*(p+q)+(p+q)-1] [5]    7.382 0.04185
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.05326 0.8175
## Lag[2*(p+q)+(p+q)-1] [8]    2.48372 0.7787
## Lag[4*(p+q)+(p+q)-1] [14]   4.72712 0.8025
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##
##                Statistic Shape Scale P-Value
## ARCH Lag[4]    0.3297 0.500 2.000 0.5658
## ARCH Lag[6]    0.5928 1.461 1.711 0.8657
## ARCH Lag[8]    0.8223 2.368 1.583 0.9486
##
## Nyblom stability test
## -----
## Joint Statistic: 4.8984
## Individual Statistics:
## mu      0.05268
## omega   0.12865
## alpha1  0.07112
## alpha2  0.60819
## beta1   0.06712
## gamma1  0.22618
## gamma2  0.20112
## skew    0.16180
## shape   0.08188
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      2.1 2.32 2.82
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##                t-value      prob sig

```

```
## Sign Bias          2.133 0.03301  **
## Negative Sign Bias 0.625 0.53204
## Positive Sign Bias 1.489 0.13673
## Joint Effect       8.780 0.03236  **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      23.58    0.21257
## 2    30      56.45    0.00167
## 3    40      56.28    0.03610
## 4    50      62.73    0.08993
##
##
## Elapsed time : 4.890011
```

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(2,2)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(2,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      -0.000062   0.000544 -0.113278 0.909811
## omega    0.000250   0.000075  3.326406 0.000880
## alpha1   0.392820   0.080214  4.897134 0.000001
## alpha2   0.000000   0.136761  0.000001 0.999999
## beta1    0.217187   0.321488  0.675567 0.499316
## beta2    0.283618   0.144337  1.964969 0.049418
## gamma1   -0.010421   0.091185 -0.114284 0.909013
## gamma2    0.123906   0.050189  2.468772 0.013558
## skew     1.303377   0.037370 34.877867 0.000000
## shape     3.006382   0.192534 15.614837 0.000000
##
## Robust Standard Errors:
##      Estimate  Std. Error   t value Pr(>|t|)
## mu      -0.000062   0.000574 -0.107387 0.91448
## omega    0.000250   0.000144  1.738685 0.08209
## alpha1   0.392820   0.074009  5.307725 0.00000
## alpha2   0.000000   0.228499  0.000001 1.00000
## beta1    0.217187   0.525521  0.413279 0.67940
## beta2    0.283618   0.292396  0.969978 0.33206
```

```

## gamma1 -0.010421    0.092780 -0.112319  0.91057
## gamma2  0.123906    0.098028  1.263983  0.20624
## skew    1.303377    0.044862 29.053180  0.00000
## shape   3.006382    0.201190 14.943004  0.00000
##
## LogLikelihood : 5759.305
##
## Information Criteria
## -----
##
## Akaike          -4.4225
## Bayes           -4.4000
## Shibata         -4.4226
## Hannan-Quinn   -4.4144
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                5.880 0.01531
## Lag[2*(p+q)+(p+q)-1][2] 5.925 0.02303
## Lag[4*(p+q)+(p+q)-1][5] 6.777 0.05873
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.215 0.6428
## Lag[2*(p+q)+(p+q)-1][11] 3.112 0.8552
## Lag[4*(p+q)+(p+q)-1][19] 5.378 0.9178
## d.o.f=4
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[5]    0.4797 0.500 2.000 0.4886
## ARCH Lag[7]    0.6932 1.473 1.746 0.8439
## ARCH Lag[9]    1.4579 2.402 1.619 0.8594
##
## Nyblom stability test
## -----
## Joint Statistic:  1.1057
## Individual Statistics:
## mu      0.06388
## omega   0.12788
## alpha1  0.05695
## alpha2  0.06136
## beta1   0.06087
## beta2   0.06195
## gamma1  0.18352
## gamma2  0.14391
## skew    0.16535
## shape   0.08022
##

```

```
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      2.29 2.54 3.05
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##          t-value    prob sig
## Sign Bias      2.0963 0.03615 **
## Negative Sign Bias 0.5505 0.58204
## Positive Sign Bias 1.7315 0.08349 *
## Joint Effect      8.3630 0.03908 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      15.63      0.68175
## 2    30      48.17      0.01411
## 3    40      44.55      0.24953
## 4    50      54.04      0.28796
##
##
## Elapsed time : 10.728
```

sGARCH(0,2) Akaike -4.2988 sstd sGARCH(0,1) Akaike -4.2996 sstd sGARCH(1,0) Akaike -4.3933 sstd
sGARCH(2,0) Akaike -4.4074 sstd gjrGARCH(2,1) Akaike -4.4198 sstd sGARCH(2,1) Akaike -4.4208 sstd
gjrGARCH(1,1) Akaike -4.4214 sstd sGARCH(1,1) Akaike -4.4216 sstd gjrGARCH(2,2) Akaike -4.4225 sstd
sGARCH(2,2) Akaike -4.4229 sstd gjrGARCH(1,2) Akaike -4.4233 sstd sGARCH(1,2) Akaike -4.4237 sstd

interestingly a simple garch model is the best choice also to make the model simple i am taking sGARCH
(1,2) with no ARMA component.

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(1,3)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(1,3)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      0.000025   0.000547  0.045533 0.963683
## omega    0.000237   0.000049  4.810035 0.000002
## alpha1   0.367888   0.074968  4.907253 0.000001
## beta1    0.288182   0.107093  2.690956 0.007125
```

```

## beta2    0.124810    0.109319    1.141698    0.253580
## beta3    0.117955    0.072893    1.618187    0.105622
## gamma1   0.100251    0.086270    1.162063    0.245210
## skew     1.309344    0.037506   34.910587    0.000000
## shape    2.994535    0.193704   15.459313    0.000000
##
## Robust Standard Errors:
##      Estimate   Std. Error   t value Pr(>|t|)
## mu          0.000025    0.000573    0.043518  0.965289
## omega       0.000237    0.000059    4.010179  0.000061
## alpha1     0.367888    0.073876    4.979831  0.000001
## beta1      0.288182    0.092425    3.118009  0.001821
## beta2      0.124810    0.106565    1.171208  0.241515
## beta3      0.117955    0.074213    1.589413  0.111967
## gamma1     0.100251    0.092058    1.089006  0.276151
## skew       1.309344    0.044128   29.671711  0.000000
## shape      2.994535    0.192015   15.595303  0.000000
##
## LogLikelihood : 5759.558
##
## Information Criteria
## -----
##
## Akaike          -4.4235
## Bayes           -4.4032
## Shibata         -4.4235
## Hannan-Quinn   -4.4162
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##                statistic p-value
## Lag[1]                5.773 0.01627
## Lag[2*(p+q)+(p+q)-1] [2]    5.837 0.02432
## Lag[4*(p+q)+(p+q)-1] [5]    6.623 0.06393
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##                statistic p-value
## Lag[1]                0.1674 0.6824
## Lag[2*(p+q)+(p+q)-1] [11]    2.8791 0.8826
## Lag[4*(p+q)+(p+q)-1] [19]    5.1483 0.9315
## d.o.f=4
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[5]    0.3158 0.500 2.000 0.5741
## ARCH Lag[7]    0.5154 1.473 1.746 0.8931
## ARCH Lag[9]    1.3908 2.402 1.619 0.8710
##
## Nyblom stability test
## -----

```

```

## Joint Statistic: 1.2466
## Individual Statistics:
## mu      0.04389
## omega   0.13528
## alpha1  0.05930
## beta1   0.07445
## beta2   0.07391
## beta3   0.06655
## gamma1  0.18270
## skew    0.15168
## shape   0.08080
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      2.1 2.32 2.82
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##              t-value      prob sig
## Sign Bias      2.6117 0.009061 ***
## Negative Sign Bias 0.6038 0.546006
## Positive Sign Bias 1.8867 0.059317 *
## Joint Effect    11.5143 0.009246 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      16.06    0.653168
## 2    30      51.61    0.006027
## 3    40      40.98    0.383511
## 4    50      60.85    0.119393
##
##
## Elapsed time : 3.780011

```

```

spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(3,1)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

```

```

##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(3,1)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##           Estimate Std. Error  t value Pr(>|t|)

```

```

## mu      -0.000094    0.000545 -0.172581 0.862981
## omega   0.000223    0.000074  3.001972 0.002682
## alpha1  0.328450    0.056066  5.858312 0.000000
## alpha2  0.000000    0.052268  0.000000 1.000000
## alpha3  0.000000    0.029344  0.000001 0.999999
## beta1   0.576413    0.117849  4.891113 0.000001
## gamma1  0.087838    0.106428  0.825326 0.409186
## gamma2 -0.023570    0.121681 -0.193700 0.846410
## gamma3  0.028463    0.082635  0.344447 0.730510
## skew    1.298689    0.036790 35.300223 0.000000
## shape   2.991832    0.175448 17.052511 0.000000
##
## Robust Standard Errors:
##      Estimate Std. Error t value Pr(>|t|)
## mu      -0.000094    0.000565 -0.16647 0.867787
## omega   0.000223    0.000125  1.77463 0.075959
## alpha1  0.328450    0.061530  5.33809 0.000000
## alpha2  0.000000    0.104541  0.00000 1.000000
## alpha3  0.000000    0.094022  0.00000 1.000000
## beta1   0.576413    0.181975  3.16753 0.001537
## gamma1  0.087838    0.099288  0.88467 0.376332
## gamma2 -0.023570    0.120729 -0.19523 0.845215
## gamma3  0.028463    0.089868  0.31672 0.751453
## skew    1.298689    0.045521 28.52944 0.000000
## shape   2.991832    0.241797 12.37331 0.000000
##
## LogLikelihood : 5754.926
##
## Information Criteria
## -----
##
## Akaike      -4.4184
## Bayes       -4.3936
## Shibata     -4.4184
## Hannan-Quinn -4.4094
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]              6.354 0.01171
## Lag[2*(p+q)+(p+q)-1] [2] 6.457 0.01662
## Lag[4*(p+q)+(p+q)-1] [5] 7.344 0.04277
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##              statistic p-value
## Lag[1]              0.0622 0.8030
## Lag[2*(p+q)+(p+q)-1] [11] 3.5799 0.7936
## Lag[4*(p+q)+(p+q)-1] [19] 6.2946 0.8494
## d.o.f=4
##
## Weighted ARCH LM Tests

```



```

## -----
##           Statistic Shape Scale P-Value
## ARCH Lag[5]    0.3065 0.500 2.000 0.5799
## ARCH Lag[7]    0.3700 1.473 1.746 0.9311
## ARCH Lag[9]    1.0197 2.402 1.619 0.9286
##
## Nyblom stability test
## -----
## Joint Statistic: 5.4518
## Individual Statistics:
## mu      0.05276
## omega   0.12722
## alpha1  0.07353
## alpha2  0.59598
## alpha3  0.30636
## beta1   0.06683
## gamma1  0.22349
## gamma2  0.20180
## gamma3  0.17450
## skew    0.16074
## shape   0.08257
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      2.49 2.75 3.27
## Individual Statistic: 0.35 0.47 0.75
##
## Sign Bias Test
## -----
##           t-value      prob sig
## Sign Bias      2.1249 0.03369 **
## Negative Sign Bias 0.6319 0.52749
## Positive Sign Bias 1.5047 0.13252
## Joint Effect      8.7621 0.03263 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      20.20    0.382635
## 2    30      50.78    0.007439
## 3    40      52.77    0.069489
## 4    50      61.88    0.102339
##
##
## Elapsed time : 6.719008

```

```

spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(2,3)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm

```

```

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

```

```

##
## Conditional Variance Dynamics
## -----
## GARCH Model : gjrGARCH(2,3)
## Mean Model : ARFIMA(0,0,0)
## Distribution : sstd
##
## Optimal Parameters
## -----
##      Estimate Std. Error t value Pr(>|t|)
## mu      -0.000011  0.000548 -0.02041 0.983716
## omega    0.000250  0.000043  5.84800 0.000000
## alpha1   0.392020  0.080671  4.85950 0.000001
## alpha2   0.000000  0.099375  0.00000 1.000000
## beta1    0.216412  0.268215  0.80686 0.419748
## beta2    0.183339  0.059000  3.10747 0.001887
## beta3    0.097993  0.075505  1.29783 0.194347
## gamma1   0.026369  0.107491  0.24531 0.806216
## gamma2   0.095793  0.074995  1.27733 0.201486
## skew     1.306845  0.037593 34.76264 0.000000
## shape    3.000046  0.194163 15.45120 0.000000
##
## Robust Standard Errors:
##      Estimate Std. Error t value Pr(>|t|)
## mu      -0.000011  0.000580 -0.019313 0.984592
## omega    0.000250  0.000076  3.278399 0.001044
## alpha1   0.392020  0.076777  5.105936 0.000000
## alpha2   0.000000  0.091554  0.000000 1.000000
## beta1    0.216412  0.204553  1.057976 0.290066
## beta2    0.183339  0.086443  2.120927 0.033928
## beta3    0.097993  0.113170  0.865893 0.386549
## gamma1   0.026369  0.111585  0.236312 0.813191
## gamma2   0.095793  0.069281  1.382668 0.166767
## skew     1.306845  0.044321 29.485989 0.000000
## shape    3.000046  0.193384 15.513390 0.000000
##
## LogLikelihood : 5760.064
##
## Information Criteria
## -----
##
## Akaike      -4.4224
## Bayes       -4.3976
## Shibata     -4.4224
## Hannan-Quinn -4.4134
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]              5.740 0.01658
## Lag[2*(p+q)+(p+q)-1] [2] 5.786 0.02508
## Lag[4*(p+q)+(p+q)-1] [5] 6.600 0.06476
## d.o.f=0
## H0 : No serial correlation

```

```

##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##               statistic p-value
## Lag[1]                0.2185  0.6402
## Lag[2*(p+q)+(p+q)-1][14]  3.7329  0.9043
## Lag[4*(p+q)+(p+q)-1][24]  6.0974  0.9662
## d.o.f=5
##
## Weighted ARCH LM Tests
## -----
##               Statistic Shape Scale P-Value
## ARCH Lag[6]      0.06996 0.500 2.000  0.7914
## ARCH Lag[8]      0.53803 1.480 1.774  0.8907
## ARCH Lag[10]     2.23710 2.424 1.650  0.7260
##
## Nyblom stability test
## -----
## Joint Statistic:  1.5146
## Individual Statistics:
## mu      0.05340
## omega   0.13186
## alpha1  0.05610
## alpha2  0.05066
## beta1   0.06674
## beta2   0.06798
## beta3   0.05911
## gamma1  0.17166
## gamma2  0.15653
## skew    0.15770
## shape   0.07998
##
## Asymptotic Critical Values (10% 5% 1%)
## Joint Statistic:      2.49 2.75 3.27
## Individual Statistic:  0.35 0.47 0.75
##
## Sign Bias Test
## -----
##               t-value   prob sig
## Sign Bias      2.1676 0.03028 **
## Negative Sign Bias 0.5882 0.55644
## Positive Sign Bias 1.7249 0.08467 *
## Joint Effect    8.9867 0.02947 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      16.05      0.6542
## 2    30      46.46      0.0211
## 3    40      41.85      0.3483
## 4    50      48.50      0.4933
##
##

```

```
## Elapsed time : 5.529996
```

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(3,2)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(3,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Convergence Problem:
## Solver Message:
```

```
spec_of_garch_hm<-ugarchspec(variance.model =list(model="gjrGARCH",garchOrder=c(3,3)),mean.model = list
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm)
my_model_hm
```

```
##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : gjrGARCH(3,3)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd
##
## Optimal Parameters
## -----
##      Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.000169   0.000001 -193.470    0
## omega    0.000137   0.000001  180.895    0
## alpha1   0.209953   0.001009  208.170    0
## alpha2   0.001999   0.000024   84.275    0
## alpha3   0.001229   0.000020   60.930    0
## beta1    0.166145   0.000819  202.961    0
## beta2    0.537078   0.002369  226.753    0
## beta3    0.018319   0.000192   95.198    0
## gamma1   0.469651   0.002180  215.426    0
## gamma2   0.096881   0.000536  180.905    0
## gamma3  -0.457302   0.002027 -225.660    0
## skew     1.334417   0.032719   40.784    0
## shape    2.913417   0.060530   48.132    0
##
## Robust Standard Errors:
```

```

##      Estimate Std. Error  t value Pr(>|t|)
## mu      -0.000169   0.000888 -0.190842  0.84865
## omega    0.000137   0.000089  1.535929  0.12456
## alpha1   0.209953   0.440330  0.476807  0.63350
## alpha2   0.001999   0.015057  0.132773  0.89437
## alpha3   0.001229   0.015425  0.079688  0.93649
## beta1    0.166145   0.319364  0.520238  0.60290
## beta2    0.537078   1.535627  0.349745  0.72653
## beta3    0.018319   0.110220  0.166202  0.86800
## gamma1   0.469651   1.068786  0.439425  0.66035
## gamma2   0.096881   0.067141  1.442950  0.14904
## gamma3  -0.457302   2.665251 -0.171579  0.86377
## skew     1.334417   0.171809  7.766846  0.00000
## shape    2.913417  19.175016  0.151938  0.87924
##
## LogLikelihood : 5748.73
##
## Information Criteria
## -----
##
## Akaike          -4.4121
## Bayes           -4.3828
## Shibata         -4.4121
## Hannan-Quinn   -4.4015
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]                6.415 0.01132
## Lag[2*(p+q)+(p+q)-1] [2] 6.422 0.01698
## Lag[4*(p+q)+(p+q)-1] [5] 7.172 0.04710
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##              statistic p-value
## Lag[1]                0.2099 0.6468
## Lag[2*(p+q)+(p+q)-1] [17] 4.2598 0.9414
## Lag[4*(p+q)+(p+q)-1] [29] 8.2184 0.9567
## d.o.f=6
##
## Weighted ARCH LM Tests
## -----
##
##      Statistic Shape Scale P-Value
## ARCH Lag[7]    0.03311 0.500 2.000 0.8556
## ARCH Lag[9]    1.58863 1.485 1.796 0.6160
## ARCH Lag[11]   3.72096 2.440 1.677 0.4717
##
## Nyblom stability test
## -----
## Joint Statistic: 13.7408
## Individual Statistics:
## mu      0.05238

```

```

## omega 0.14063
## alpha1 0.03677
## alpha2 0.07893
## alpha3 0.09772
## beta1 0.03707
## beta2 0.03719
## beta3 0.10439
## gamma1 0.03688
## gamma2 0.18498
## gamma3 0.03735
## skew 0.26005
## shape 0.06294
##
## 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      prob sig
## Sign Bias      2.2360 0.025436 **
## Negative Sign Bias 0.8967 0.369944
## Positive Sign Bias 0.5444 0.586206
## Joint Effect    12.2257 0.006649 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      18.66   0.4787337
## 2    30      28.35   0.4994676
## 3    40      50.40   0.1044144
## 4    50      88.88   0.0004258
##
##
## Elapsed time : 6.875004

```

going further is not leading any good results

```

spec_of_garch_hm<-ugarchspec(variance.model =list(garchOrder=c(1,2)),mean.model = list(armaOrder=c(0,0))
my_model_hm<-ugarchfit(spec=spec_of_garch_hm,data=ret_hm,out.sample = 500)
my_model_hm

```

```

##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model   : sGARCH(1,2)
## Mean Model    : ARFIMA(0,0,0)
## Distribution   : sstd

```

```

##
## Optimal Parameters
## -----
##      Estimate   Std. Error   t value Pr(>|t|)
## mu      0.000017    0.000599   0.027762 0.977852
## omega   0.000247    0.000055   4.448606 0.000009
## alpha1  0.396450    0.080932   4.898560 0.000001
## beta1   0.297301    0.103122   2.883017 0.003939
## beta2   0.234754    0.088927   2.639842 0.008294
## skew    1.321476    0.042175  31.332971 0.000000
## shape   2.999525    0.218506  13.727418 0.000000
##
## Robust Standard Errors:
##      Estimate   Std. Error   t value Pr(>|t|)
## mu      0.000017    0.000615   0.02702 0.978444
## omega   0.000247    0.000065   3.82094 0.000133
## alpha1  0.396450    0.080241   4.94076 0.000001
## beta1   0.297301    0.079405   3.74413 0.000181
## beta2   0.234754    0.086551   2.71233 0.006681
## skew    1.321476    0.049427  26.73572 0.000000
## shape   2.999525    0.207501  14.45549 0.000000
##
## LogLikelihood : 4672.518
##
## Information Criteria
## -----
##
## Akaike      -4.4434
## Bayes      -4.4245
## Shibata    -4.4434
## Hannan-Quinn -4.4365
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##
##              statistic p-value
## Lag[1]              5.621 0.01775
## Lag[2*(p+q)+(p+q)-1] [2]    5.628 0.02764
## Lag[4*(p+q)+(p+q)-1] [5]    5.960 0.09191
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##
##              statistic p-value
## Lag[1]              0.2961 0.5864
## Lag[2*(p+q)+(p+q)-1] [8]    1.9989 0.8591
## Lag[4*(p+q)+(p+q)-1] [14]   4.1402 0.8666
## d.o.f=3
##
## Weighted ARCH LM Tests
## -----
##              Statistic Shape Scale P-Value
## ARCH Lag[4]      0.1754 0.500 2.000 0.6753
## ARCH Lag[6]      0.3865 1.461 1.711 0.9230

```

```

## ARCH Lag[8]      0.9404 2.368 1.583 0.9329
##
## Nyblom stability test
## -----
## Joint Statistic: 0.8594
## Individual Statistics:
## mu      0.02994
## omega   0.21873
## alpha1  0.05295
## beta1   0.08089
## beta2   0.07362
## skew    0.07846
## shape   0.09488
##
## 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      2.3633 0.01821 **
## Negative Sign Bias 0.3329 0.73924
## Positive Sign Bias 1.6455 0.10001
## Joint Effect    8.5895 0.03528 **
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1    20      15.68      0.6788
## 2    30      35.23      0.1971
## 3    40      48.30      0.1459
## 4    50      47.67      0.5273
##
##
## Elapsed time : 1.310992

```

```
back_testing<-ugarchroll(spec_of_garch_hm,ret_hm,n.ahead=1,n.start = 2000,refit.every =30,refit.window
```

```

##
## Iter: 1 fn: -4438.3025   Pars: 0.0003191 0.0002506 0.4141641 0.2941073 0.2506736 1.3396645 2.90325
## Iter: 2 fn: -4438.3025   Pars: 0.0003192 0.0002506 0.4141935 0.2940687 0.2506947 1.3396678 2.90321
## Iter: 3 fn: -4438.3025   Pars: 0.0003192 0.0002506 0.4141935 0.2940687 0.2506947 1.3396678 2.90321
## solnp--> Completed in 3 iterations
##
## Iter: 1 fn: -4432.0539   Pars: 0.0002559 0.0002456 0.4115616 0.3170721 0.2328361 1.3382652 2.91266
## Iter: 2 fn: -4432.0539   Pars: 0.0002559 0.0002456 0.4115616 0.3170721 0.2328361 1.3382652 2.91266
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4430.1153   Pars: 0.0001412 0.0002383 0.3948317 0.3170265 0.2283056 1.3342451 3.00282
## Iter: 2 fn: -4430.1153   Pars: 0.0001412 0.0002383 0.3948368 0.3170189 0.2283117 1.3342451 3.00280
## Iter: 3 fn: -4430.1153   Pars: 0.0001412 0.0002383 0.3948368 0.3170189 0.2283117 1.3342451 3.00280
## solnp--> Completed in 3 iterations

```



```

##
## Iter: 1 fn: -4437.5357    Pars:  0.00009238 0.00022411 0.37991764 0.32819760 0.22662345 1.32913901 3
## Iter: 2 fn: -4437.5357    Pars:  0.00009235 0.00022411 0.37992346 0.32821076 0.22661947 1.32913287 3
## Iter: 3 fn: -4437.5357    Pars:  0.00009235 0.00022411 0.37992346 0.32821076 0.22661947 1.32913287 3
## solnp--> Completed in 3 iterations
##
## Iter: 1 fn: -4457.7985    Pars:  0.0001463 0.0002006 0.3642601 0.3219088 0.2617950 1.3257079 3.03613
## Iter: 2 fn: -4457.7985    Pars:  0.0001463 0.0002006 0.3642601 0.3219088 0.2617950 1.3257079 3.03613
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4455.5486    Pars:  0.0001491 0.0001870 0.3518530 0.3235934 0.2680945 1.3183685 3.09579
## Iter: 2 fn: -4455.5486    Pars:  0.0001491 0.0001870 0.3518530 0.3235934 0.2680945 1.3183685 3.09579
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4449.8214    Pars:  0.0002003 0.0001919 0.3571111 0.3028881 0.2830643 1.3167092 3.09720
## Iter: 2 fn: -4449.8214    Pars:  0.0002003 0.0001919 0.3571111 0.3028881 0.2830643 1.3167092 3.09720
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4456.0332    Pars:  0.00008679 0.00018749 0.35402371 0.31096276 0.27289886 1.30938385 3
## Iter: 2 fn: -4456.0332    Pars:  0.00008679 0.00018749 0.35402371 0.31096276 0.27289886 1.30938385 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4476.3422    Pars:  0.0001112 0.0001987 0.3567669 0.3358767 0.2341392 1.3304676 3.14201
## Iter: 2 fn: -4476.3422    Pars:  0.0001112 0.0001987 0.3567669 0.3358767 0.2341392 1.3304676 3.14201
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4485.5811    Pars:  0.00009406 0.00019011 0.32871442 0.35971664 0.22233564 1.31916175 3
## Iter: 2 fn: -4485.5811    Pars:  0.00009406 0.00019011 0.32871441 0.35971664 0.22233564 1.31916175 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4497.8384    Pars:  0.00007323 0.00019600 0.33984839 0.37879152 0.18772301 1.32552939 3
## Iter: 2 fn: -4497.8384    Pars:  0.00007323 0.00019600 0.33984839 0.37879152 0.18772301 1.32552939 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4507.9647    Pars:  0.0000911 0.0001967 0.3442811 0.3753093 0.1898310 1.3237932 3.18727
## Iter: 2 fn: -4507.9647    Pars:  0.00009114 0.00019667 0.34427479 0.37531025 0.18983020 1.32379872 3
## Iter: 3 fn: -4507.9647    Pars:  0.00009114 0.00019667 0.34427478 0.37531025 0.18983021 1.32379872 3
## solnp--> Completed in 3 iterations
##
## Iter: 1 fn: -4501.7633    Pars:  -0.00002738 0.00019099 0.34118478 0.36788207 0.20101396 1.3171
## Iter: 2 fn: -4501.7633    Pars:  -0.00002732 0.00019099 0.34119375 0.36788494 0.20101041 1.3171
## Iter: 3 fn: -4501.7633    Pars:  -0.00002732 0.00019099 0.34119375 0.36788494 0.20101041 1.3171
## solnp--> Completed in 3 iterations
##
## Iter: 1 fn: -4484.4871    Pars:  0.00008735 0.00018178 0.33171290 0.32929802 0.25581101 1.32701297 3
## Iter: 2 fn: -4484.4871    Pars:  0.00008734 0.00018178 0.33170903 0.32930009 0.25581051 1.32701197 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4478.6381    Pars:  0.0002059 0.0001860 0.3518316 0.3314664 0.2456153 1.3332225 3.19314
## Iter: 2 fn: -4478.6381    Pars:  0.000206 0.000186 0.351842 0.331468 0.245609 1.333226 3.193112
## Iter: 3 fn: -4478.6381    Pars:  0.000206 0.000186 0.351842 0.331468 0.245609 1.333226 3.193112
## solnp--> Completed in 3 iterations
##
## Iter: 1 fn: -4473.5635    Pars:  0.00009406 0.00018897 0.33836745 0.33116154 0.23848076 1.32168473 3

```

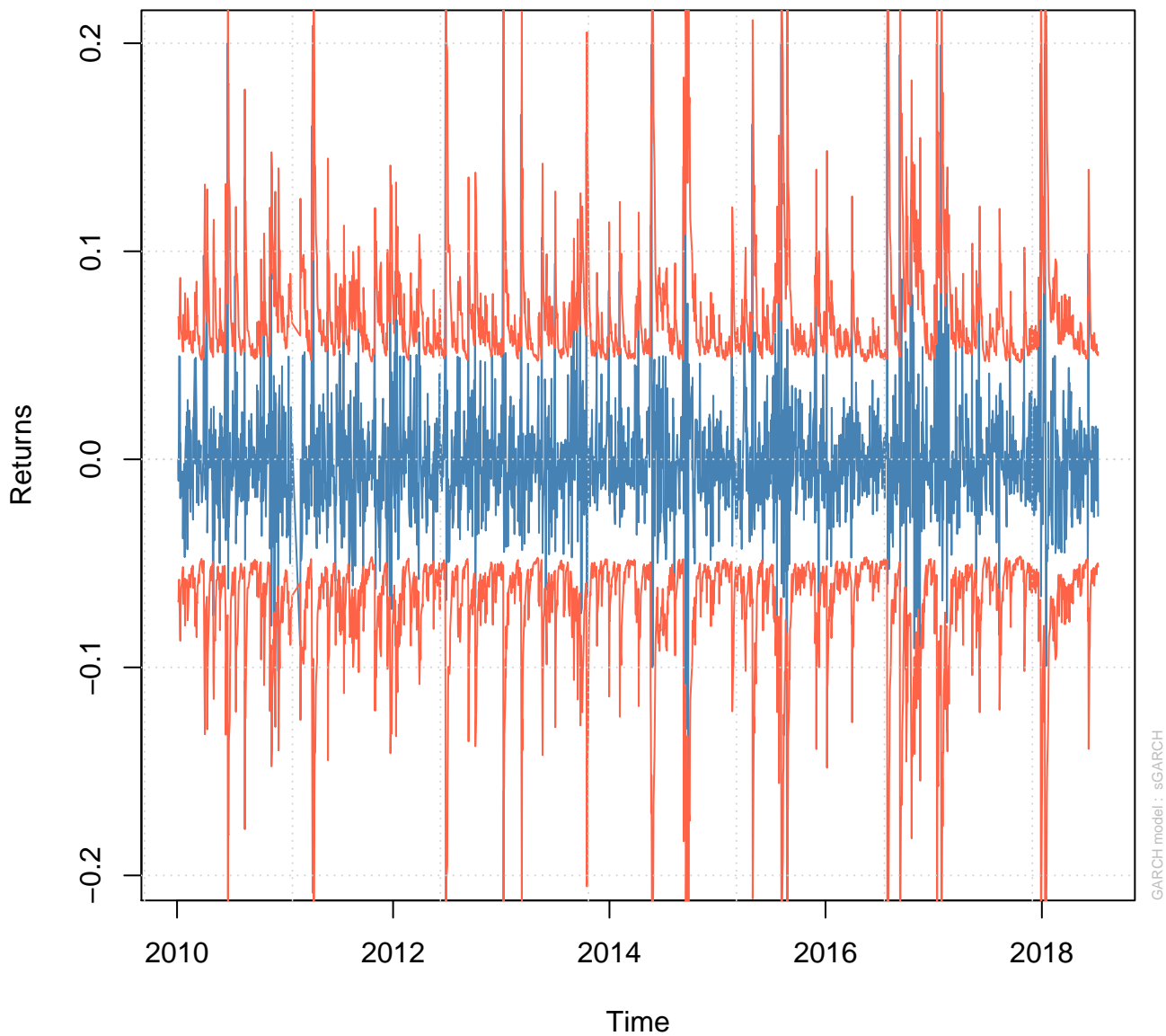
```
## Iter: 2 fn: -4473.5635 Pars: 0.00009406 0.00018897 0.33836745 0.33116154 0.23848076 1.32168473 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4494.9272 Pars: 0.0002717 0.0001870 0.3349683 0.3328525 0.2444990 1.3331944 3.21822
## Iter: 2 fn: -4494.9272 Pars: 0.0002717 0.0001870 0.3349683 0.3328525 0.2444990 1.3331944 3.21822
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4492.4002 Pars: 0.0001051 0.0002015 0.3512651 0.3209563 0.2488804 1.3197470 3.10757
## Iter: 2 fn: -4492.4002 Pars: 0.0001051 0.0002015 0.3512651 0.3209563 0.2488804 1.3197470 3.10757
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4473.8841 Pars: -0.0000255 0.0002111 0.3595951 0.3127036 0.2391634 1.3072296 3
## Iter: 2 fn: -4473.8841 Pars: -0.0000255 0.0002111 0.3595951 0.3127036 0.2391634 1.3072296 3
## solnp--> Completed in 2 iterations
##
## Iter: 1 fn: -4463.7398 Pars: 0.0001854 0.0002160 0.3791622 0.3051964 0.2561402 1.3172979 2.98605
## Iter: 2 fn: -4463.7398 Pars: 0.0001854 0.0002160 0.3791619 0.3051971 0.2561402 1.3172983 2.98605
## solnp--> Completed in 2 iterations
```

```
report(back_testing)
```

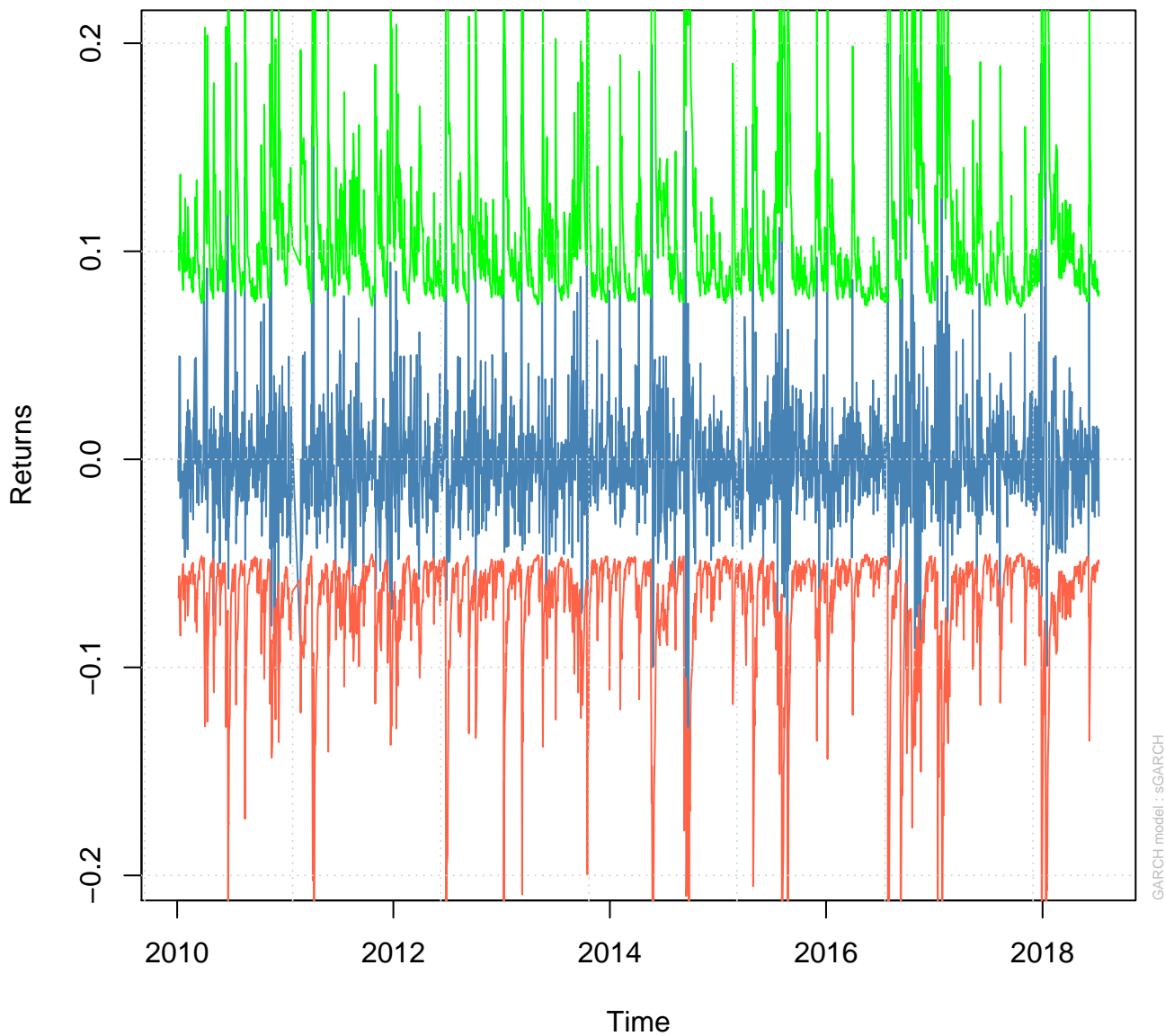
```
## VaR Backtest Report
## =====
## Model: sGARCH-sstd
## Backtest Length: 600
## Data:
##
## =====
## alpha: 1%
## Expected Exceed: 6
## Actual VaR Exceed: 7
## Actual %: 1.2%
##
## Unconditional Coverage (Kupiec)
## Null-Hypothesis: Correct Exceedances
## LR.uc Statistic: 0.16
## LR.uc Critical: 3.841
## LR.uc p-value: 0.689
## Reject Null: NO
##
## Conditional Coverage (Christoffersen)
## Null-Hypothesis: Correct Exceedances and
## Independence of Failures
## LR.cc Statistic: 0.325
## LR.cc Critical: 5.991
## LR.cc p-value: 0.85
## Reject Null: NO
```

```
forecast<- ugarchforecast(my_model_hm,data=ret_hm,n.ahead =100,n.roll = 100)
```

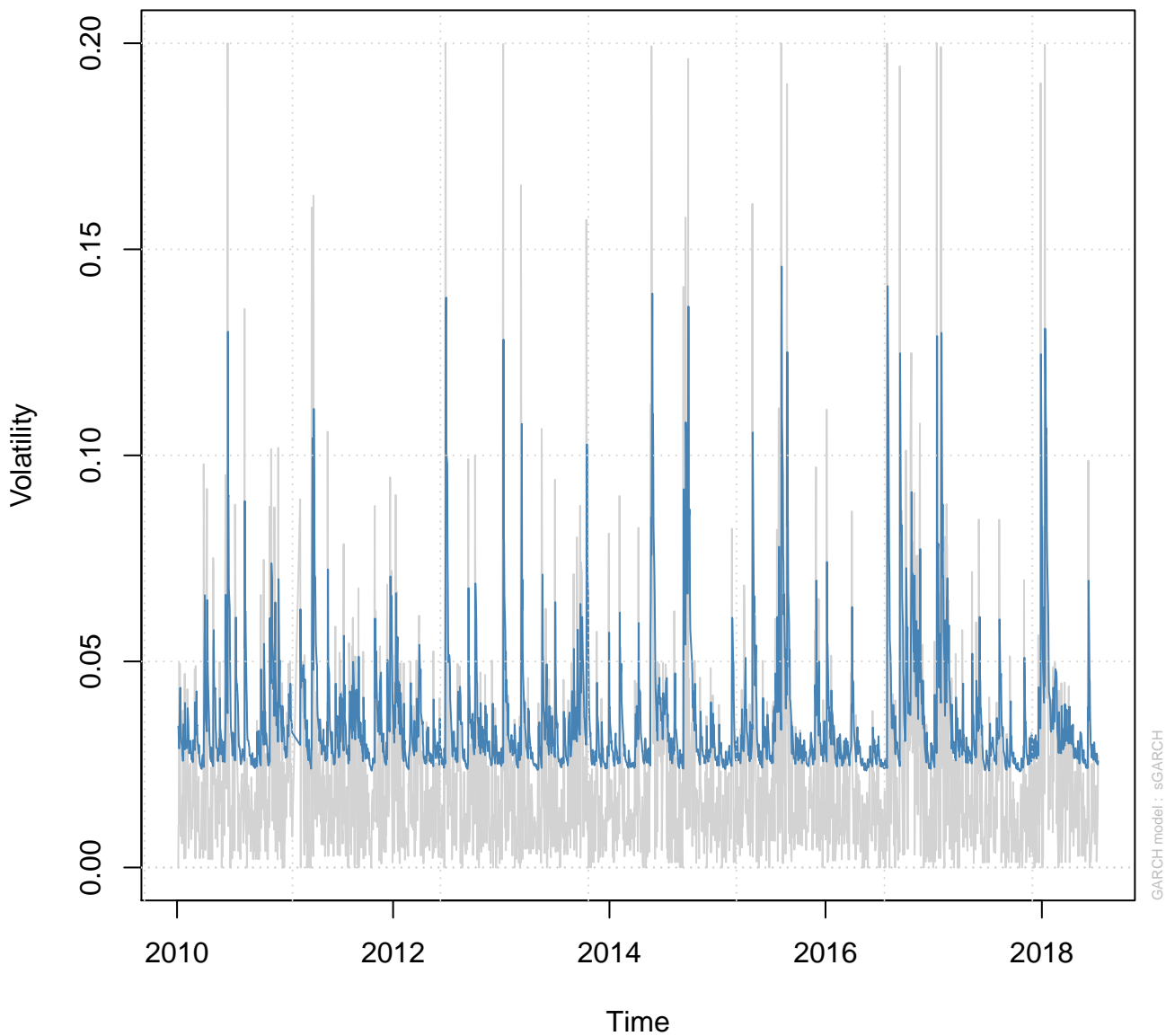
Series with 2 Conditional SD Superimposed



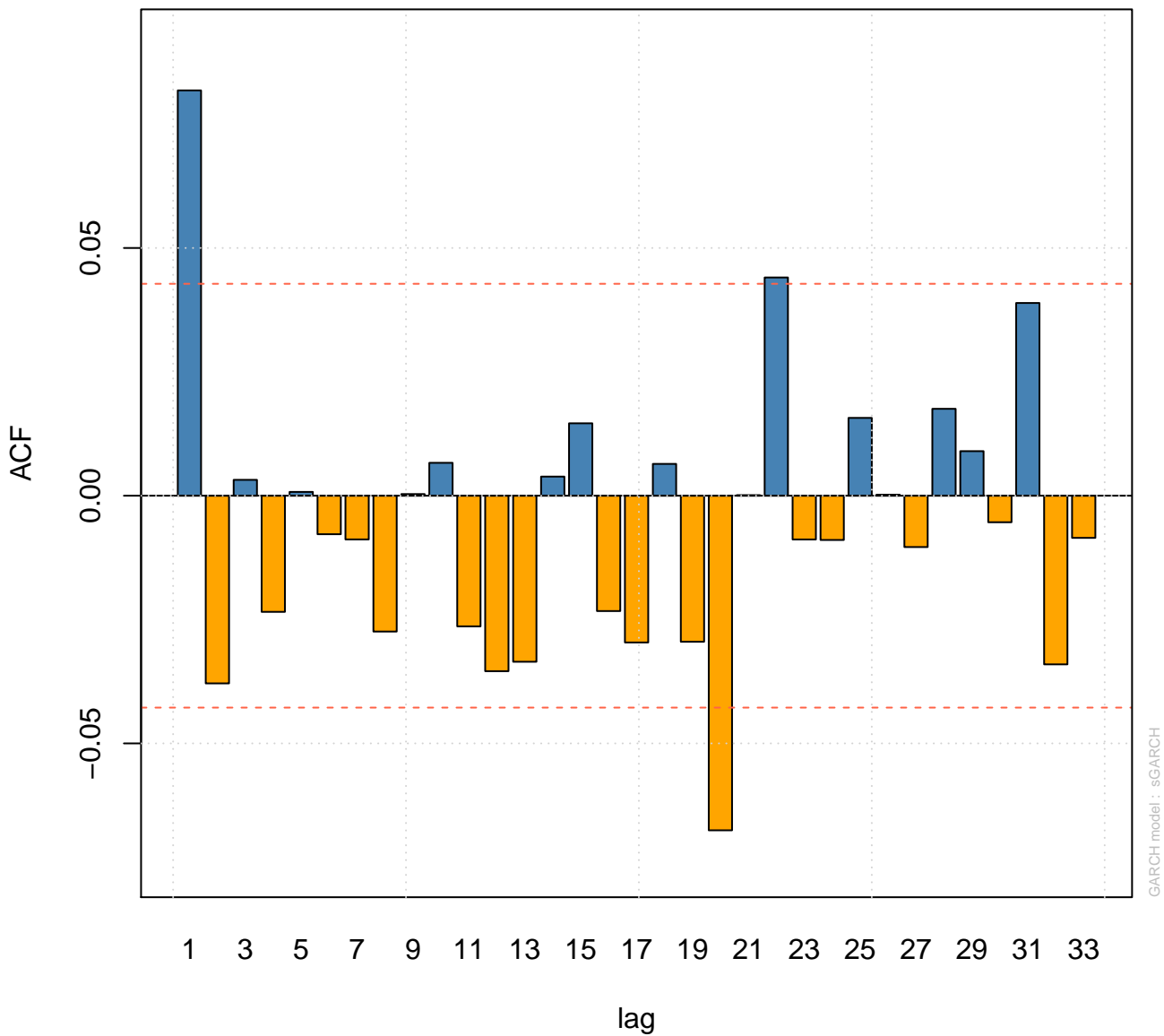
Series with with 1% VaR Limits



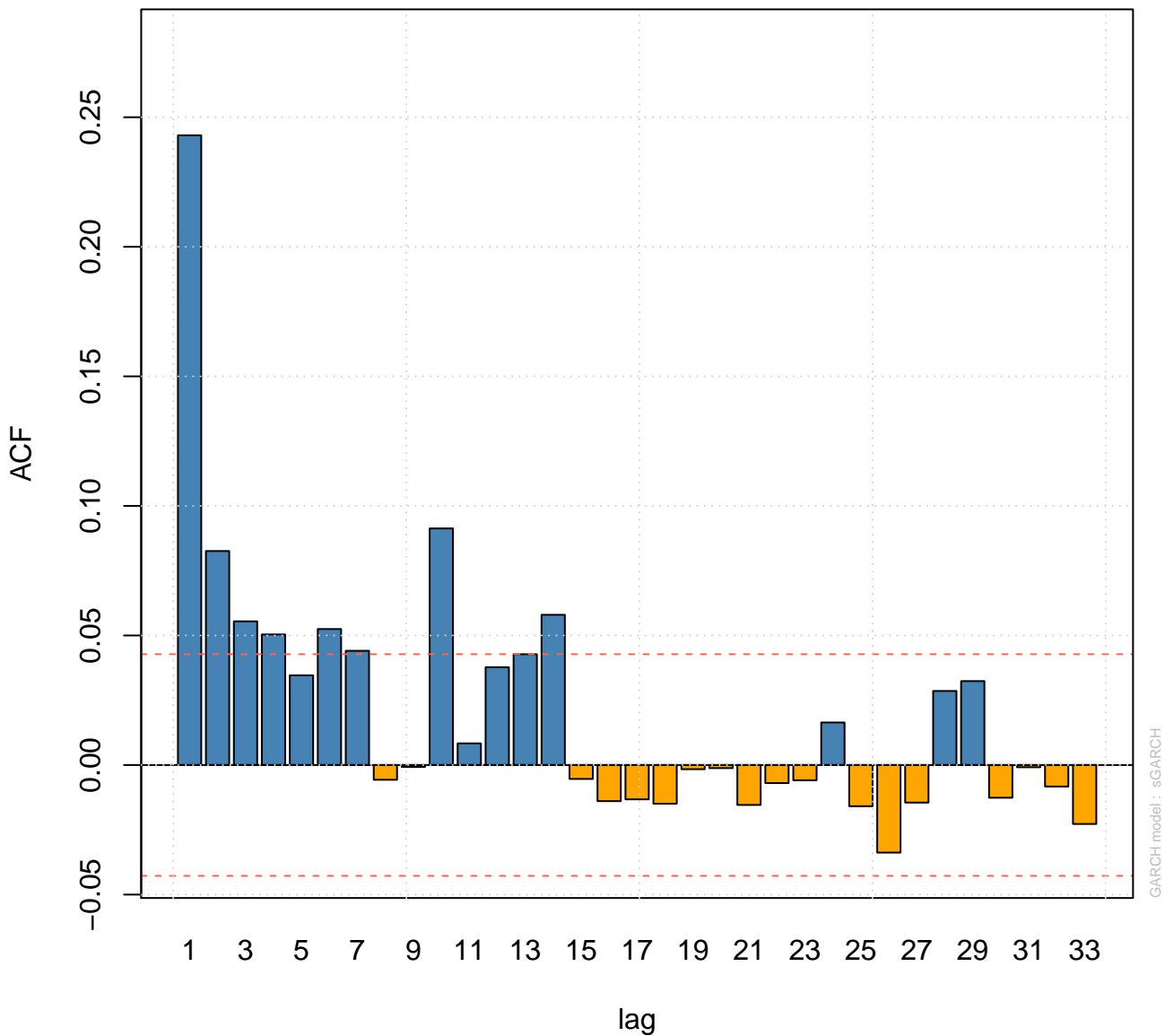
Conditional SD (vs |returns|)



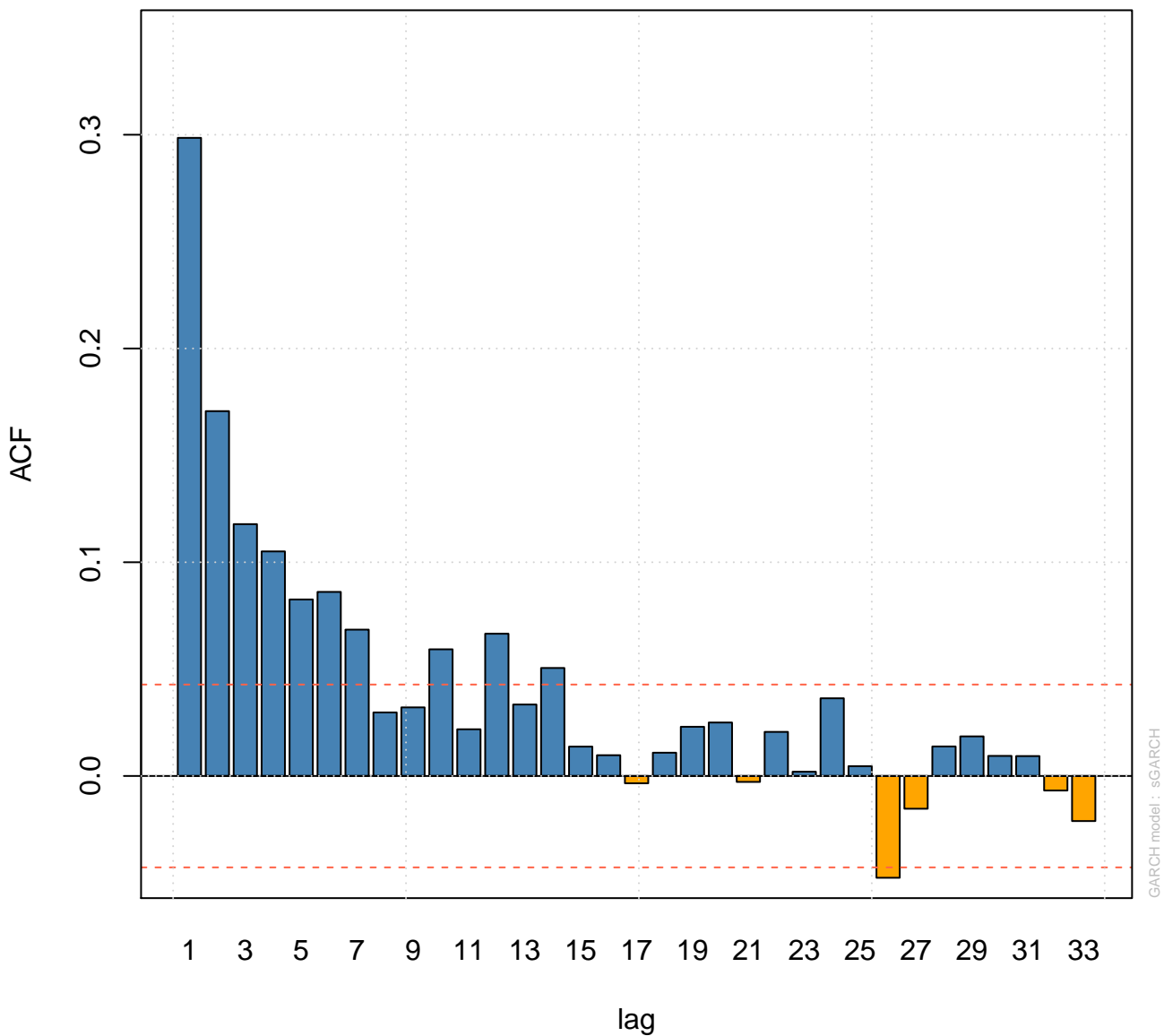
ACF of Observations



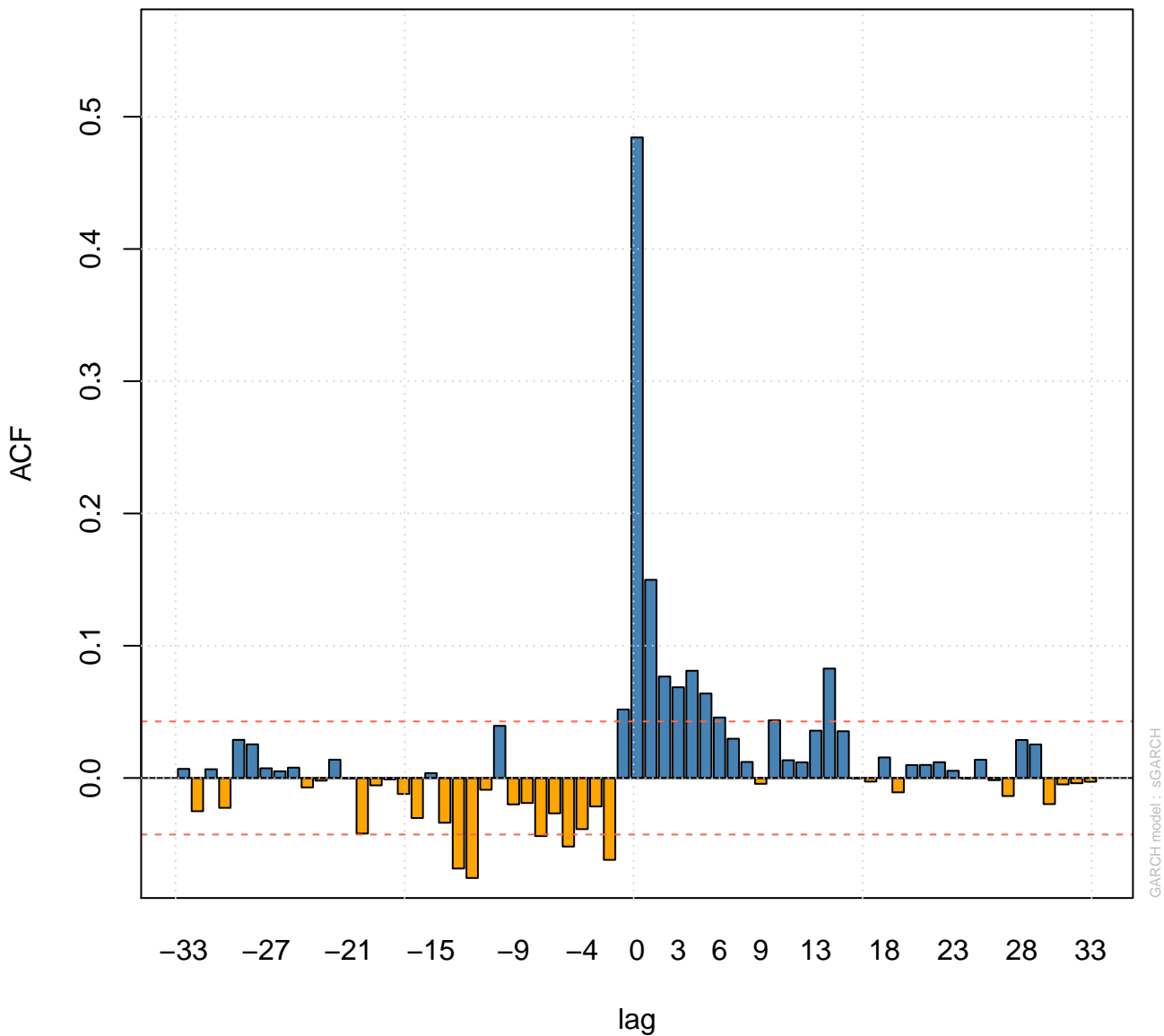
ACF of Squared Observations



ACF of Absolute Observations

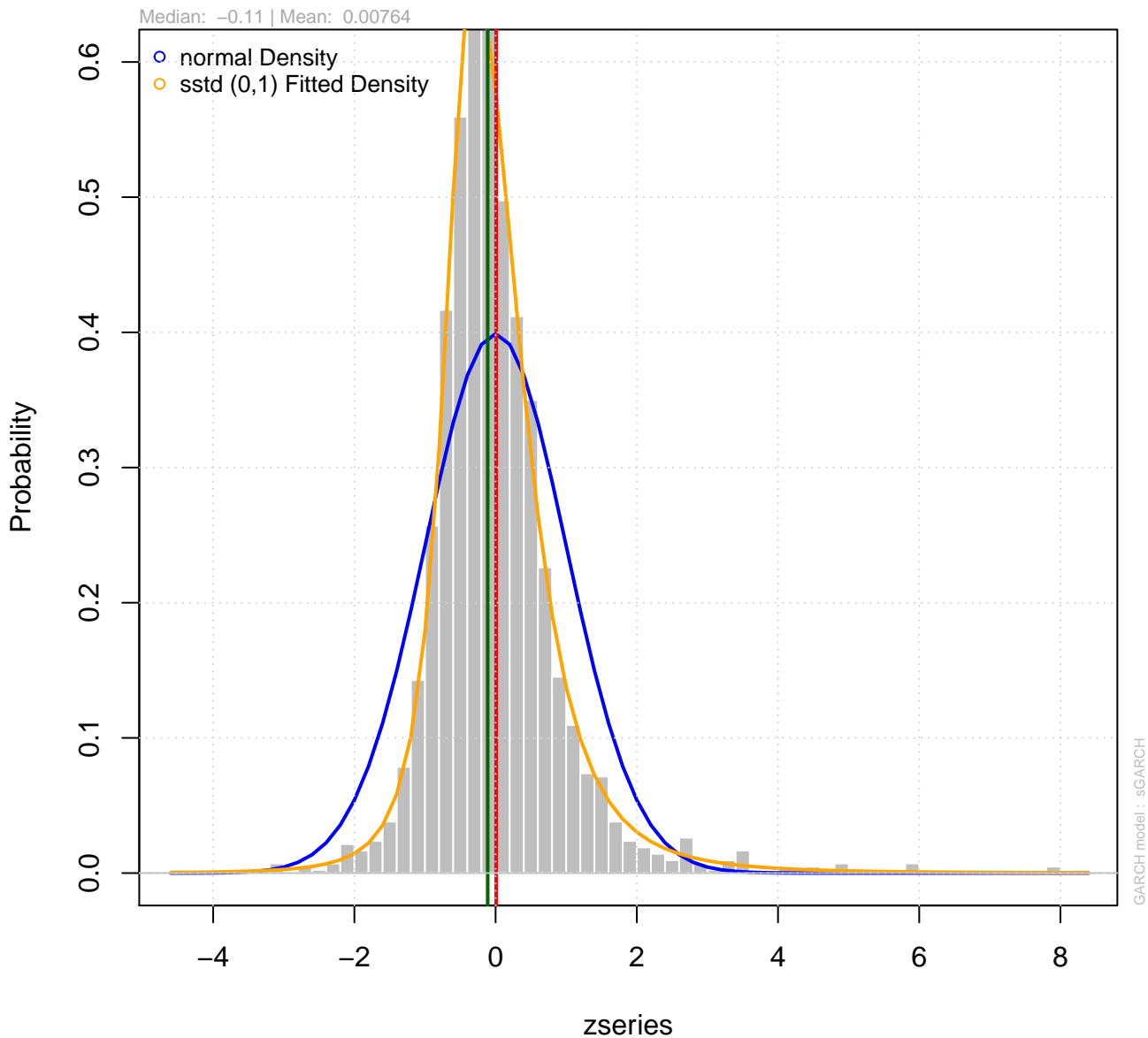


Cross-Correlations of Squared vs Actual Observations

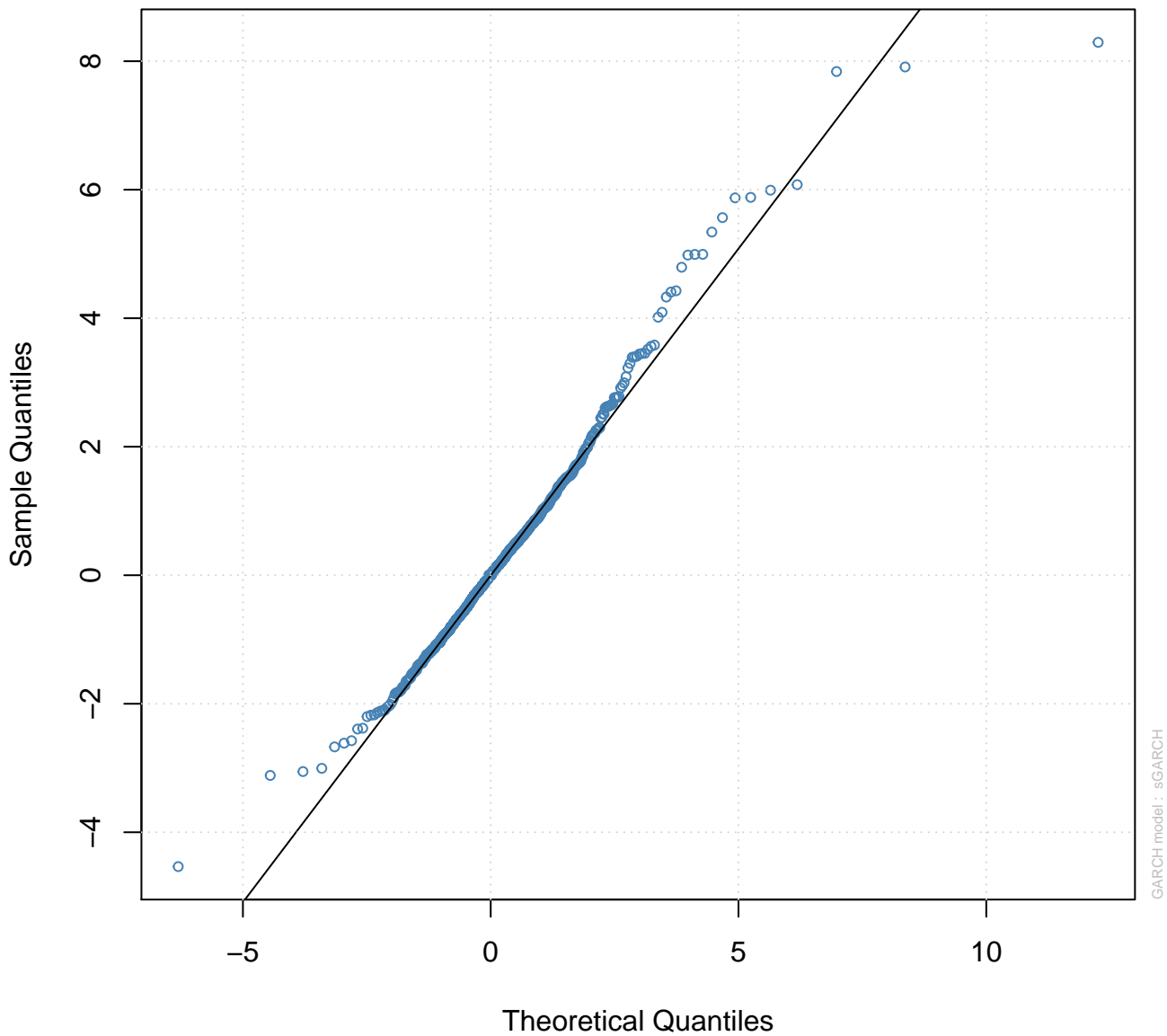


GARCH model : sgARCH

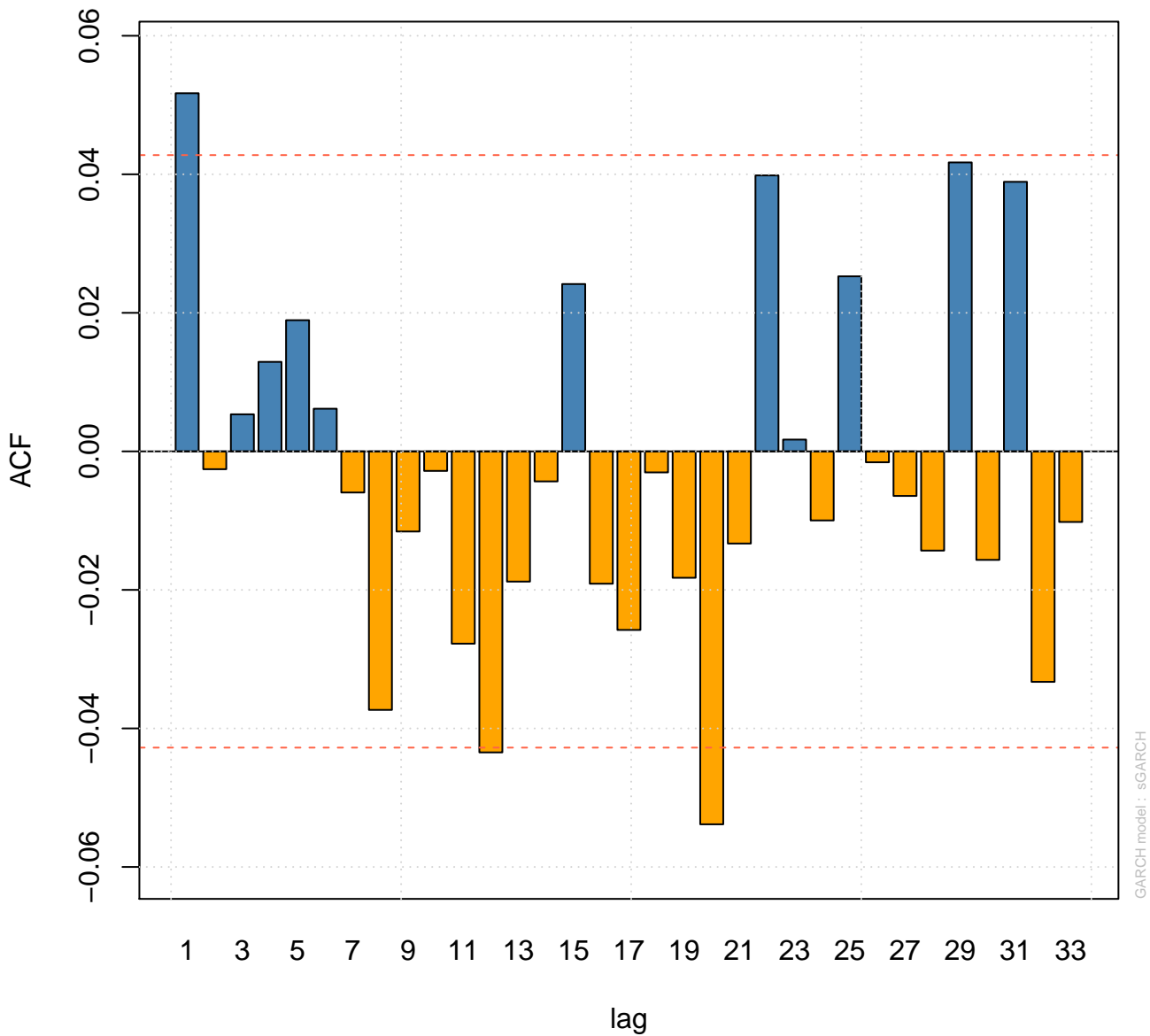
Empirical Density of Standardized Residuals



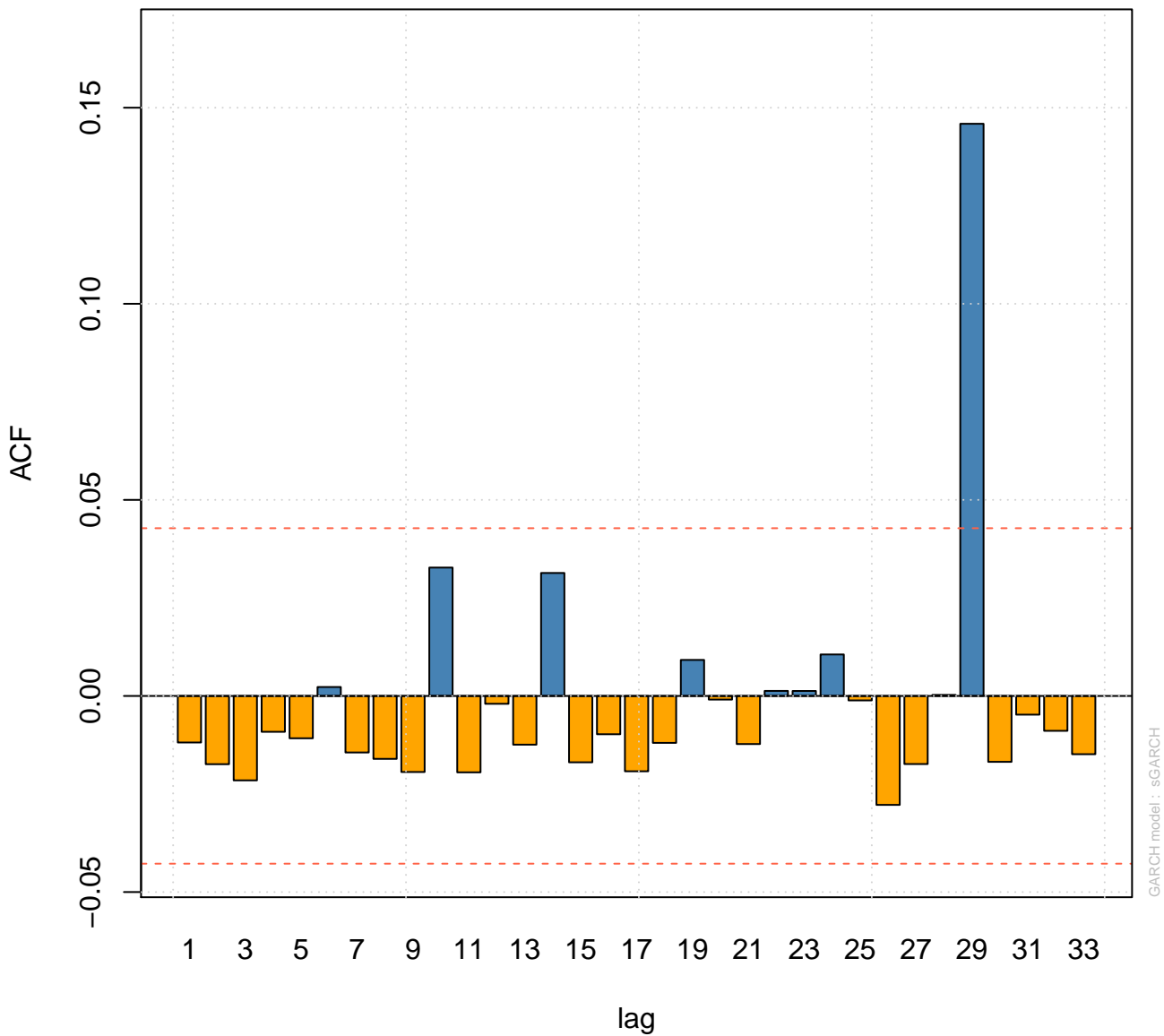
sstd – QQ Plot



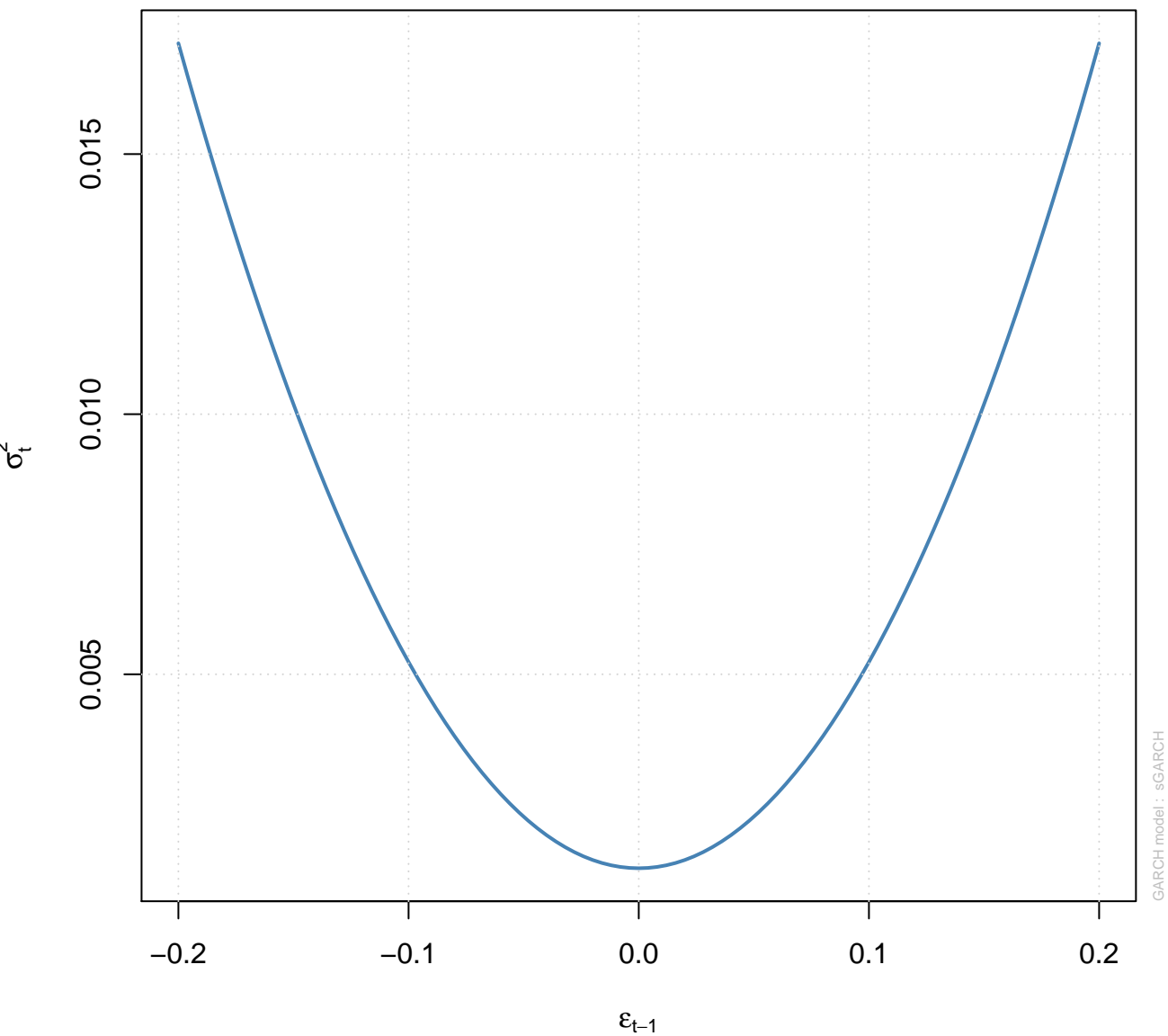
ACF of Standardized Residuals



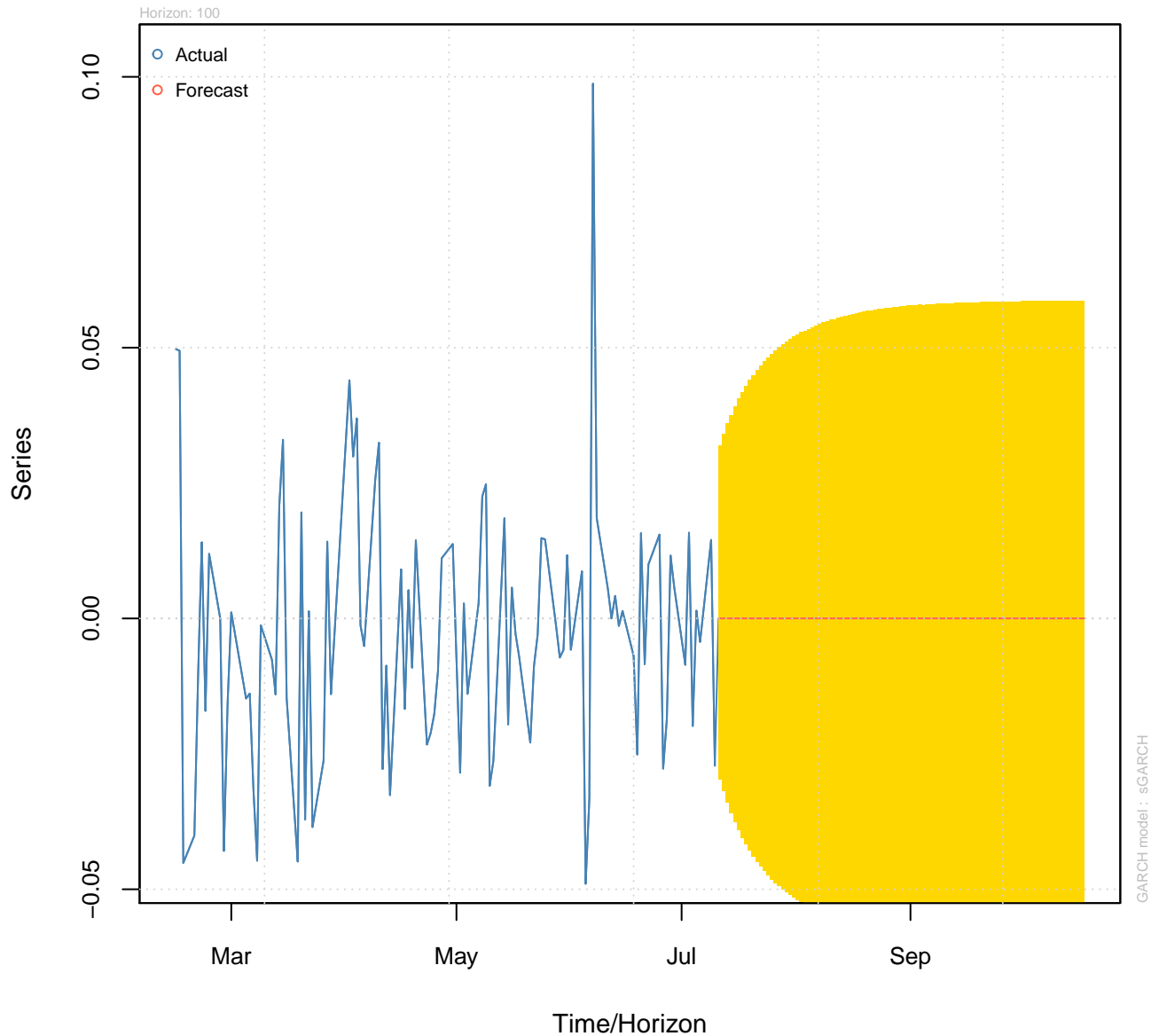
ACF of Squared Standardized Residuals



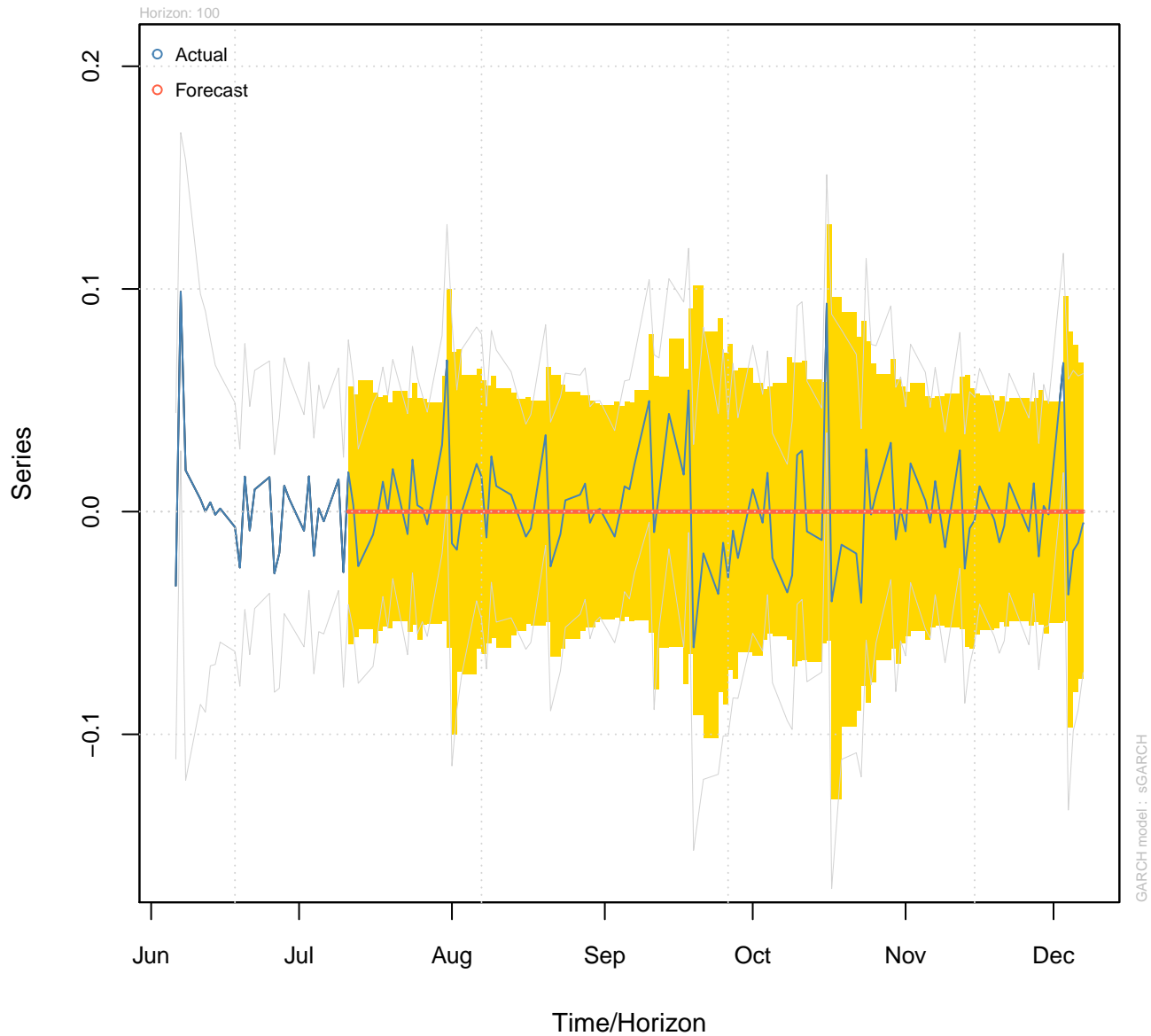
News Impact Curve



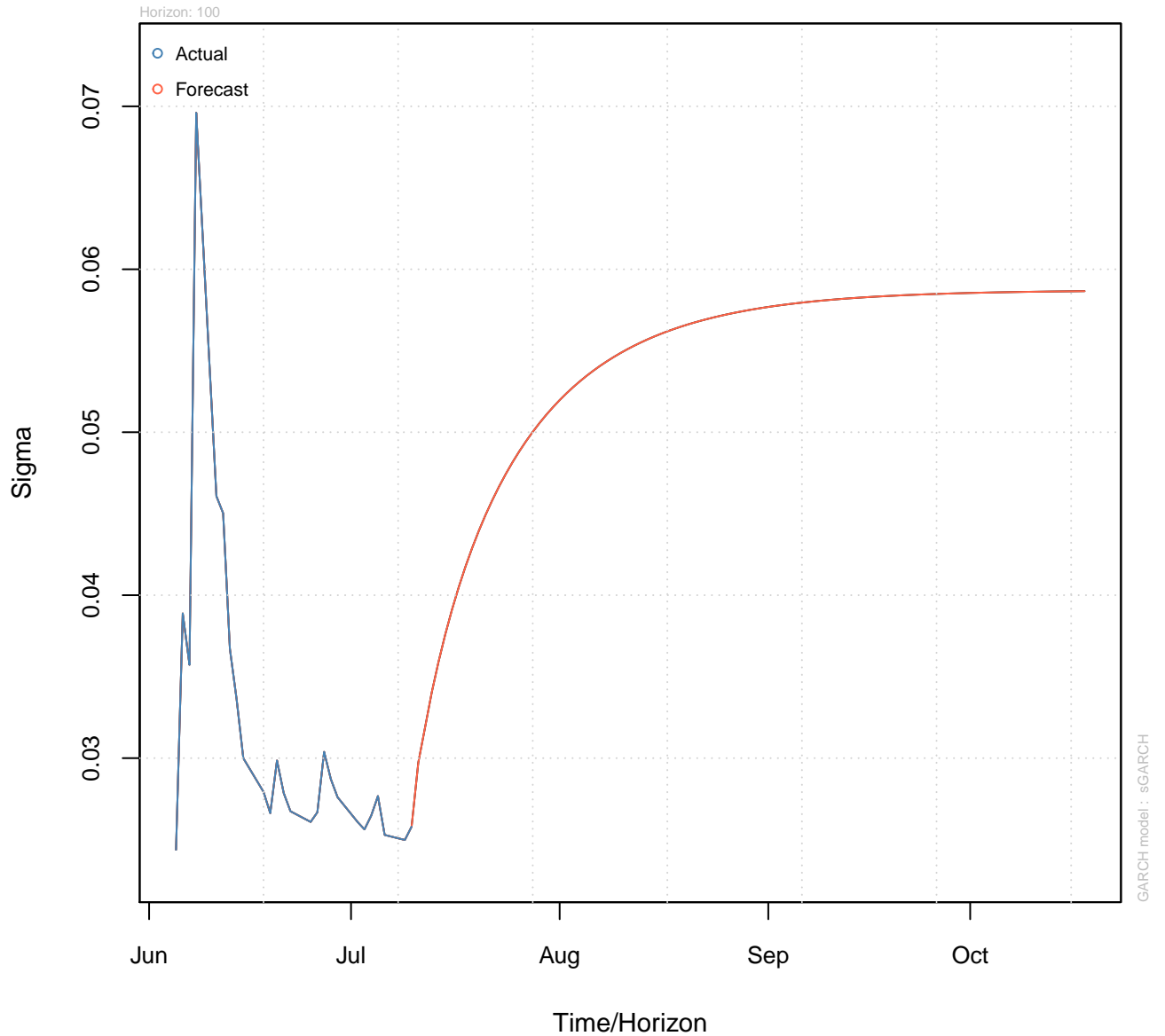
**Forecast Series
w/th unconditional 1-Sigma bands**



**Rolling Forecast vs Actual Series
w/th conditional 2-Sigma bands**



Forecast Unconditional Sigma
(n.roll = 0)



Forecast Rolling Sigma vs |Series|

