STAT 349 Final Project Report

Kenny Jin

```
## Warning: package 'tseries' was built under R version 3.5.3
```

```
## Warning: package 'TSA' was built under R version 3.5.3
```

```
##
## Attaching package: 'TSA'
```

```
## The following objects are masked from 'package:stats':
##
##     acf, arima
```

```
## The following object is masked from 'package:utils':
##
##     tar
```

Note: log based 10 is always used in this project Some of the dataset is replaced because of the length. Current datasets (* means replaced):

*BLL F *LLY LOW MCO MSFT PFE ROK *TRV *TXT

1 Steps 1-3

1.1 Dataset 1: Stock BLL

1.1.1

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## [1] 3740.503
## [1] 1 2
```

```
##
## Call:
## garch(x = BLL.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8.12455 -0.49526  0.03929  0.57964 10.91165
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 4.892e-06   2.768e-07   17.675  < 2e-16 ***
## a1 7.677e-02   1.227e-02    6.258 3.90e-10 ***
## a2 1.441e-01   2.072e-02    6.954 3.54e-12 ***
## b1 6.926e-01   1.611e-02   42.980  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 7117.9, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.070794, df = 1, p-value = 0.7902
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3740.503
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.1.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.95955, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 7117.9, df = 2, p-value < 2.2e-16

## skewness:  0.1792892

## kurtosis:  6.671514
```

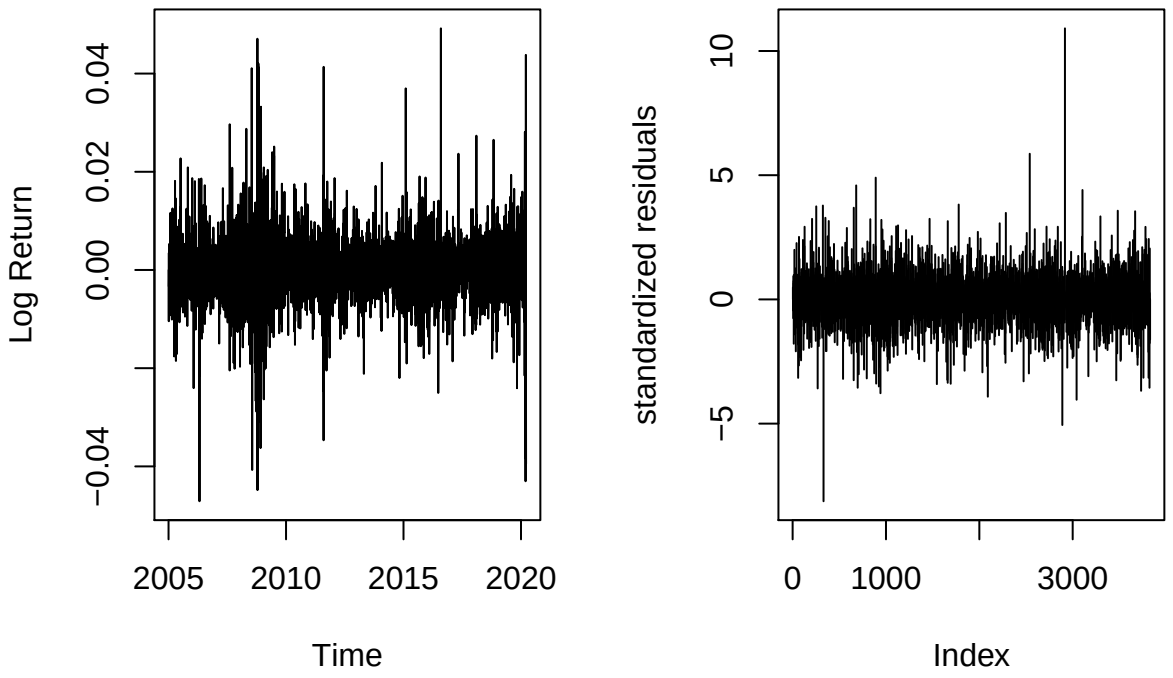

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

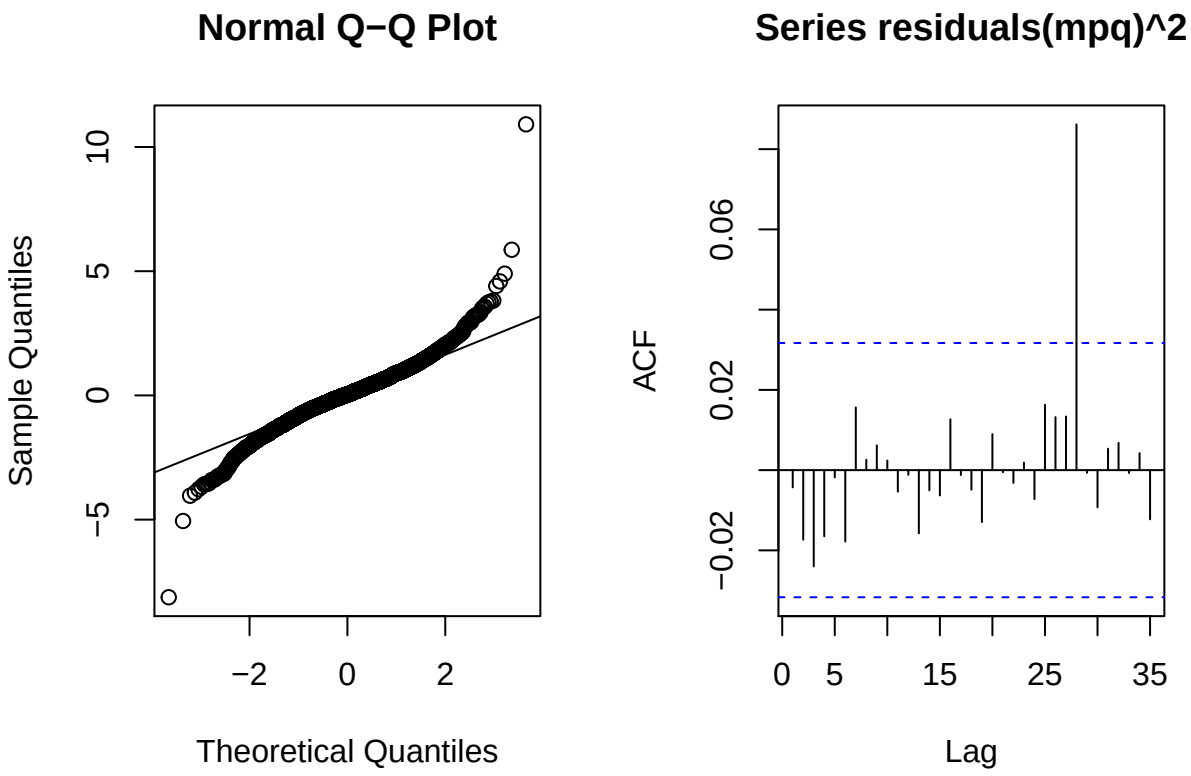

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.2-1.10 Same as 1.1

1.2 Dataset 1: Stock F

1.2.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3669.49
## [1] 1 2

##
## Call:
## garch(x = F.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.0528 -0.5422  0.0000  0.5238  6.9223
##
```

```
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 4.217e-06   3.797e-07    11.11   <2e-16 ***
## a1 2.171e-01   1.711e-02    12.69   <2e-16 ***
## a2 8.688e-08   2.070e-02     0.00        1
## b1 7.777e-01   1.247e-02    62.37   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 3814.9, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.30565, df = 1, p-value = 0.5804
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3669.49
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.2.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.95581, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 3814.9, df = 2, p-value < 2.2e-16

## skewness:  -0.4561754

## kurtosis:  4.805406
```

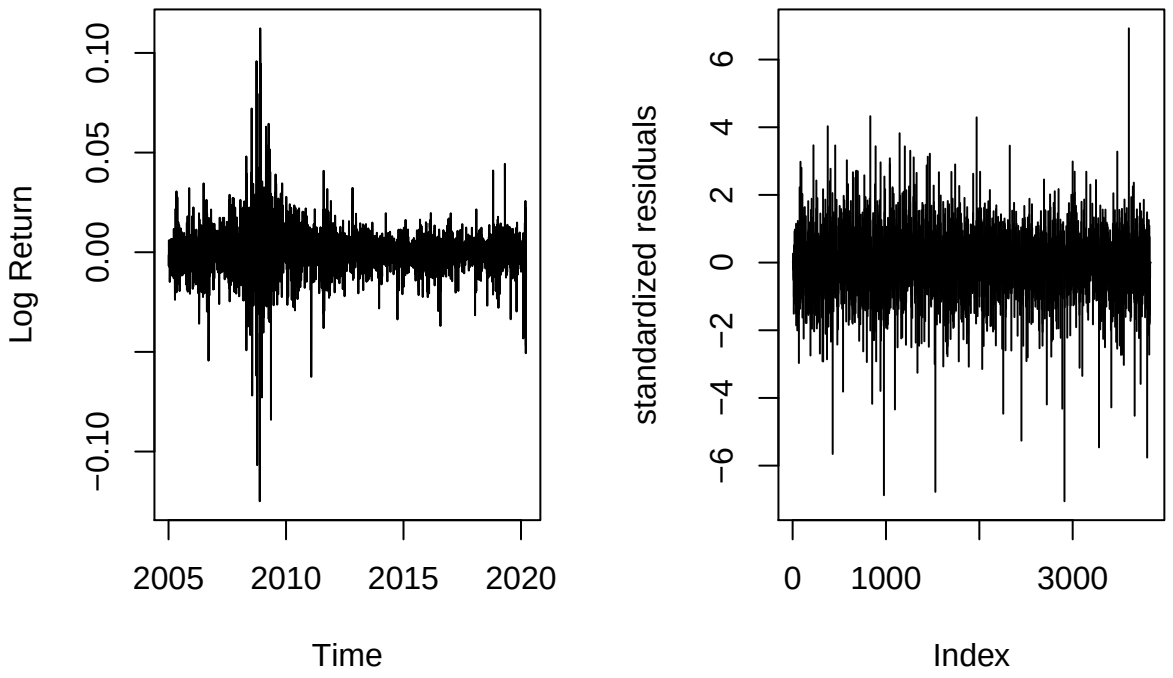

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

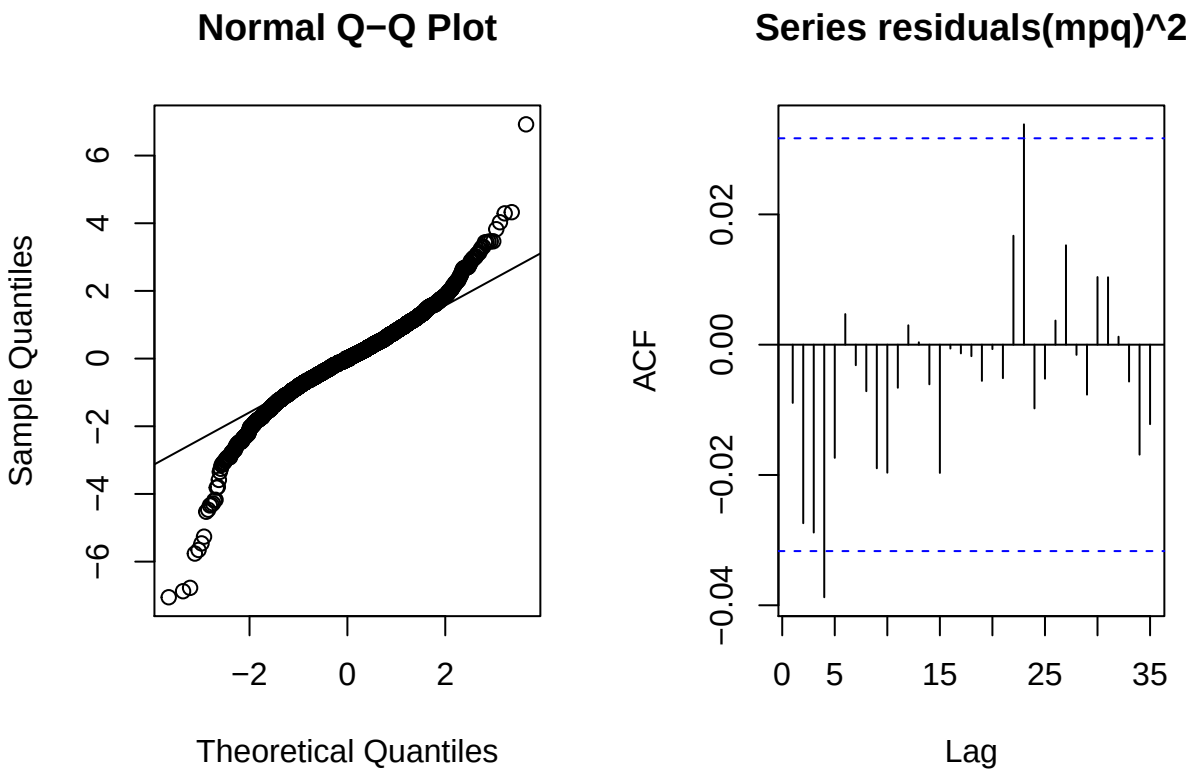

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.3 Dataset 1: Stock LLY

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.3.1

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## [1] 3684.924
## [1] 1 2
```

```
##
## Call:
## garch(x = LLY.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8.41665 -0.51273  0.04902  0.57247  4.90148
##
## Coefficient(s):
```

```
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 2.276e-06   1.848e-07    12.31   <2e-16 ***
## a1 1.912e-01   2.101e-02     9.10   <2e-16 ***
## a2 2.447e-10   2.276e-02     0.00        1
## b1 7.736e-01   1.170e-02    66.11   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 2327.6, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 1.8415, df = 1, p-value = 0.1748
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3684.924
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.3.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.96634, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 2327.6, df = 2, p-value < 2.2e-16

## skewness:  -0.2212471

## kurtosis:  3.794858
```

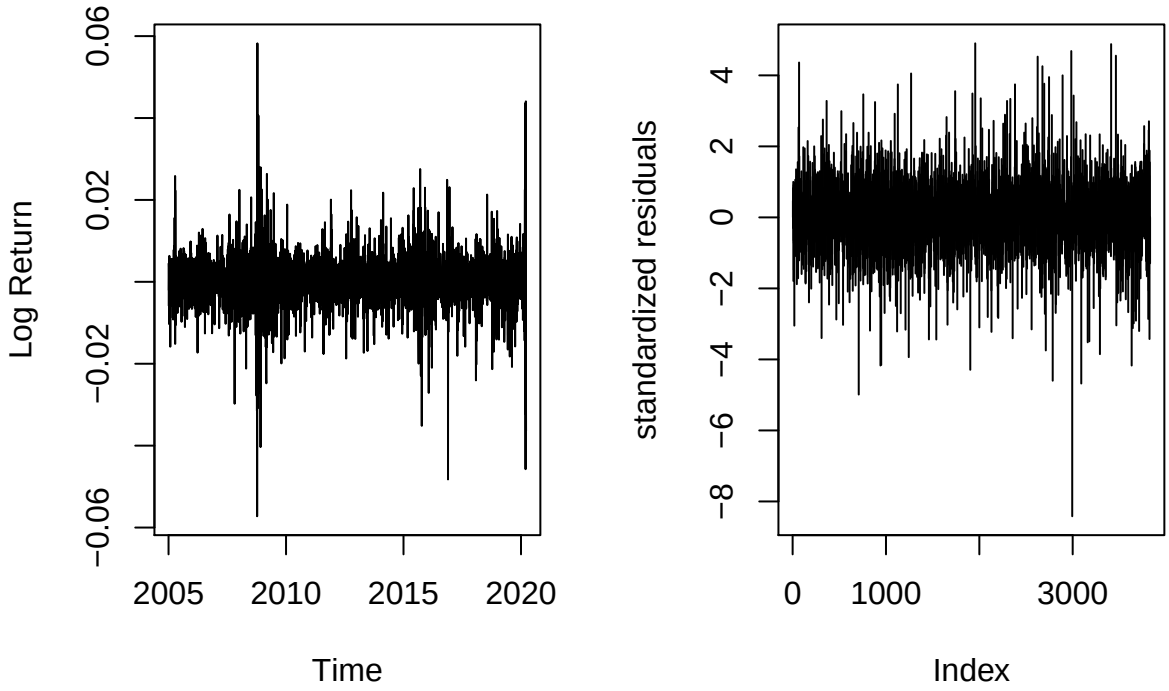

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

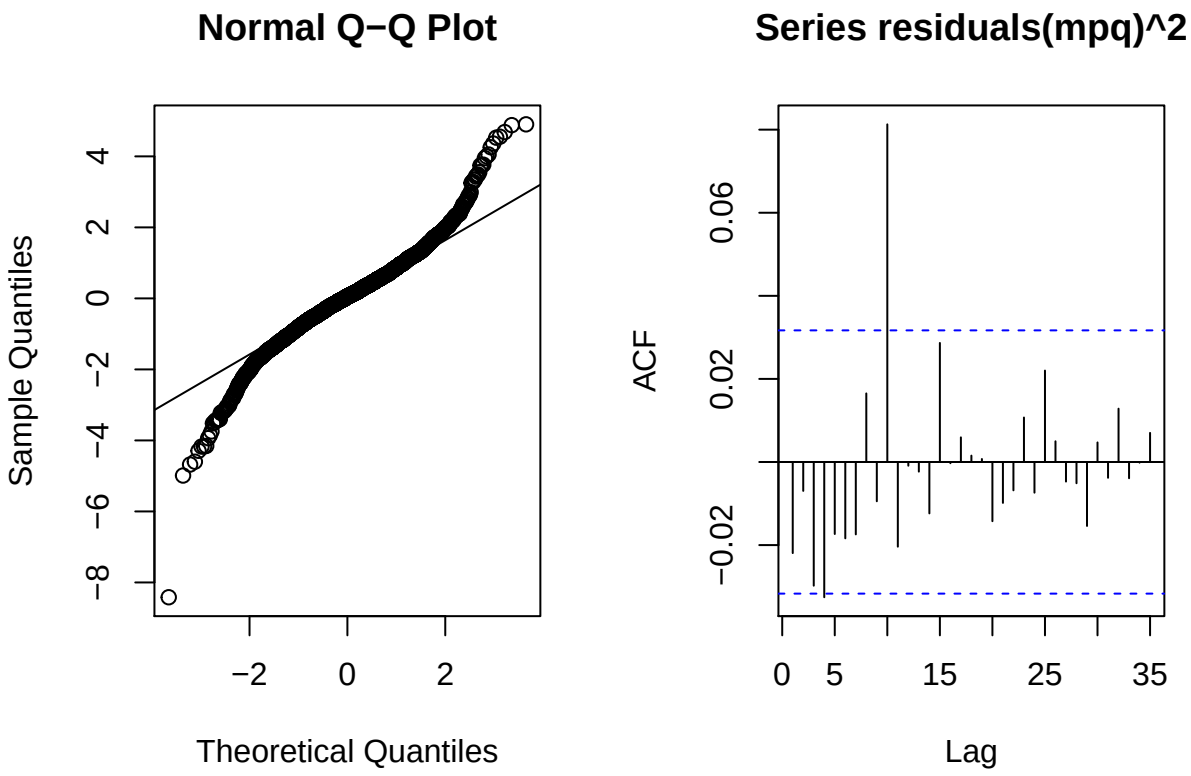

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.4 Dataset 1: Stock LOW

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.4.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information
## [1] 3752.975
## [1] 2 2
## Warning in garch(x = LOW.return, order = best_params): singular information
##
## Call:
## garch(x = LOW.return, order = best_params)
##
## Model:
## GARCH(2,2)
##
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -8.54097 -0.53378  0.01902  0.55716  6.63831
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 5.449e-06          NA       NA       NA
## a1 1.123e-01          NA       NA       NA
## a2 1.304e-01          NA       NA       NA
## b1 2.257e-01          NA       NA       NA
## b2 4.718e-01          NA       NA       NA
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 3638.7, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.47682, df = 1, p-value = 0.4899
```

The best fitted model is GARCH(2,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3752.975
```

State the reason why this model is the final model.

GARCH(2,2) gives the smallest sum of squared residuals for this dataset.

1.4.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.95904, p-value < 2.2e-16
```

```
##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 3638.7, df = 2, p-value < 2.2e-16
```

```
## skewness:  -0.05093237
```

```
## kurtosis:  4.775853
```

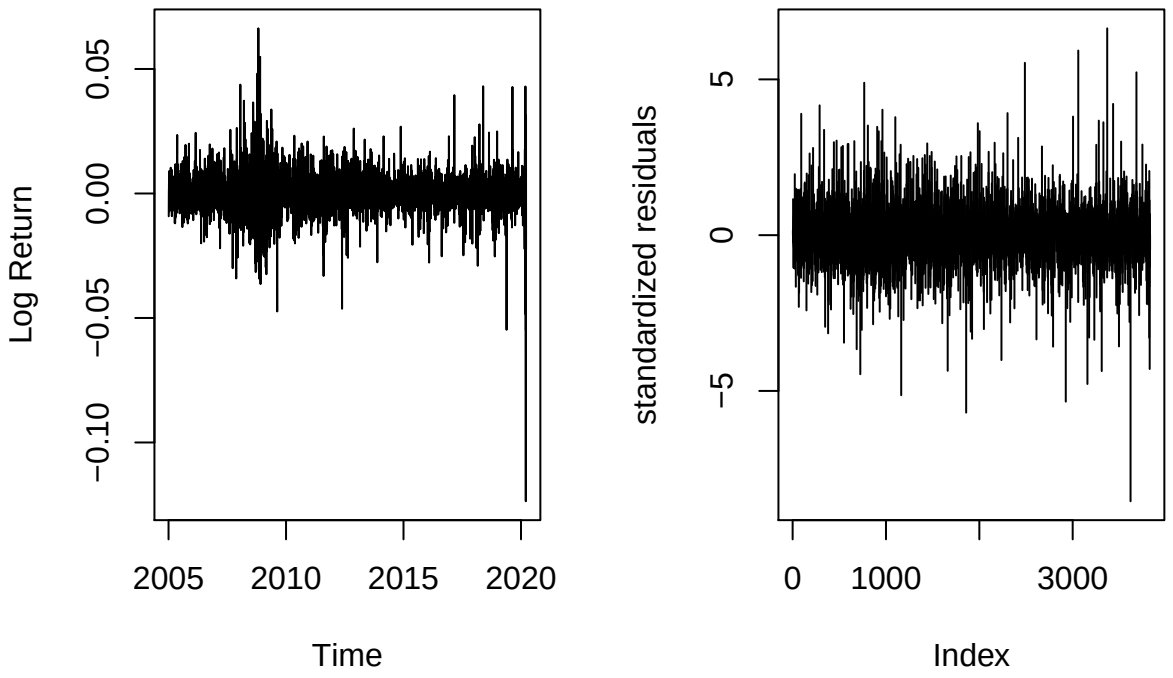

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

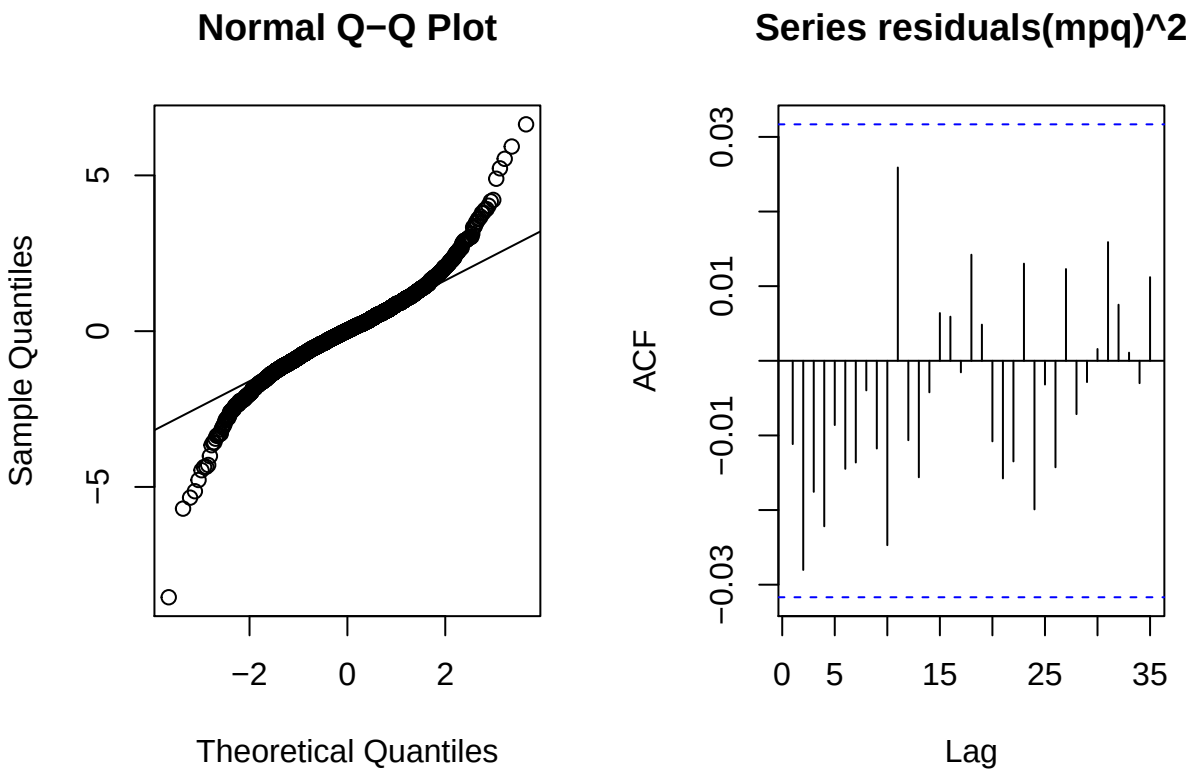

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.5 Dataset 1: Stock MCO

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.5.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3773.204
## [1] 1 2

##
## Call:
## garch(x = MCO.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -10.72984  -0.46826   0.05438   0.58179   7.25452
```

```
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 3.643e-06   3.221e-07    11.31   <2e-16 ***
## a1 1.645e-01   1.309e-02    12.56   <2e-16 ***
## a2 5.127e-09   1.776e-02     0.00        1
## b1 8.064e-01   1.427e-02    56.49   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 14350, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.026958, df = 1, p-value = 0.8696
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3773.204
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.5.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.93483, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 14350, df = 2, p-value < 2.2e-16

## skewness:  -0.5428057

## kurtosis:  9.424122
```

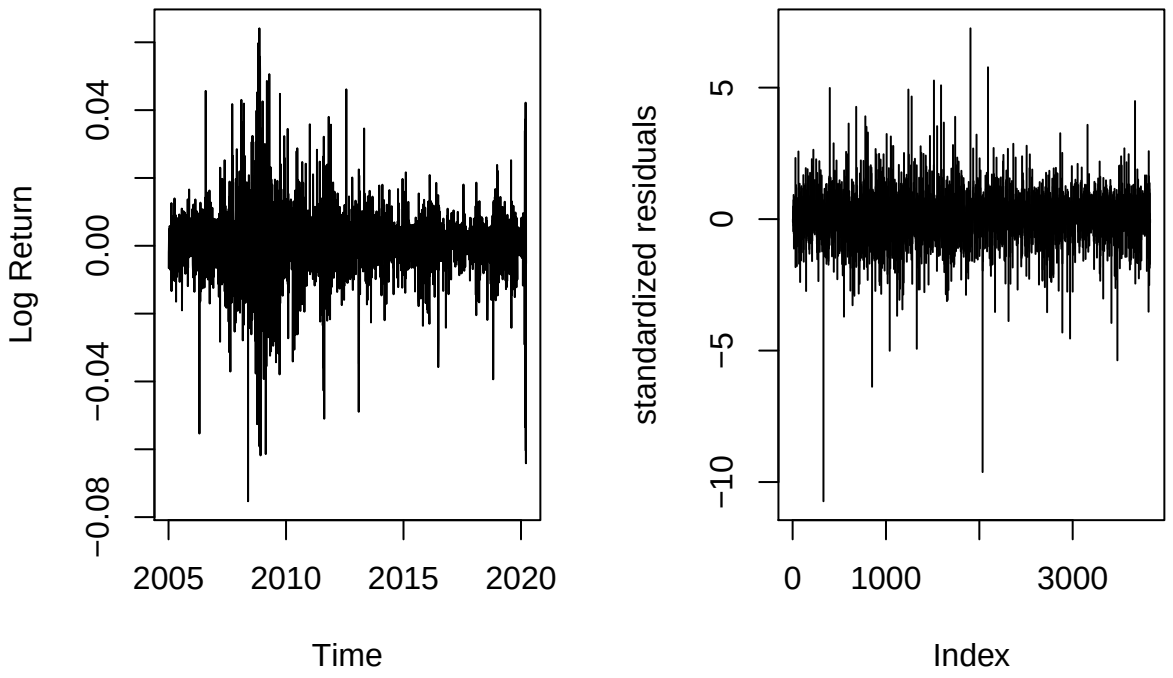

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

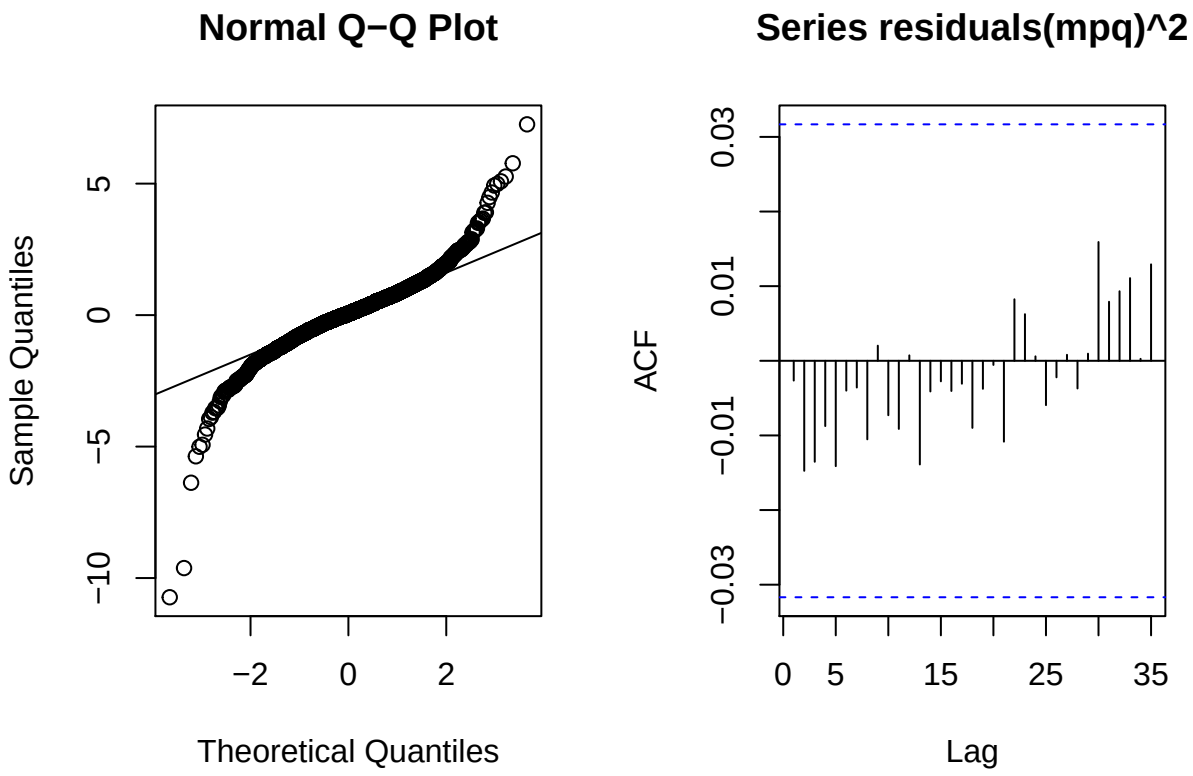

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.6 Dataset 1: Stock MSFT

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.6.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3772.626
## [1] 1 2

##
## Call:
## garch(x = MSFT.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -11.58003  -0.48279   0.02266   0.56984   7.05862
```

```
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 4.311e-06   4.075e-07    10.58   <2e-16 ***
## a1 1.791e-01   1.604e-02    11.17   <2e-16 ***
## a2 6.559e-10   1.890e-02     0.00        1
## b1 7.525e-01   2.019e-02    37.28   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 17052, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.82838, df = 1, p-value = 0.3627
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3772.626
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.6.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.9334, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 17052, df = 2, p-value < 2.2e-16

## skewness:  -0.3523854

## kurtosis:  10.31701
```

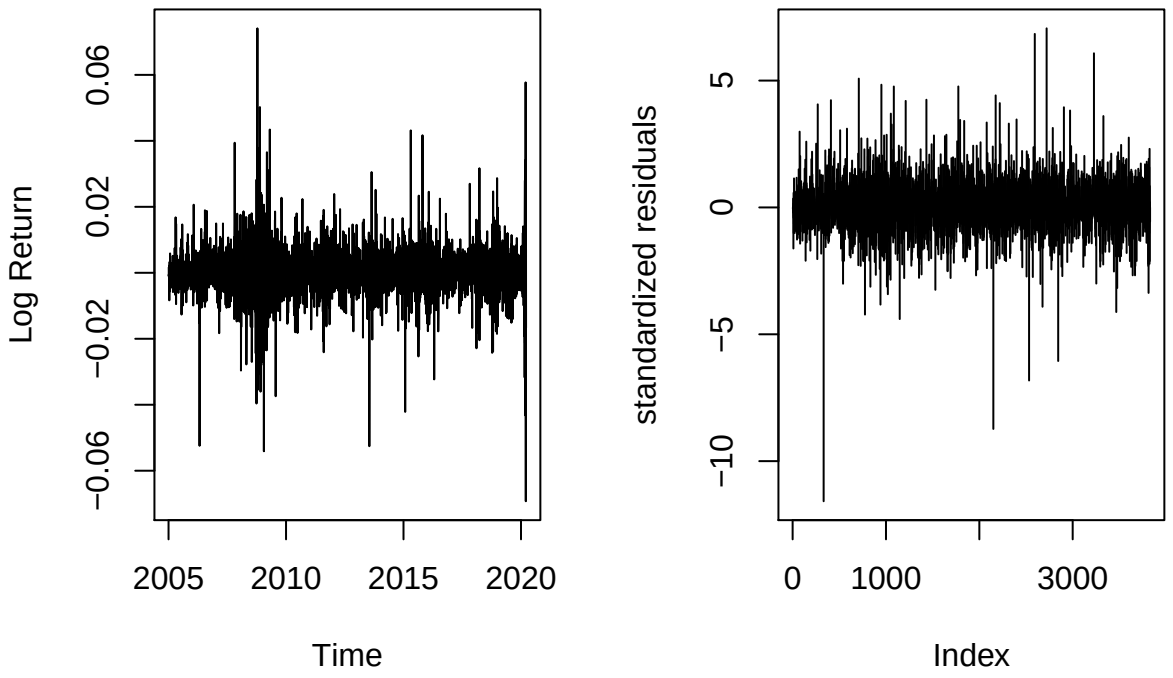

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

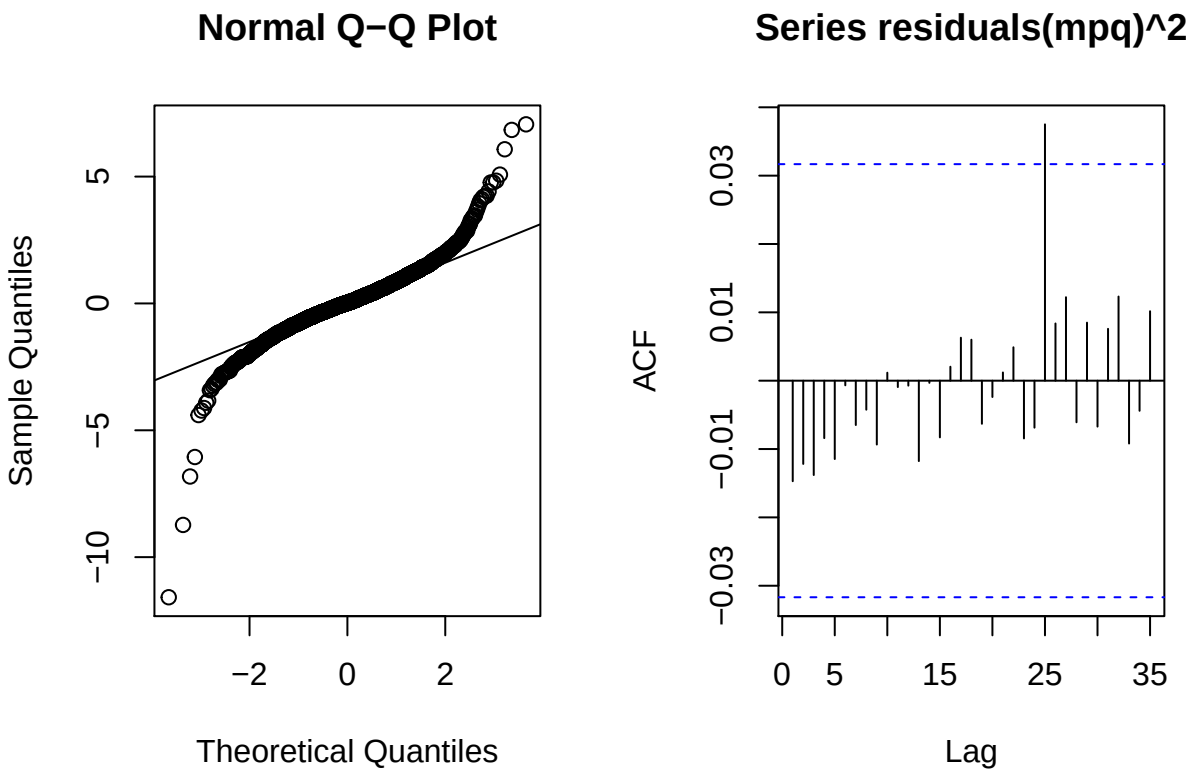

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.7 Dataset 1: Stock PFE

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.7.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3802.875
## [1] 1 2

##
## Call:
## garch(x = PFE.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6496 -0.5520  0.0000  0.5713  5.5237
```

```
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 1.353e-06   1.609e-07    8.411   <2e-16 ***
## a1 1.427e-01   1.509e-02    9.457   <2e-16 ***
## a2 3.126e-10   1.653e-02    0.000        1
## b1 8.309e-01   1.298e-02   64.004   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 5047.9, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.021347, df = 1, p-value = 0.8838
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3802.875
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.7.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.96319, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 5047.9, df = 2, p-value < 2.2e-16

## skewness:  -0.348042

## kurtosis:  5.583209
```

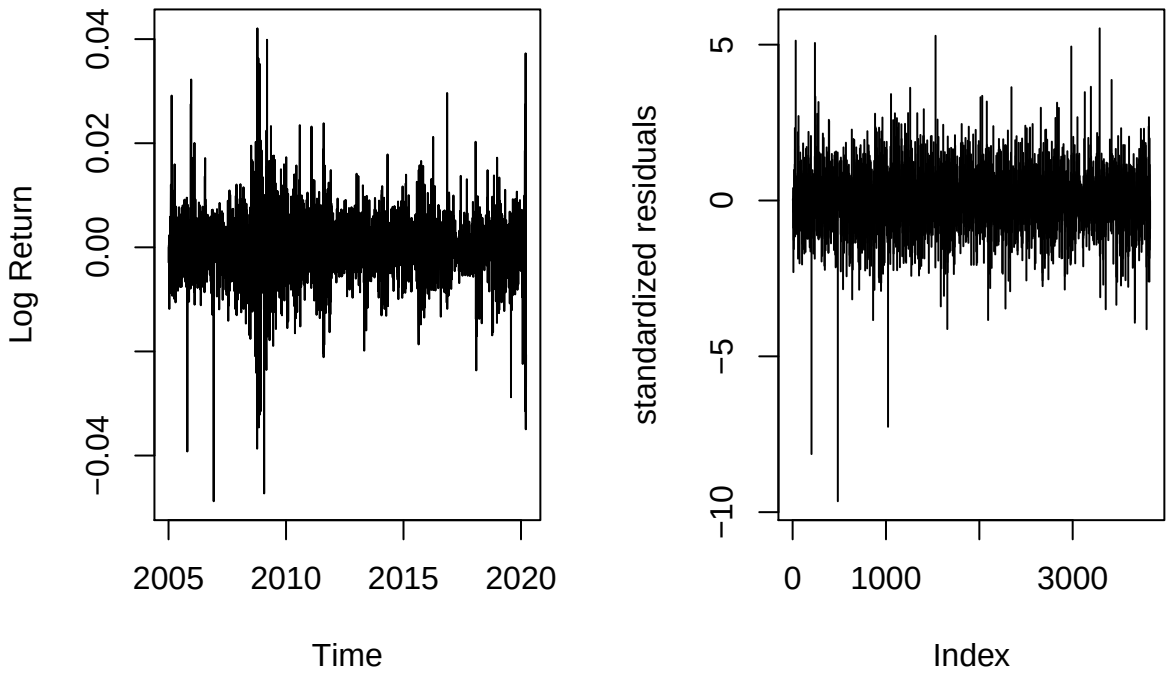

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

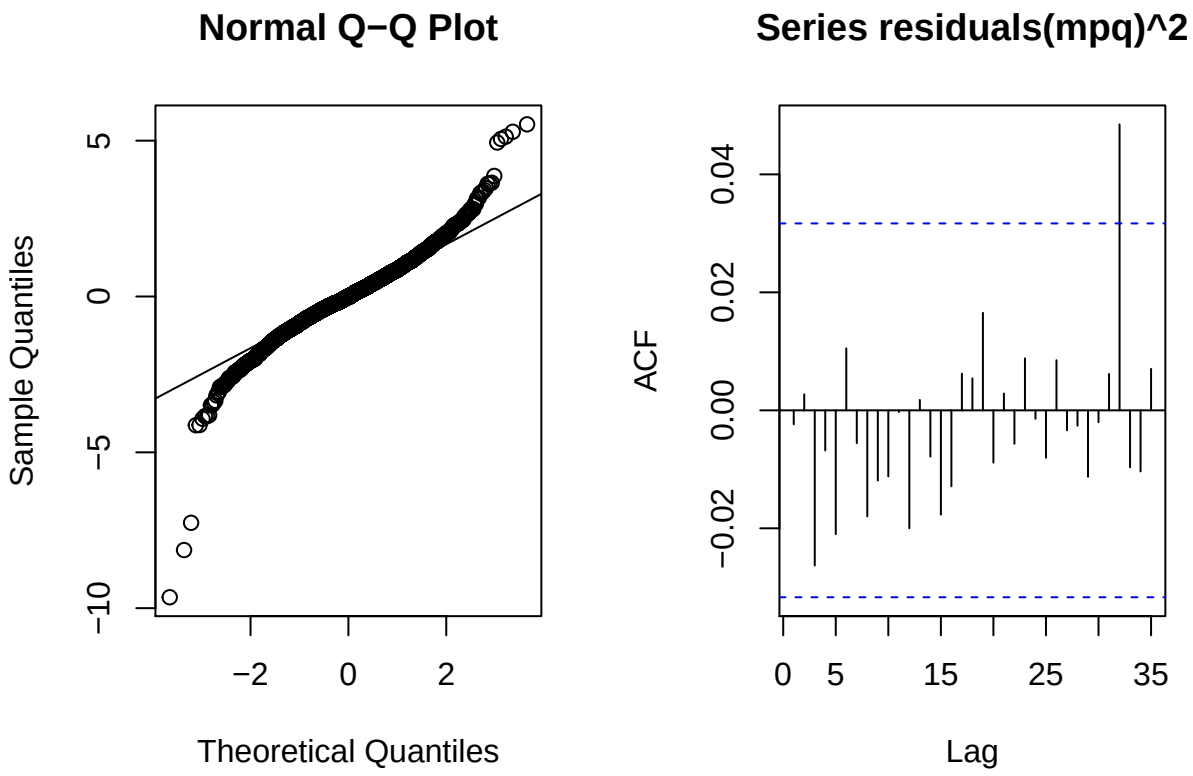

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.8 Dataset 1: Stock ROK

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.8.1

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## [1] 3706.784
## [1] 2 1
```

```
##
## Call:
## garch(x = ROK.return, order = best_params)
##
## Model:
## GARCH(2,1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.02956 -0.51420  0.02852  0.55477  6.39944
##
## Coefficient(s):
```

```
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 6.824e-06   5.191e-07   13.146  < 2e-16 ***
## a1 2.990e-01   1.760e-02   16.983  < 2e-16 ***
## b1 2.541e-01   4.079e-02    6.229 4.71e-10 ***
## b2 4.061e-01   3.696e-02   10.990  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 3282, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 7.5971, df = 1, p-value = 0.005846
```

The best fitted model is GARCH(2,1) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3706.784
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.8.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.95807, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 3282, df = 2, p-value < 2.2e-16

## skewness:  -0.08604433

## kurtosis:  4.533523
```

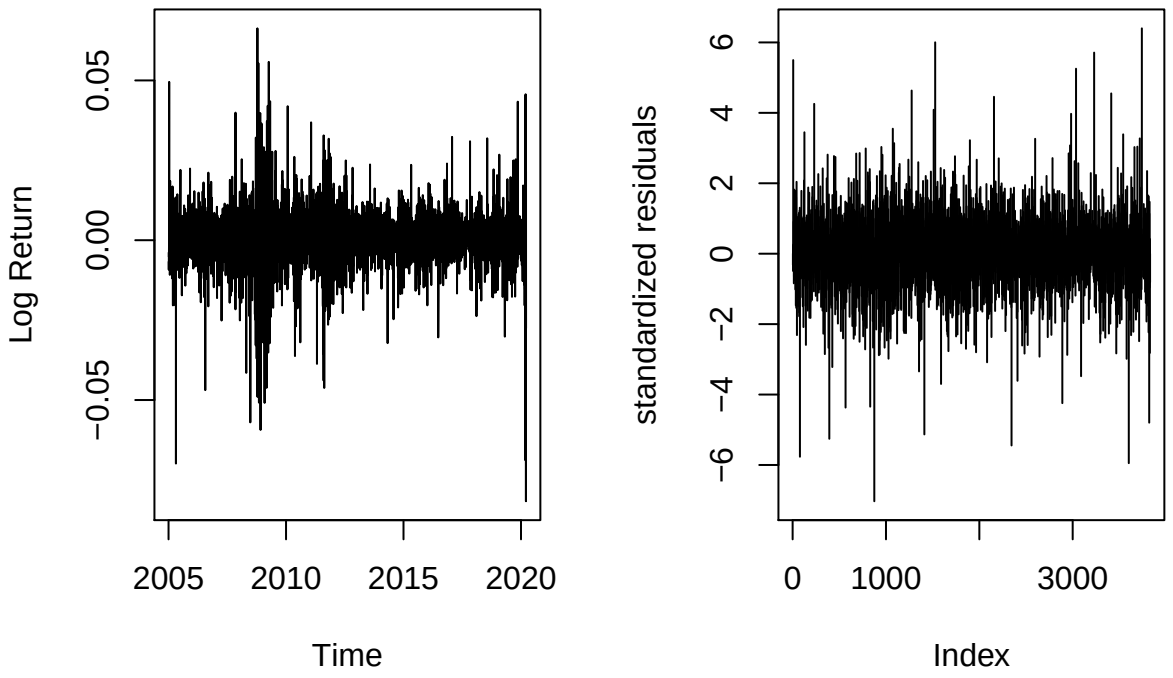

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

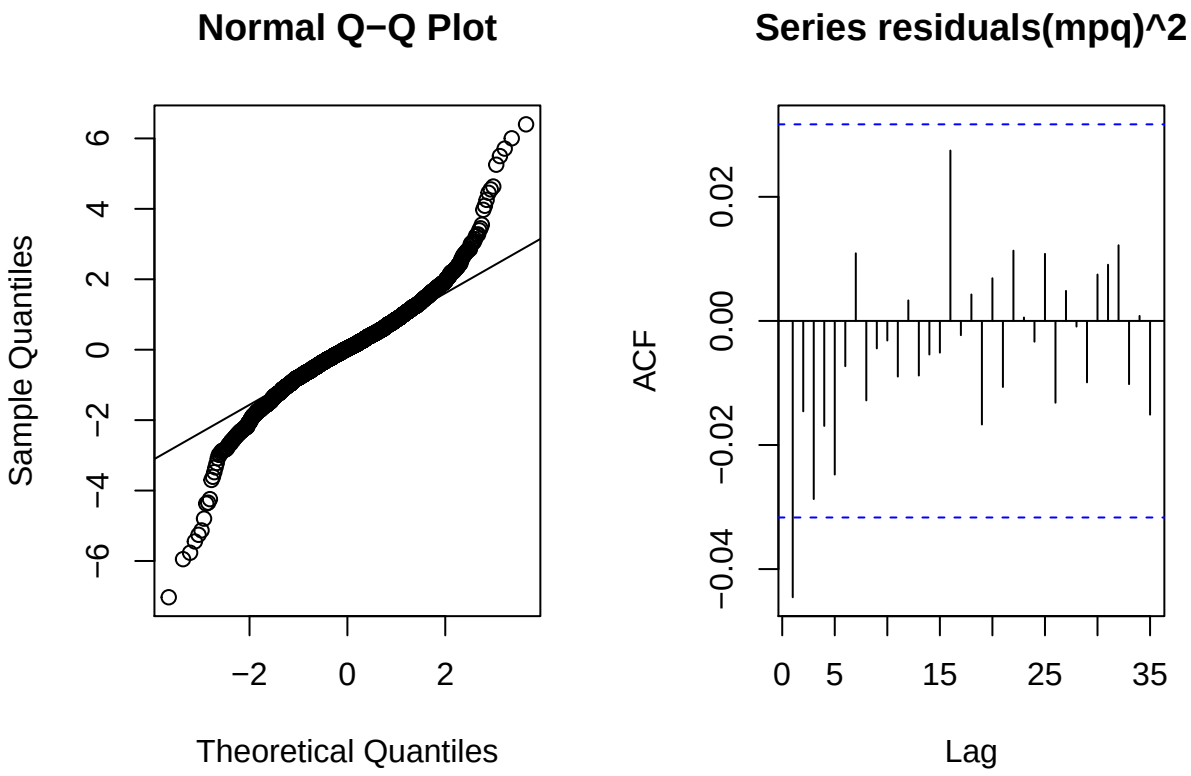

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.9 Dataset 1: Stock TRV

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.9.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3761.931
## [1] 1 2

##
## Call:
## garch(x = TRV.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.83779 -0.51256  0.04509  0.57973  6.88621
```

```
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 8.292e-07   8.897e-08    9.320  < 2e-16 ***
## a1 1.012e-01   1.427e-02    7.093 1.31e-12 ***
## a2 2.096e-09   1.602e-02    0.000        1
## b1 8.843e-01   7.008e-03  126.187  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 4367.7, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.75537, df = 1, p-value = 0.3848
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3761.931
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.9.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.95639, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 4367.7, df = 2, p-value < 2.2e-16

## skewness:  -0.4956872

## kurtosis:  5.138883
```

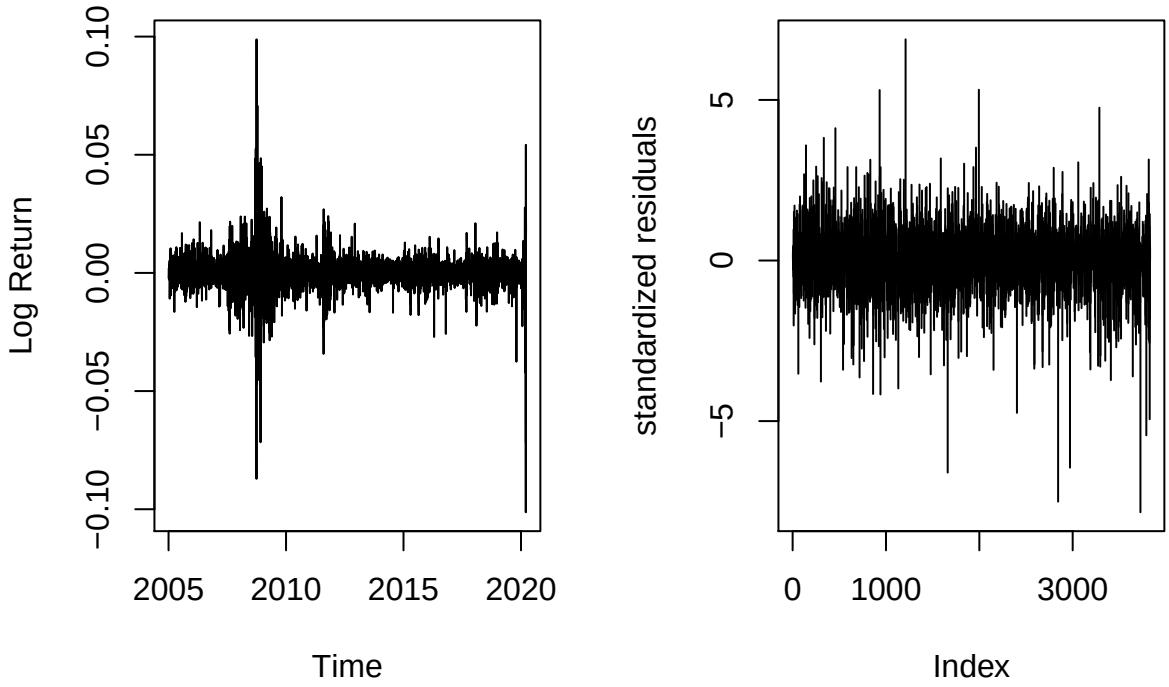

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

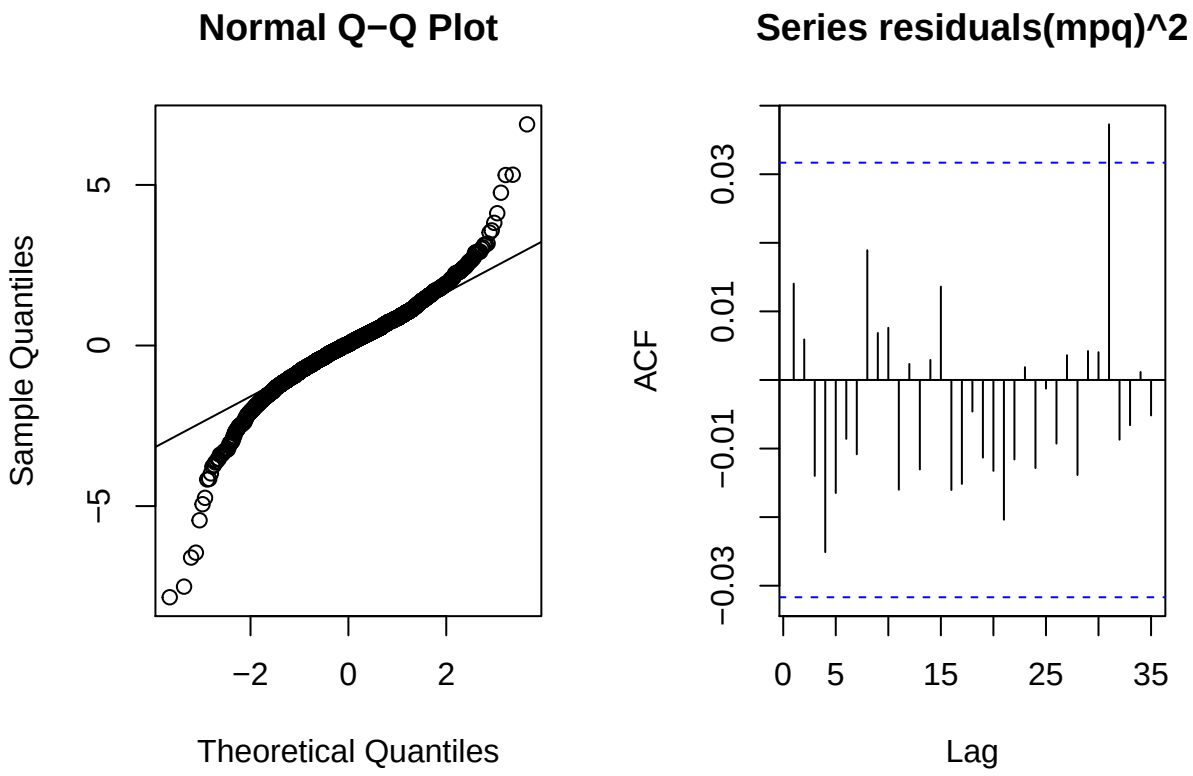

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1.10 Dataset 1: Stock TXT

The original log return series is plotted in Figure on the left panel. The fitted residuals (standardized returns or pseudo-returns) are plotted on the right panel.

1.10.1

```
## Warning in garch(x = data, order = c(p, q)): singular information

## Warning in garch(x = data, order = c(p, q)): singular information

## [1] 3816.051
## [1] 1 2

##
## Call:
## garch(x = TXT.return, order = best_params)
##
## Model:
## GARCH(1,2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.71315 -0.52860  0.01008  0.57339  8.79217
```

```
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 1.841e-06   1.174e-07   15.686  < 2e-16 ***
## a1 6.465e-02   1.286e-02    5.029 4.92e-07 ***
## a2 4.805e-02   1.540e-02    3.121   0.0018 **
## b1 8.788e-01   5.815e-03  151.124  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 9601.6, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.14179, df = 1, p-value = 0.7065
```

The best fitted model is GARCH(1,2) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3816.051
```

State the reason why this model is the final model.

GARCH(1,2) gives the smallest sum of squared residuals for this dataset.

1.10.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.93782, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 9601.6, df = 2, p-value < 2.2e-16

## skewness:  0.08111025

## kurtosis:  7.758057
```

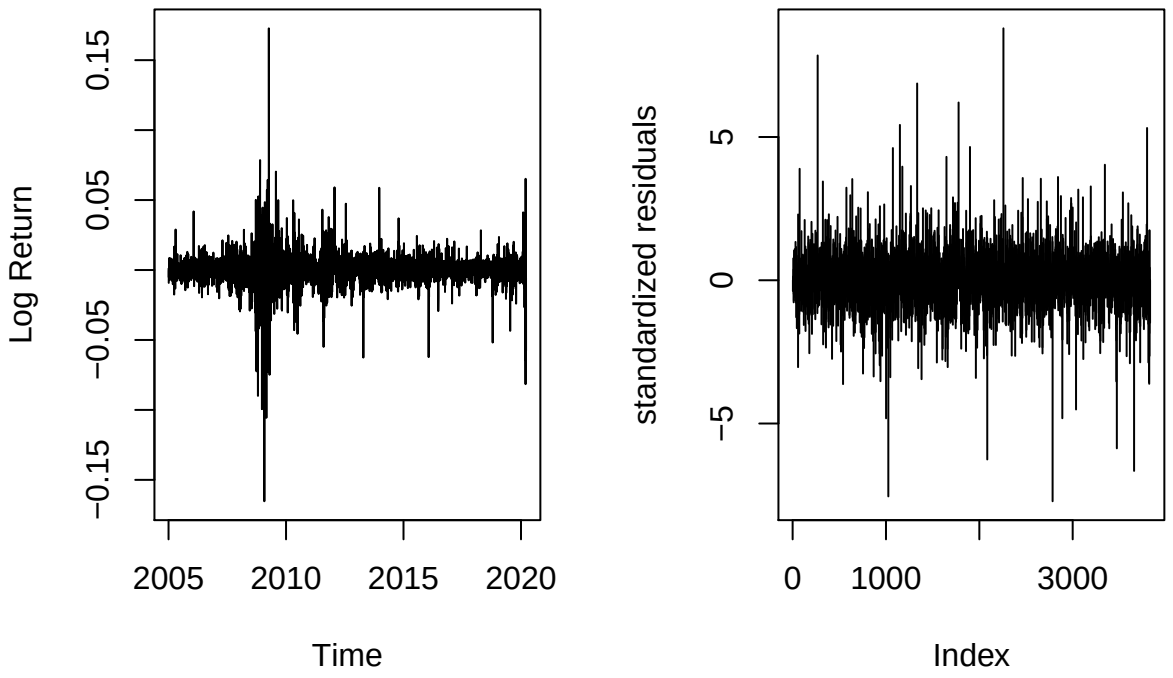

Figure: The left panel is the log return original series from 01/04/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

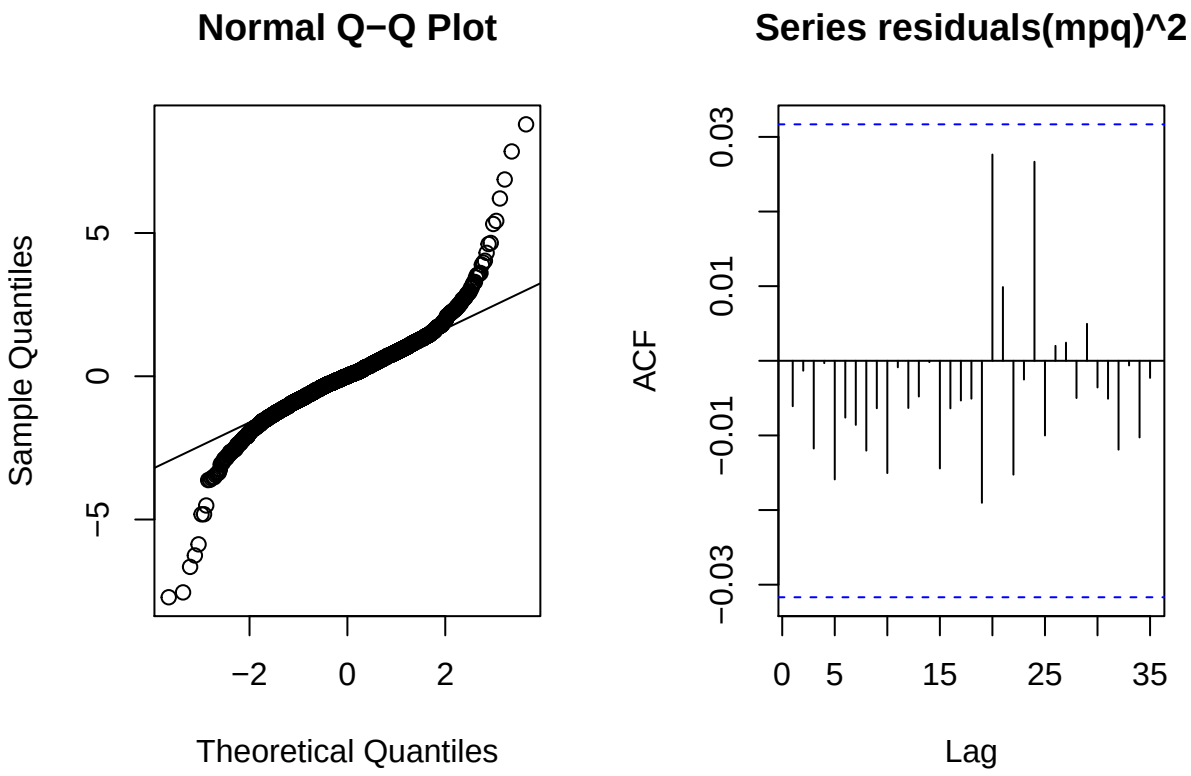

Figure: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

Step 5

1. Report the sample mean and sample standard deviation ($c_i = 1/10$) of r_t.

```
## mean:  7.376142e-05
## standard deviation:  0.006107586
```

2. Report the sample mean and sample standard deviation (c_i =?) of r_t.

```
## Warning: package 'Surrogate' was built under R version 3.5.3
## c_best:  0.4226344 0.0207333 0.1406372 0.06416519 0.007635655 0.1853899 0.0007749104 0.0756523 0.081
## mean:  0.0001452132
## standard deviation:  0.005593865
```

3. Report your optimization procedure.

I used Monte Carlo method to simulate the best c vector. I generated a lot of c vectors $c(c_1, c_2, ..., c_{10})$ that are uniformly distributed in the space where $c_1 + c_2 + ... + c_{10} = 1$ and $c_i \geq 0$. I select the best c vector which generates the largest objective value and satisfy the condition that the std smaller than or equal to the std from c(1/10).

3 Step 6

1. Report the sample mean and sample standard deviation ($c_i = 1/10$) of r_t^ϵ.

```
## mean:  0.01828762
```

```
## standard deviation:  0.6505152
```

2. Report the sample mean and sample standard deviation (c_i =?) of r_t^ϵ.

```
## c_best:  0.03089828 0.1176029 0.1693533 0.1289134 0.1167062 0.13979 0.09868266 0.07171978 0.07194399
```

```
## mean:  0.01835864
```

```
## standard deviation:  0.6493505
```

3. Report your optimization procedure.

I used Monte Carlo method to simulate the best c vector. I generated a lot of c vectors $c(c_1, c_2, ..., c_{10})$ that are uniformly distributed in the space where $c_1 + c_2 + ... + c_{10} = 1$ and $c_i \geq 0$. I select the best c vector which generates the largest objective value and satisfy the condition that the std smaller than or equal to the std from c(1/10).

4 Step 7

1. Report the sample mean and sample standard deviation ($c_i = 1/10$) of r_t^p.

```
## mean:  0.0001049287
```

```
## standard deviation:  0.006093258
```

2. Report the sample mean and sample standard deviation (c_i =?) of r_t^p.

```
## c_best:  0.5358484 0.02768855 0.110723 0.1013489 0.007871983 0.1850356 0.01902716 0.003747687 0.0019
```

```
## mean:  0.0001452168
```

```
## standard deviation:  0.005444439
```

3. Report your optimization procedure.

I used Monte Carlo method to simulate the best c vector. I generated a lot of c vectors $c(c_1, c_2, ..., c_{10})$ that are uniformly distributed in the space where $c_1 + c_2 + ... + c_{10} = 1$ and $c_i \geq 0$. I select the best c vector which generates the largest objective value and satisfy the condition that the std smaller than or equal to the std from c(1/10).

5 Step 8

5.1 Dataset:

r_t^p from $c_i = 1/10$

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## [1] 3816.207
## [1] 2 1
```

5.1.1

The best fitted model is GARCH(p,q) with the following estimated parameter values and standard errors.

```
## Warning in garch(x = rtp.c1, order = best_params): singular information
```

```
##
## Call:
## garch(x = rtp.c1, order = best_params)
##
## Model:
## GARCH(2,1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.61251 -0.52827  0.07624  0.64961  4.87576
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 5.692e-07          NA       NA       NA
## a1 1.165e-01          NA       NA       NA
## b1 8.651e-01          NA       NA       NA
## b2 4.384e-09          NA       NA       NA
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 394.43, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.068531, df = 1, p-value = 0.7935
```

Report the sum of the squared error of the final model.

```
## [1] 3816.207
```

State the reason why this model is the final model, instead of GARCH(1,2), GARCH(2,1), or GARCH(2,2).

5.1.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.98631, p-value < 2.2e-16
```

```
##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 394.43, df = 2, p-value < 2.2e-16
```

```
## skewness:  -0.3635358
```

```
## kurtosis:  1.394617
```

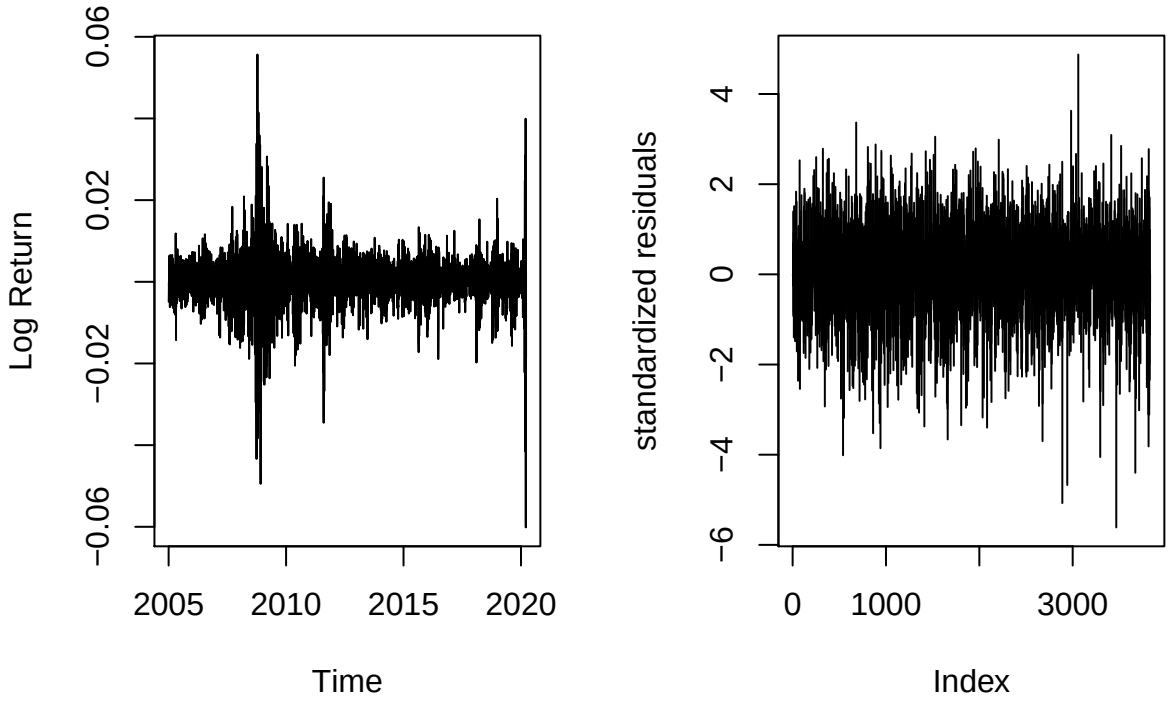

Figure 5.1: The left panel is the log return original series from 01/05/2005 to 03/20/2020. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

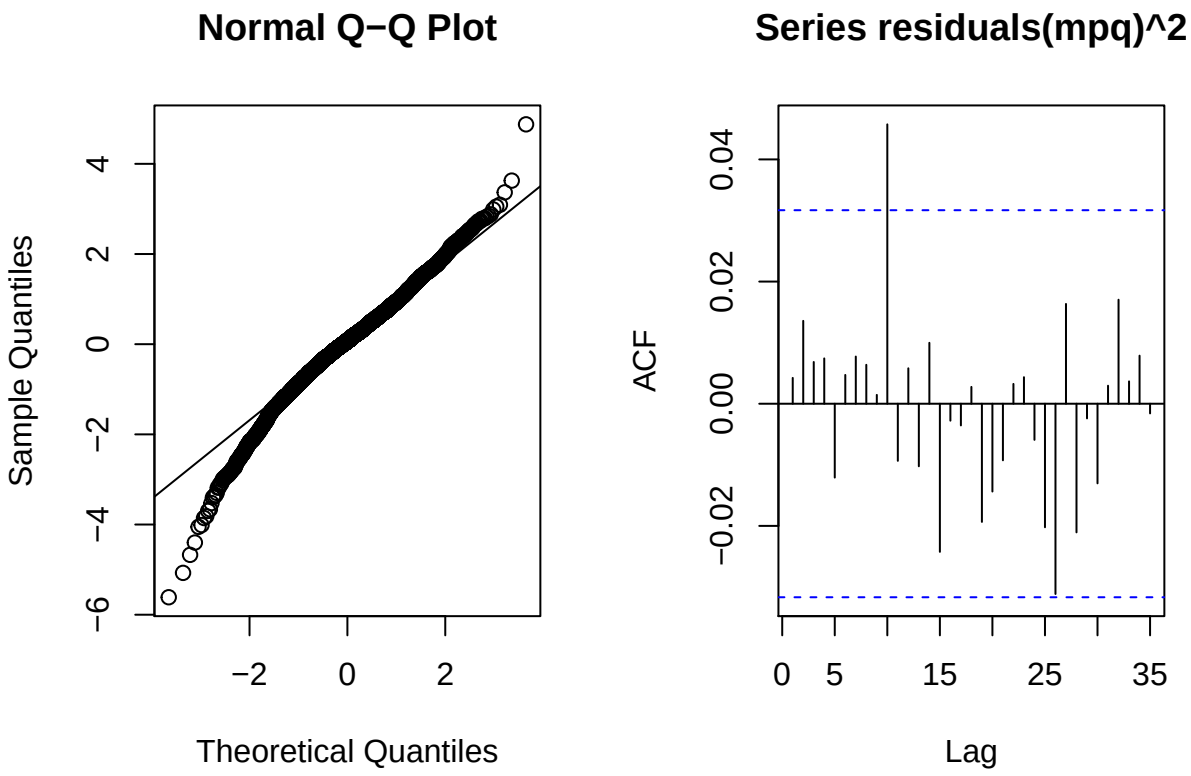

Figure 5.2: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1. Report the sample mean and sample standard deviation ($c_i = 1/10$) of ϵ_t.

```
## mean:  0.03621546
```

```
## standard deviation:  0.9980624
```

6 Step 9

TODO

6.1 Dataset:

r_t^p from c_i =?

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## Warning in garch(x = data, order = c(p, q)): singular information
```

```
## [1] 3744.663
## [1] 2 2
```

```
## Warning in garch(x = rtp.cbest, order = best_params): singular information
```

```
##
## Call:
```

```
## garch(x = rtp.cbest, order = best_params)
##
## Model:
## GARCH(2,2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -6.22818 -0.52659  0.06439  0.64123  6.44664
##
## Coefficient(s):
##     Estimate  Std. Error  t value Pr(>|t|)
## a0 1.767e-06          NA       NA       NA
## a1 9.870e-02          NA       NA       NA
## a2 1.430e-01          NA       NA       NA
## b1 3.215e-01          NA       NA       NA
## b2 3.757e-01          NA       NA       NA
##
## Diagnostic Tests:
##  Jarque Bera Test
##
## data:  Residuals
## X-squared = 509.35, df = 2, p-value < 2.2e-16
##
##
##  Box-Ljung test
##
## data:  Squared.Residuals
## X-squared = 0.07266, df = 1, p-value = 0.7875
```

6.1.1

The best fitted model is GARCH(p,q) with the following estimated parameter values and standard errors.

Report the sum of the squared error of the final model.

```
## [1] 3744.663
```

State the reason why this model is the final model, instead of GARCH(1,2), GARCH(2,1), or GARCH(2,2).

6.1.2 Some diagnostic results

```
##
##  Shapiro-Wilk normality test
##
## data:  na.omit(residuals(mpq))
## W = 0.98683, p-value < 2.2e-16

##
##  Jarque Bera Test
##
## data:  na.omit(residuals(mpq))
## X-squared = 509.35, df = 2, p-value < 2.2e-16

## [1] -0.2150195

## [1] 1.73473
```

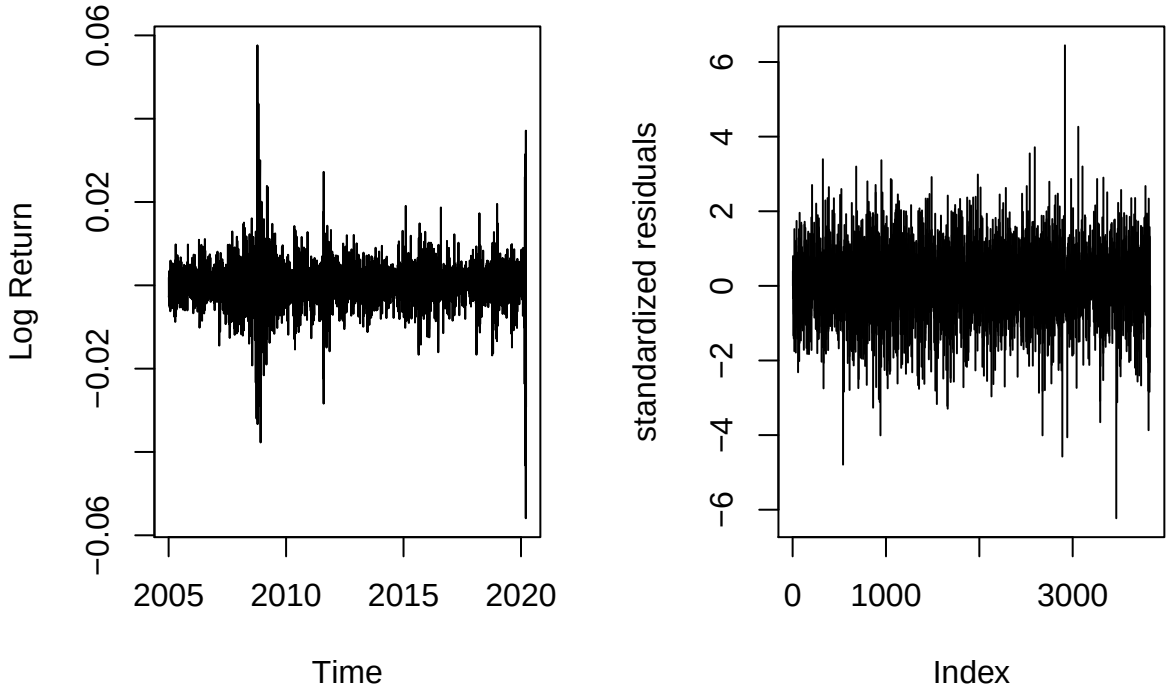

Figure 6.1: The left panel is the log return original series from xx/xx/xxxx to xx/xx/xxxx. The right panel is the fitted residuals (standardized returns or pseudo- returns.)

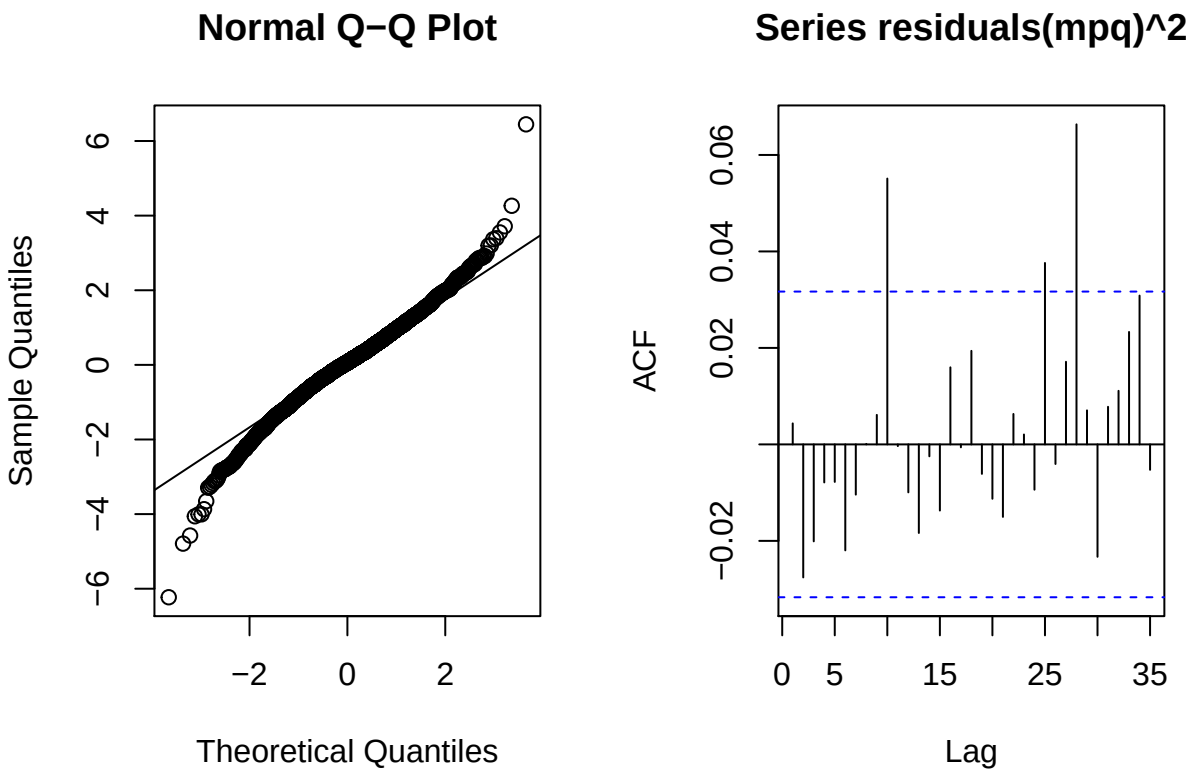

Figure 6.2: The left panel is the residual QQ plot. The right panel is the squared residual ACF plot.

1. Report the sample mean and sample standard deviation (c_i =?) of ϵ_t.

```
## mean:  0.04006906
```

```
## standard deviation:  0.9885014
```

7 Step 10

Compare results from Step 5 to Step 9. (Compare the results of the best c_i and mean values.)

From Step 5 to Step 7, there are 3 distinct best c vectors (Step 8 and 9 are just using the c vector from Step 7). We see that the c_best vectors from Step 5 and Step 7 are pretty close to each other. The means are also very similar (about 0.00014). This is probably because the formula of r_t and r_tˆp are very similar and both are computed through similar log returns approach.

However, the c_best for step 6 is very different from step 5 and 7, and the mean is also much larger than step 5 and 7. This c_best is actually close to (1/10,...,1/10). This is probably because of the fact that the GARCH models did not fit the data so well.