

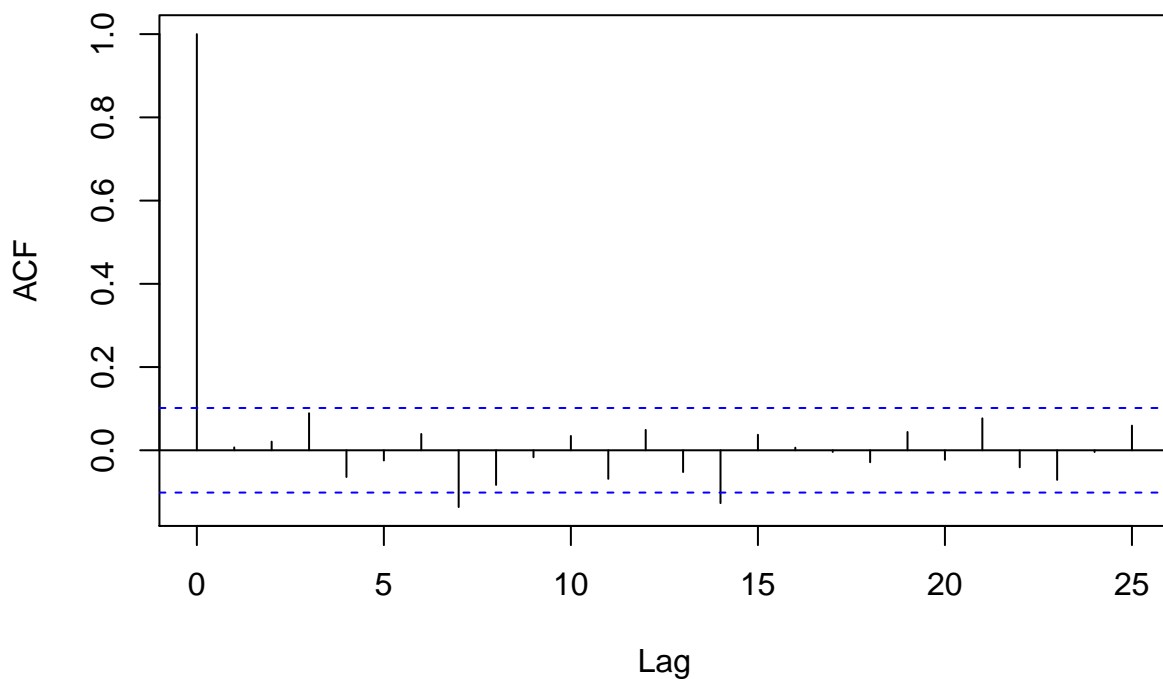
Conditional Heteroscedastic Models

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This paper is a practice from the book called Analysis of Financial Time Series by Ruey S. Tsay. All R codes and comments below are belonged to the book and author.

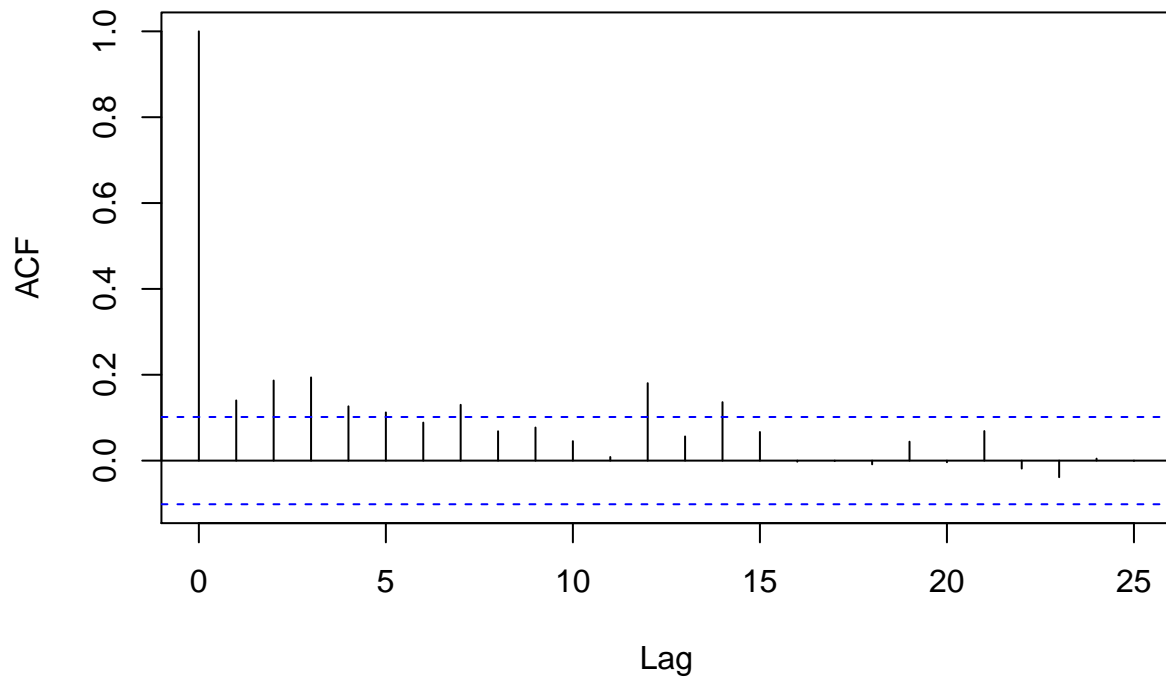
```
suppressPackageStartupMessages(require(fGarch))  
www<-"http://faculty.chicagobooth.edu/ruey.tsay/teaching/bs41202/sp2014/m-intc7303.txt"  
da=read.table(www,header=T)  
intc=log(da$rtm+1) # log returns  
acf(intc)
```

Series intc



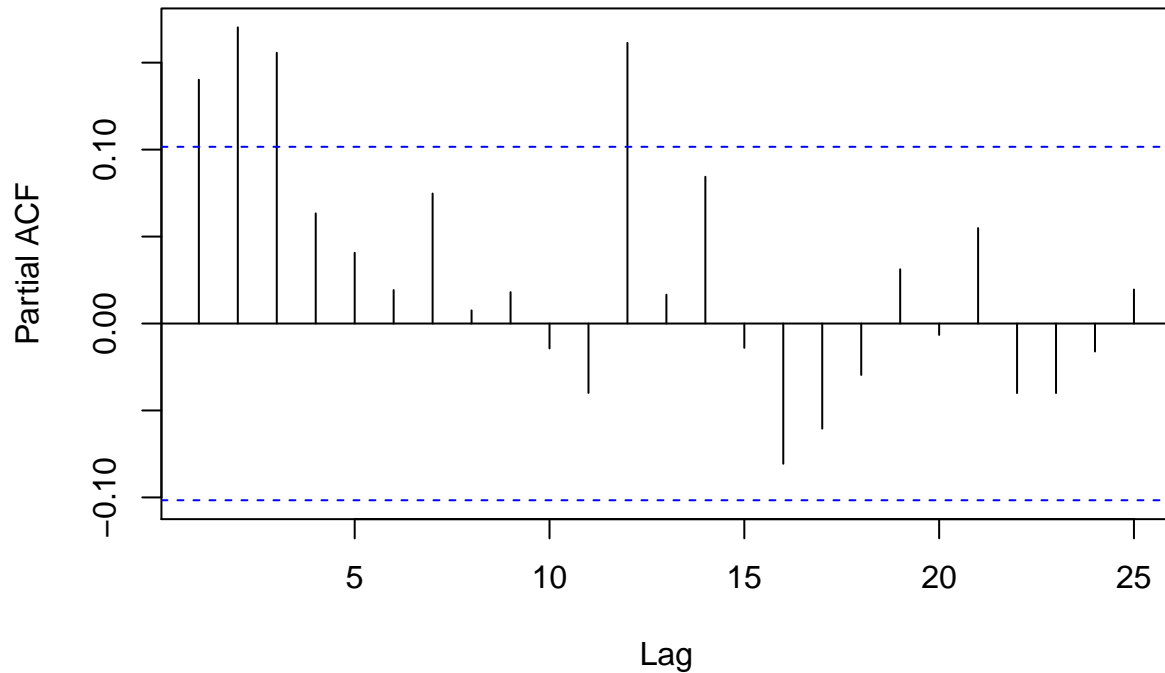
```
acf(intc^2)
```

Series intc^2



```
pacf(intc^2)
```

Series intc^2



```
Box.test(intc^2,lag=10,type='Ljung')
```

```
##  
## Box-Ljung test  
##  
## data: intc^2  
## X-squared = 59.722, df = 10, p-value = 4.091e-09
```

```
m1=garchFit(~garch(3,0),data=intc,trace=F)# trace=F reduces output.  
summary(m1)
```

```
##  
## Title:  
## GARCH Modelling  
##  
## Call:  
## garchFit(formula = ~garch(3, 0), data = intc, trace = F)  
##  
## Mean and Variance Equation:  
## data ~ garch(3, 0)  
## <environment: 0x7ffa7551c508>  
## [data = intc]  
##  
## Conditional Distribution:
```

```

## norm
##
## Coefficient(s):
##      mu      omega    alpha1    alpha2    alpha3
## 0.016572 0.012043 0.208649 0.071837 0.049045
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.016572    0.006423    2.580 0.00988 **
## omega   0.012043    0.001579    7.627 2.4e-14 ***
## alpha1  0.208649    0.129177    1.615 0.10626
## alpha2  0.071837    0.048551    1.480 0.13897
## alpha3  0.049045    0.048847    1.004 0.31536
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 233.4286    normalized: 0.6274962
##
## Description:
## Tue May 10 22:13:40 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test  R    Chi^2 169.773 0
## Shapiro-Wilk Test R    W    0.960696 1.970626e-08
## Ljung-Box Test   R    Q(10) 10.97025 0.3598405
## Ljung-Box Test   R    Q(15) 19.59024 0.1882211
## Ljung-Box Test   R    Q(20) 20.82192 0.40768
## Ljung-Box Test   R^2  Q(10) 5.376602 0.8646439
## Ljung-Box Test   R^2  Q(15) 22.7346 0.08993974
## Ljung-Box Test   R^2  Q(20) 23.70577 0.255481
## LM Arch Test     R    TR^2 20.48506 0.05844884
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -1.228111 -1.175437 -1.228466 -1.207193

```

```

m1=garchFit(~garch(1,0),data=intc,trace=F)
summary(m1)

```

```

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 0), data = intc, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 0)

```

```

## <environment: 0x7ffa75e385c8>
## [data = intc]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      omega  alpha1
## 0.01657  0.01249  0.36345
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate  Std. Error  t value  Pr(>|t|)
## mu          0.016570    0.006161    2.689    0.00716 **
## omega       0.012490    0.001549    8.061    6.66e-16 ***
## alpha1     0.363447    0.131598    2.762    0.00575 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 230.2423      normalized:  0.6189309
##
## Description:
## Tue May 10 22:13:40 2016 by user:
##
##
## Standardised Residuals Tests:
##
##              Statistic p-Value
## Jarque-Bera Test  R      Chi^2 122.404  0
## Shapiro-Wilk Test R      W      0.9647625 8.273101e-08
## Ljung-Box Test   R      Q(10) 13.72604 0.1858587
## Ljung-Box Test   R      Q(15) 22.31714 0.09975386
## Ljung-Box Test   R      Q(20) 23.88257 0.2475594
## Ljung-Box Test   R^2    Q(10) 12.50025 0.25297
## Ljung-Box Test   R^2    Q(15) 30.11276 0.01152131
## Ljung-Box Test   R^2    Q(20) 31.46404 0.04935483
## LM Arch Test     R      TR^2  22.036  0.0371183
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -1.221733 -1.190129 -1.221861 -1.209182

# t student innovation (cond.dist="std")
m2=garchFit(~garch(1,0),data=intc,cond.dist="std",trace=F)
summary(m2)

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 0), data = intc, cond.dist = "std",

```

```

##      trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 0)
## <environment: 0x7ffa7388f588>
## [data = intc]
##
## Conditional Distribution:
## std
##
## Coefficient(s):
##      mu      omega    alpha1    shape
## 0.021571 0.013424 0.259867 5.985979
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.021571  0.006054   3.563 0.000366 ***
## omega   0.013424  0.001968   6.820 9.09e-12 ***
## alpha1  0.259867  0.119901   2.167 0.030209 *
## shape   5.985979  1.660030   3.606 0.000311 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 242.9678      normalized: 0.6531391
##
## Description:
## Tue May 10 22:13:40 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test  R      Chi^2 130.8931 0
## Shapiro-Wilk Test R      W      0.9637533 5.744995e-08
## Ljung-Box Test   R      Q(10) 14.31288 0.1591926
## Ljung-Box Test   R      Q(15) 23.34043 0.07717449
## Ljung-Box Test   R      Q(20) 24.87286 0.2063387
## Ljung-Box Test   R^2    Q(10) 15.35917 0.1195054
## Ljung-Box Test   R^2    Q(15) 33.96318 0.003446127
## Ljung-Box Test   R^2    Q(20) 35.46828 0.01774746
## LM Arch Test     R      TR^2 24.11517 0.01961957
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -1.284773 -1.242634 -1.285001 -1.268039

```

```
predict(m2,5)
```

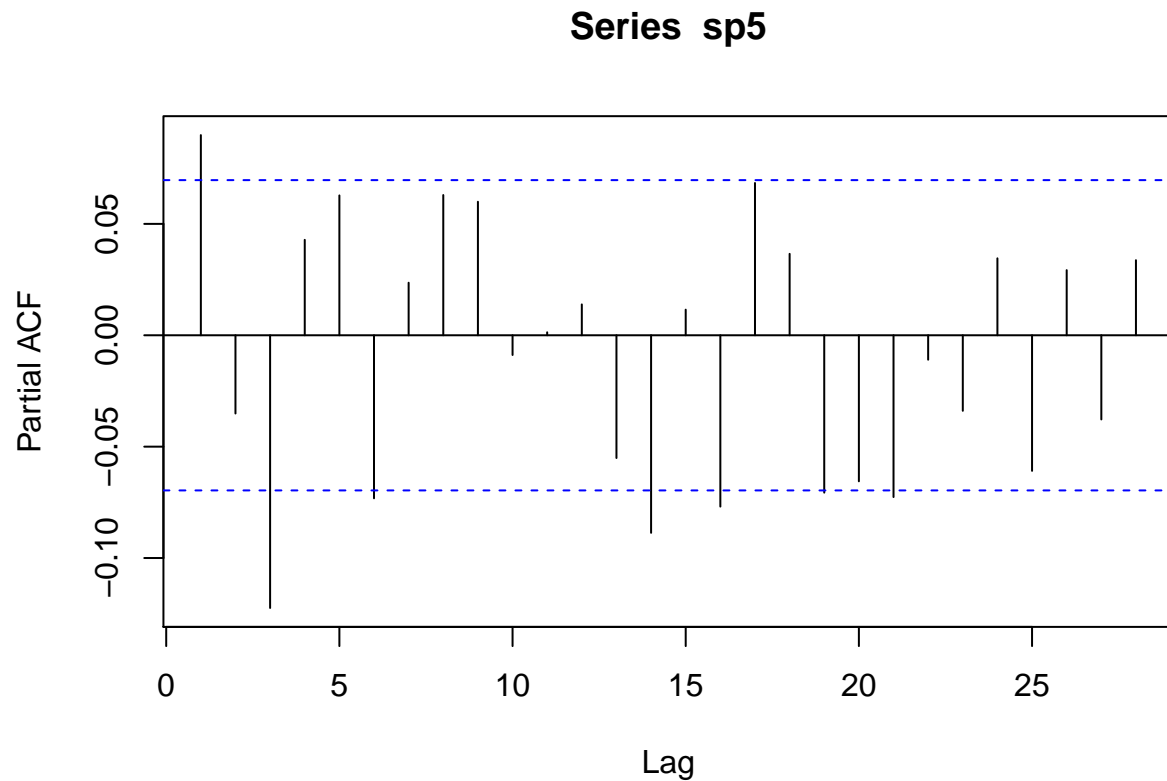
```

##      meanForecast meanError standardDeviation
## 1      0.021571 0.1207911      0.1207911
## 2      0.021571 0.1312069      0.1312069

```

```
## 3    0.021571 0.1337810      0.1337810
## 4    0.021571 0.1344418      0.1344418
## 5    0.021571 0.1346130      0.1346130
```

```
www<-"https://faculty.chicagobooth.edu/ruey.tsay/teaching/fts/sp500.dat"
sp5<-read.table(www,header=F)
pacf(sp5)# AR(3)
```



```
m1=arima(sp5,order=c(3,0,0))
m1
```

```
##
## Call:
## arima(x = sp5, order = c(3, 0, 0))
##
## Coefficients:
##      ar1      ar2      ar3  intercept
##  0.0890 -0.0238 -0.1229    0.0062
## s.e.  0.0353  0.0355  0.0353    0.0019
##
## sigma^2 estimated as 0.00333:  log likelihood = 1135.25,  aic = -2260.5
```

```
m2=garchFit(~arma(3,0)+garch(1,1),data=sp5,trace=F)
summary(m2)
```

```

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~arma(3, 0) + garch(1, 1), data = sp5, trace = F)
##
## Mean and Variance Equation:
## data ~ arma(3, 0) + garch(1, 1)
## <environment: 0x7ffa75a2cf90>
## [data = sp5]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      ar1      ar2      ar3      omega
## 7.7077e-03 3.1968e-02 -3.0261e-02 -1.0649e-02 7.9746e-05
## alpha1    beta1
## 1.2425e-01 8.5302e-01
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      7.708e-03 1.607e-03 4.798 1.61e-06 ***
## ar1     3.197e-02 3.837e-02 0.833 0.40473
## ar2    -3.026e-02 3.841e-02 -0.788 0.43076
## ar3    -1.065e-02 3.756e-02 -0.284 0.77677
## omega  7.975e-05 2.810e-05 2.838 0.00454 **
## alpha1 1.242e-01 2.247e-02 5.529 3.22e-08 ***
## beta1  8.530e-01 2.183e-02 39.075 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1272.179    normalized: 1.606287
##
## Description:
## Tue May 10 22:13:43 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test  R    Chi^2 73.04842 1.110223e-16
## Shapiro-Wilk Test R    W    0.9857968 5.961507e-07
## Ljung-Box Test   R    Q(10) 11.56744 0.315048
## Ljung-Box Test   R    Q(15) 17.78747 0.2740039
## Ljung-Box Test   R    Q(20) 24.11916 0.2372256
## Ljung-Box Test   R^2  Q(10) 10.31614 0.4132089
## Ljung-Box Test   R^2  Q(15) 14.22819 0.5082978
## Ljung-Box Test   R^2  Q(20) 16.79405 0.6663038
## LM Arch Test     R    TR^2 13.34305 0.3446075

```



```
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -3.194897 -3.153581 -3.195051 -3.179018
```

```
m2=garchFit(~garch(1,1),data=sp5,trace=F)
summary(m2)
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 1), data = sp5, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 1)
## <environment: 0x7ffa75416b80>
## [data = sp5]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      omega      alpha1      beta1
## 7.4497e-03 8.0615e-05 1.2198e-01 8.5436e-01
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      7.450e-03 1.538e-03  4.845 1.27e-06 ***
## omega  8.061e-05 2.833e-05  2.845 0.00444 **
## alpha1 1.220e-01 2.202e-02  5.540 3.02e-08 ***
## beta1  8.544e-01 2.175e-02 39.276 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1269.455      normalized: 1.602848
##
## Description:
## Tue May 10 22:13:43 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test R Chi^2 80.32111 0
## Shapiro-Wilk Test R W 0.98505 3.136885e-07
## Ljung-Box Test R Q(10) 11.2205 0.340599
## Ljung-Box Test R Q(15) 17.99703 0.262822
## Ljung-Box Test R Q(20) 24.29896 0.2295768
## Ljung-Box Test R^2 Q(10) 9.920157 0.4475259
```

```
## Ljung-Box Test      R^2  Q(15)  14.21124  0.509572
## Ljung-Box Test      R^2  Q(20)  16.75081  0.6690903
## LM Arch Test        R    TR^2   13.04872  0.3655092
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -3.195594 -3.171985 -3.195645 -3.186520
```

```
m3=garchFit(~garch(1,1),data=sp5,cond.dist="std",trace=F)
summary(m3) # t student innovation
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~garch(1, 1), data = sp5, cond.dist = "std",
## trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 1)
## <environment: 0x7ffa7792b498>
## [data = sp5]
##
## Conditional Distribution:
## std
##
## Coefficient(s):
##      mu      omega      alpha1      beta1      shape
## 0.00845504 0.00012485 0.11302582 0.84220210 7.00318063
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      8.455e-03 1.515e-03  5.581 2.39e-08 ***
## omega  1.248e-04 4.519e-05  2.763 0.00573 **
## alpha1 1.130e-01 2.693e-02  4.198 2.70e-05 ***
## beta1  8.422e-01 3.186e-02 26.432 < 2e-16 ***
## shape  7.003e+00 1.680e+00  4.169 3.06e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1283.417 normalized: 1.620476
##
## Description:
## Tue May 10 22:13:43 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test  R    Chi^2 99.61249 0
```

```

## Shapiro-Wilk Test R W 0.9836345 9.72802e-08
## Ljung-Box Test R Q(10) 11.37961 0.3287173
## Ljung-Box Test R Q(15) 18.2163 0.2514649
## Ljung-Box Test R Q(20) 24.91842 0.2045699
## Ljung-Box Test R^2 Q(10) 10.52266 0.3958941
## Ljung-Box Test R^2 Q(15) 16.14586 0.3724248
## Ljung-Box Test R^2 Q(20) 18.93325 0.5261686
## LM Arch Test R TR^2 14.88667 0.247693
##
## Information Criterion Statistics:
## AIC BIC SIC HQIC
## -3.228325 -3.198814 -3.228404 -3.216983

```

```

suppressPackageStartupMessages(require(rgl))
suppressPackageStartupMessages(require(rugarch))
spec1=ugarchspec(variance.model=list(model="iGARCH",garchOrder=c(1,1)),
mean.model=list(armaOrder=c(0,0)))
mm=ugarchfit(data=sp5,spec=spec1)
mm

```

```

##
## *-----*
## *          GARCH Model Fit          *
## *-----*
##
## Conditional Variance Dynamics
## -----
## GARCH Model : iGARCH(1,1)
## Mean Model : ARFIMA(0,0,0)
## Distribution : norm
##
## Optimal Parameters
## -----
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.007417  0.001525  4.8621 0.000001
## omega   0.000051  0.000018  2.9238 0.003458
## alpha1  0.142951  0.021443  6.6667 0.000000
## beta1   0.857049      NA      NA      NA
##
## Robust Standard Errors:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.007417  0.001587  4.6726 0.000003
## omega   0.000051  0.000019  2.6913 0.007118
## alpha1  0.142951  0.024978  5.7230 0.000000
## beta1   0.857049      NA      NA      NA
##
## LogLikelihood : 1268.238
##
## Information Criteria
## -----
##
## Akaike      -3.1950
## Bayes       -3.1773
## Shibata     -3.1951

```

```

## Hannan-Quinn -3.1882
##
## Weighted Ljung-Box Test on Standardized Residuals
## -----
##                statistic p-value
## Lag[1]                0.5265  0.4681
## Lag[2*(p+q)+(p+q)-1][2]  0.5304  0.6795
## Lag[4*(p+q)+(p+q)-1][5]  2.5233  0.5009
## d.o.f=0
## H0 : No serial correlation
##
## Weighted Ljung-Box Test on Standardized Squared Residuals
## -----
##                statistic p-value
## Lag[1]                1.166  0.2803
## Lag[2*(p+q)+(p+q)-1][5]  2.672  0.4702
## Lag[4*(p+q)+(p+q)-1][9]  4.506  0.5054
## d.o.f=2
##
## Weighted ARCH LM Tests
## -----
##                Statistic Shape Scale P-Value
## ARCH Lag[3]    0.4608 0.500 2.000  0.4972
## ARCH Lag[5]    1.3891 1.440 1.667  0.6219
## ARCH Lag[7]    2.2325 2.315 1.543  0.6682
##
## Nyblom stability test
## -----
## Joint Statistic:  0.4498
## Individual Statistics:
## mu      0.08818
## omega   0.14331
## alpha1  0.22409
##
## 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          3.2677 0.001131 ***
## Negative Sign Bias  1.3431 0.179638
## Positive Sign Bias  0.9411 0.346937
## Joint Effect       19.5642 0.000209 ***
##
##
## Adjusted Pearson Goodness-of-Fit Test:
## -----
##   group statistic p-value(g-1)
## 1   20    31.84    0.03259
## 2   30    38.61    0.10944
## 3   40    50.73    0.09888
## 4   50    57.49    0.18957

```

```
##
##
## Elapsed time : 0.1402841
```

```
www<-"http://faculty.chicagobooth.edu/ruey.tsay/teaching/fts3/m-intc7308.txt"
da=read.table(www,header=T)
library(fGarch)
intc=log(da[,2]+1)
m1=garchFit(intc~garch(1,0),data=intc,trace=F)
summary(m1)
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = intc ~ garch(1, 0), data = intc, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 0)
## <environment: 0x7ffa78eae628>
## [data = intc]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      omega    alpha1
## 0.012637 0.011195 0.379492
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.012637  0.005428   2.328 0.01990 *
## omega   0.011195  0.001239   9.034 < 2e-16 ***
## alpha1  0.379492  0.115534   3.285 0.00102 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 288.0589    normalized: 0.6668031
##
## Description:
## Tue May 10 22:13:47 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test R    Chi^2 137.919 0
## Shapiro-Wilk Test R    W    0.9679248 4.024058e-08
## Ljung-Box Test R    Q(10) 12.54002 0.2505382
## Ljung-Box Test R    Q(15) 21.33508 0.1264607
```

```
## Ljung-Box Test      R      Q(20)  23.19679  0.2792354
## Ljung-Box Test      R^2    Q(10)  16.0159   0.09917815
## Ljung-Box Test      R^2    Q(15)  36.08022  0.001721296
## Ljung-Box Test      R^2    Q(20)  37.43683  0.01036728
## LM Arch Test        R      TR^2   26.57744  0.008884587
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -1.319717 -1.291464 -1.319813 -1.308563
```

```
predict(m1,5)
```

```
##      meanForecast meanError standardDeviation
## 1      0.01263656 0.1098306          0.1098306
## 2      0.01263656 0.1255897          0.1255897
## 3      0.01263656 0.1310751          0.1310751
## 4      0.01263656 0.1330976          0.1330976
## 5      0.01263656 0.1338571          0.1338571
```

```
#The next command fits a GARCH(1,1) model
m2=garchFit(intc~garch(1,1),data=intc,trace=F)
summary(m2)
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = intc ~ garch(1, 1), data = intc, trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 1)
## <environment: 0x7ffa7afb5750>
## [data = intc]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      omega      alpha1      beta1
## 0.01073352 0.00095445 0.08741989 0.85118414
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.0107335 0.0055289  1.941  0.0522 .
## omega  0.0009544 0.0003989  2.392  0.0167 *
## alpha1 0.0874199 0.0269810  3.240  0.0012 **
## beta1  0.8511841 0.0393702 21.620 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```

##
## Log Likelihood:
## 299.9705    normalized: 0.6943761
##
## Description:
## Tue May 10 22:13:47 2016 by user:
##
##
## Standardised Residuals Tests:
##
##              Statistic p-Value
## Jarque-Bera Test  R    Chi^2 165.574 0
## Shapiro-Wilk Test R    W    0.9712087 1.626854e-07
## Ljung-Box Test   R    Q(10) 8.267633 0.6027128
## Ljung-Box Test   R    Q(15) 14.42612 0.4934871
## Ljung-Box Test   R    Q(20) 15.13331 0.7687297
## Ljung-Box Test   R^2  Q(10) 0.9891848 0.9998363
## Ljung-Box Test   R^2  Q(15) 11.36596 0.7262473
## Ljung-Box Test   R^2  Q(20) 12.68143 0.8906302
## LM Arch Test     R    TR^2 10.70199 0.5546164
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -1.370234 -1.332563 -1.370403 -1.355361

```

```

m3=garchFit(intc~garch(1,0),data=intc,trace=F,
cond.dist="std")
summary(m3)

```

```

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = intc ~ garch(1, 0), data = intc, cond.dist = "std",
##         trace = F)
##
## Mean and Variance Equation:
## data ~ garch(1, 0)
## <environment: 0x7ffa7a4e3388>
## [data = intc]
##
## Conditional Distribution:
## std
##
## Coefficient(s):
##      mu      omega    alpha1    shape
## 0.016731 0.011939 0.285320 6.015195
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.016731 0.005302 3.155 0.001603 **

```

```

## omega    0.011939    0.001603    7.449 9.39e-14 ***
## alpha1   0.285320    0.110607    2.580 0.009892 **
## shape    6.015195    1.562620    3.849 0.000118 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 302.6696    normalized:  0.7006242
##
## Description:
## Tue May 10 22:13:48 2016 by user:
##
##
## Standardised Residuals Tests:
##
##           Statistic p-Value
## Jarque-Bera Test  R    Chi^2 149.6547  0
## Shapiro-Wilk Test R    W      0.96667  2.411939e-08
## Ljung-Box Test   R    Q(10) 13.13164 0.2164046
## Ljung-Box Test   R    Q(15) 22.3309   0.09941655
## Ljung-Box Test   R    Q(20) 24.15587 0.2356497
## Ljung-Box Test   R^2  Q(10) 19.03127 0.03986725
## Ljung-Box Test   R^2  Q(15) 40.73241 0.0003512451
## Ljung-Box Test   R^2  Q(20) 42.21039 0.002596137
## LM Arch Test     R    TR^2  28.70718 0.004353914
##
## Information Criterion Statistics:
##           AIC      BIC      SIC      HQIC
## -1.382730 -1.345059 -1.382899 -1.367858

```

```

# Degrees of freedom
# The next command fits an ARCH(1) model with skew Student-t dist.
m4=garchFit(intc~garch(1,0),data=intc,cond.dist="sstd",
trace=F)
# Next, fit an ARMA(1,0)+GARCH(1,1) model with Gaussian noises.
m5=garchFit(intc~arma(1,0)+garch(1,1),data=intc,trace=F)

```

```

www<-"http://faculty.chicagobooth.edu/ruey.tsay/teaching/bs41202/sp2014/m-ibm2609.txt"
da=read.table(www,header=T)
ibm=log(da$ibm+1)
#fix delta = 2 using APARCH model to estimate TGARCH model
m1=garchFit(~aparch(1,1),data=ibm,trace=F,delta=2,include.delta=F)
summary(m1)

```

```

##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~aparch(1, 1), data = ibm, delta = 2, include.delta = F,
## trace = F)
##
## Mean and Variance Equation:
## data ~ aparch(1, 1)

```



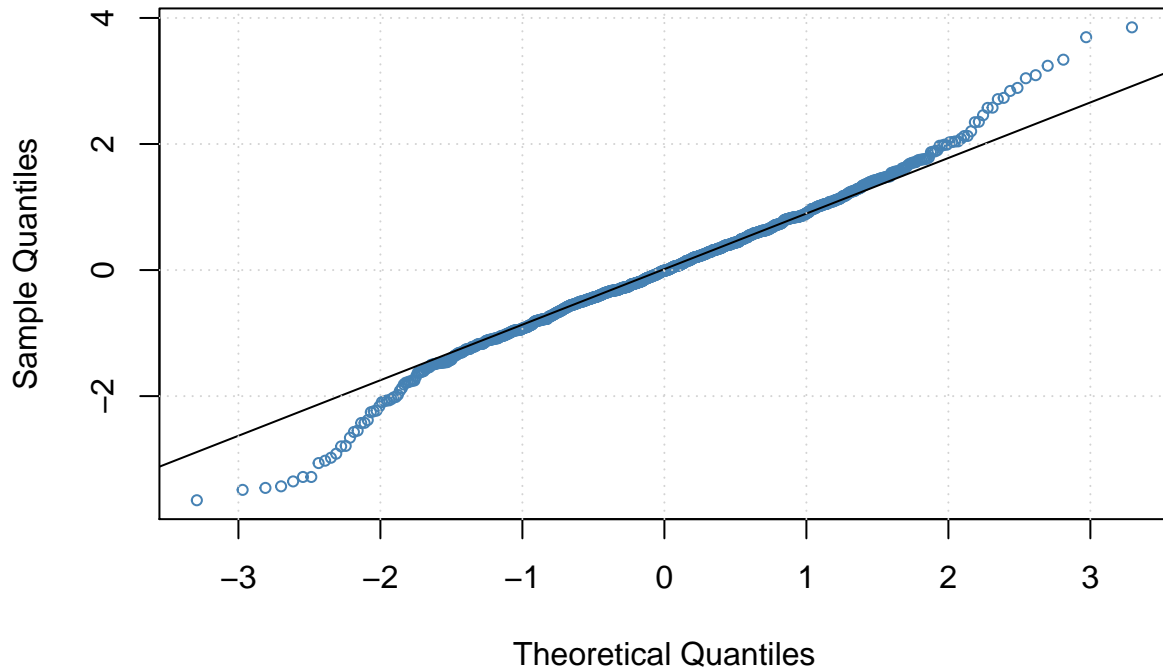
```

## <environment: 0x7ffa7acb5120>
## [data = ibm]
##
## Conditional Distribution:
## norm
##
## Coefficient(s):
##      mu      omega      alpha1      gamma1      beta1
## 0.01186587 0.00043366 0.10767004 0.22732479 0.79467553
##
## Std. Errors:
## based on Hessian
##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.0118659 0.0020019 5.927 3.08e-09 ***
## omega 0.0004337 0.0001342 3.232 0.00123 **
## alpha1 0.1076700 0.0254831 4.225 2.39e-05 ***
## gamma1 0.2273248 0.1001812 2.269 0.02326 *
## beta1 0.7946755 0.0455416 17.449 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1312.835 normalized: 1.302415
##
## Description:
## Tue May 10 22:13:50 2016 by user:
##
##
## Standardised Residuals Tests:
##
##      Statistic p-Value
## Jarque-Bera Test R Chi^2 67.07416 2.775558e-15
## Shapiro-Wilk Test R W 0.9870135 8.590935e-08
## Ljung-Box Test R Q(10) 16.90603 0.07646939
## Ljung-Box Test R Q(15) 24.19034 0.06193096
## Ljung-Box Test R Q(20) 31.89097 0.04447405
## Ljung-Box Test R^2 Q(10) 4.591692 0.9167342
## Ljung-Box Test R^2 Q(15) 11.98464 0.6801912
## Ljung-Box Test R^2 Q(20) 14.79531 0.787998
## LM Arch Test R TR^2 7.162969 0.8466585
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -2.594910 -2.570527 -2.594959 -2.585646

```

```
plot(m1,which=13)# shows normal distribution is not a good fit.
```

qnorm – QQ Plot



```
m1=garchFit(~aparch(1,1),data=ibm,trace=F,delta=2,include.delta=F,cond.dist="std")
summary(m1)
```

```
##
## Title:
## GARCH Modelling
##
## Call:
## garchFit(formula = ~aparch(1, 1), data = ibm, delta = 2, cond.dist = "std",
## include.delta = F, trace = F)
##
## Mean and Variance Equation:
## data ~ aparch(1, 1)
## <environment: 0x7ffa79c6e228>
## [data = ibm]
##
## Conditional Distribution:
## std
##
## Coefficient(s):
##      mu      omega    alpha1    gamma1    beta1    shape
## 0.01204765 0.00039898 0.10467694 0.22366007 0.80711061 6.67328744
##
## Std. Errors:
## based on Hessian
```

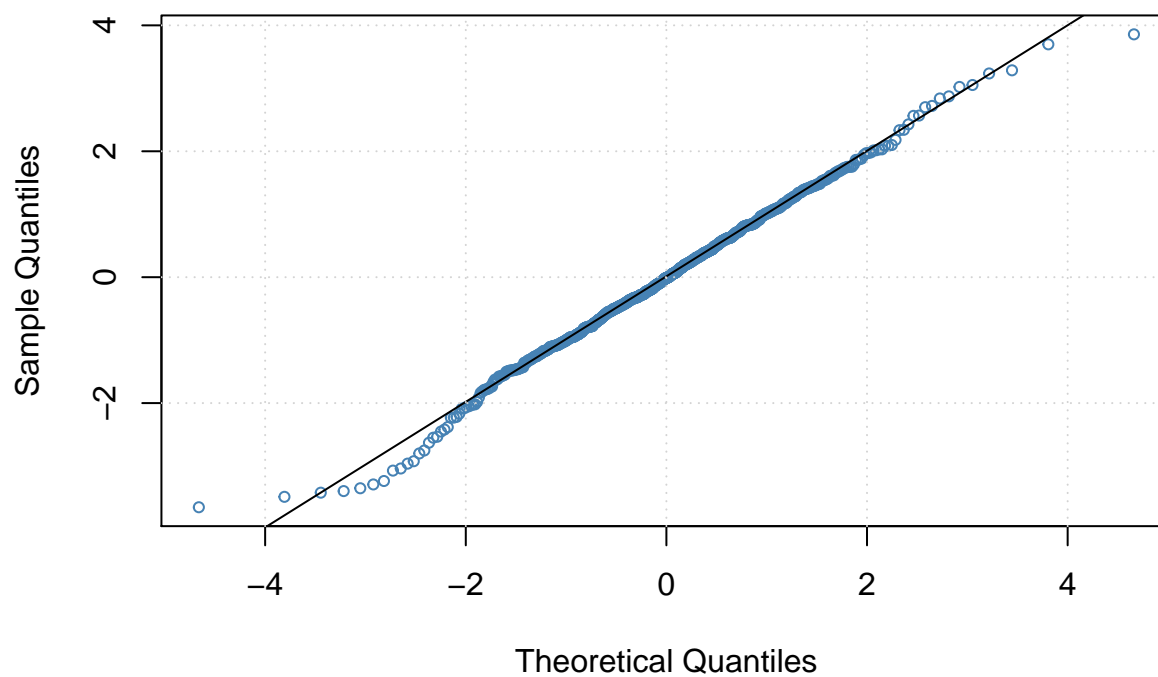
```

##
## Error Analysis:
##      Estimate Std. Error t value Pr(>|t|)
## mu      0.0120476  0.0018715   6.437 1.22e-10 ***
## omega   0.0003990  0.0001453   2.745 0.006046 **
## alpha1  0.1046769  0.0279326   3.747 0.000179 ***
## gamma1  0.2236601  0.1159495   1.929 0.053738 .
## beta1   0.8071106  0.0482517  16.727 < 2e-16 ***
## shape   6.6732874  1.3277857   5.026 5.01e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
## 1331.802    normalized:  1.321232
##
## Description:
## Tue May 10 22:13:50 2016 by user:
##
##
## Standardised Residuals Tests:
##
##              Statistic p-Value
## Jarque-Bera Test  R    Chi^2  67.82336  1.887379e-15
## Shapiro-Wilk Test R     W      0.9869701  8.215318e-08
## Ljung-Box Test   R    Q(10)  16.91352  0.07629962
## Ljung-Box Test   R    Q(15)  24.08691  0.06363225
## Ljung-Box Test   R    Q(20)  31.75305  0.04600187
## Ljung-Box Test   R^2  Q(10)  4.553248  0.9189583
## Ljung-Box Test   R^2  Q(15)  11.66891  0.7038973
## Ljung-Box Test   R^2  Q(20)  14.18533  0.8209765
## LM Arch Test     R     TR^2   6.771675  0.872326
##
## Information Criterion Statistics:
##      AIC      BIC      SIC      HQIC
## -2.630559 -2.601298 -2.630629 -2.619442

```

```
plot(m1,which=13)
```

qstd – QQ Plot



Reference:

Tsay, Ruey S. Analysis of financial time series. Vol. 543. John Wiley & Sons, 2005.