Time Series Final Project

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Data were obtained. Of interest is properly modeling conditional volatility so as to make accurate predictions of conditional volatility. Conditional volatility is used in VaR to inform markets. Data were subsetted to include January 3, 1984 - December 31, 2015. Predictions will be made on

The return(r_t) in financial time series is defined by CC as:

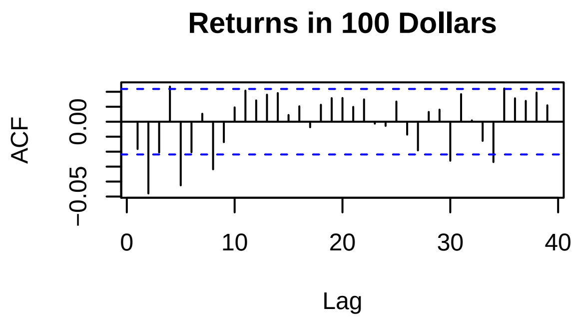
$r_t = log(price_t) - log(price_{t-1})$

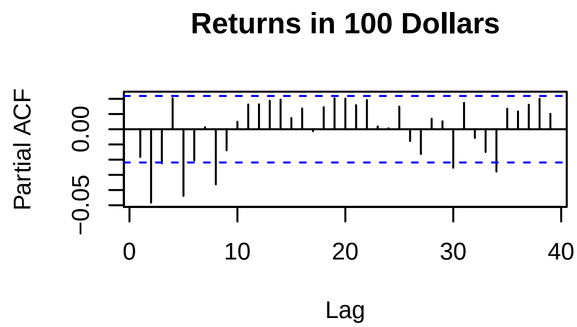
The return is thus define as the ratio of the log prices between two subsequent time points. The return is often then scaled by 100 to make numbers more easily thought about.

Compare ARCH to iid and correlated errors.

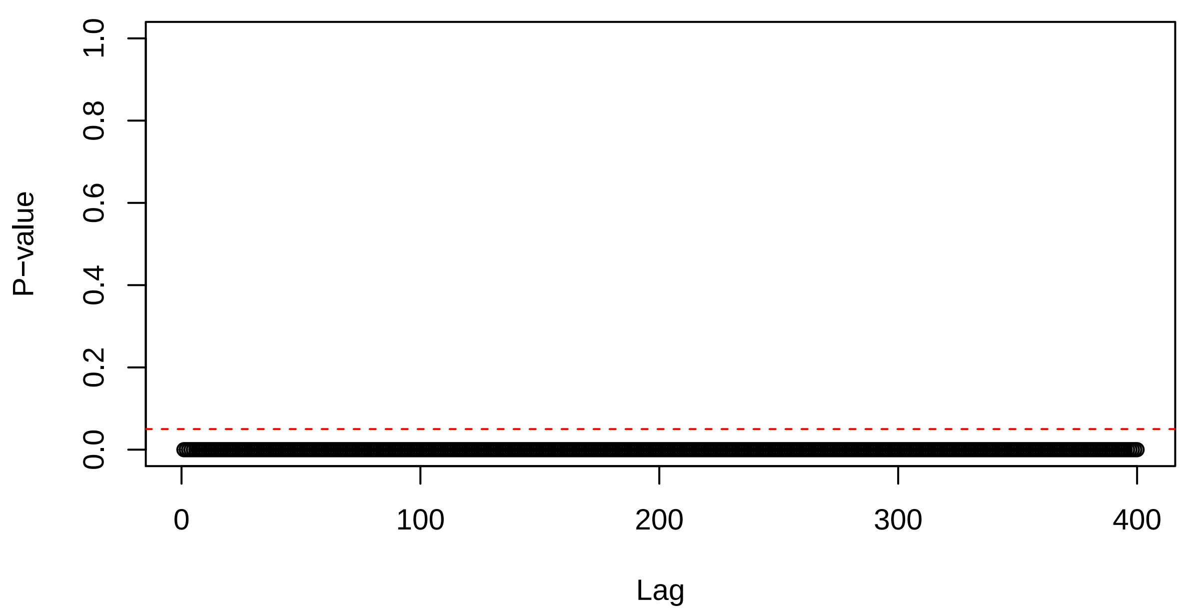
Volatility occurs when the conditional variance of a time series varies over time (CC, 279).

The ACF and PACF plots inform about the correlation in returns at different time lags. The ACF of the daily returns suggest statistically significant autocorrelation at lags 2, 4, 5, and 8 with reoccuring patterns around day 30. The PACF of the daily returns suggests significant autocorrelation at lags 2, 3, 5, and 8 with again a couple reoccurant significant partial correlations at lags 29 and 33. The reoccuring significant lags after 30 days in both the ACF and PACF plots are not likely spurious as we have daily time series data (excluding holidays and weekends). The PACF adds information about correlations conditional on previous correlations. In the ACF plot lag 4 had a significant correlation whereas in the PACF plot it did not. Given the previous lags' autocorrelation, there is no evidence of additional autocorrelation at lag 4.





Plotting non-linear transformations (versus linear as seen in correlation) of the returns aids in assessing whether observations at different time points are independent and identically distributed (CC 281). The ACF and PACF plots of the squared and absolute returns both have many signficant autocorrelations, suggesting observations at different time points are not independent and identically distributed.



The McLeod-Li Test uses the squared returns so as above, is a test against serial independence.

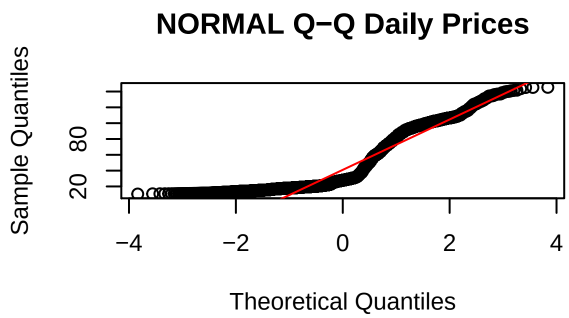
This can also be thought of as assuming no ARCH

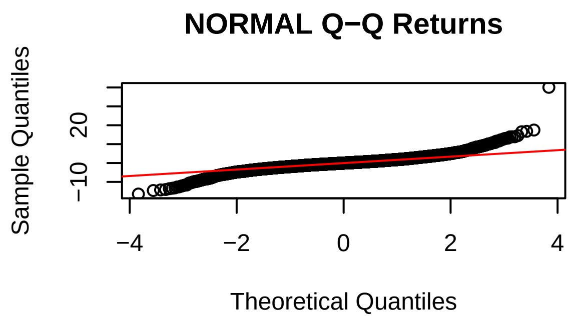
H_o: no ARCH

H_a: ARCH

The test statistic follows a χ^2_m distribution with m = the number of lags tested. `http://homepage.ntu.edu.tw/~ckuan/pdf/Lec-DiagTest.pdf` *could not find*

Both the daily prices and the returns suggest strong evidence of ARCH at all lags.





The ACF and PACF of the returns suggest significant autocorrelations at the 5% significance level. The ACF and PACF of the absolute value and squared returns both suggest independence is violated. Non-significant autocorrelation and signficiant serial dependence are commmon suggest volatility clustering. Volatility clustering visually is seen when the returns closer together display more similar variability. The Normal Q-Q plot of the returns shows heavy tails. Heavy tailed distributions and volatitlity clustering are common in financial time series data (CC 285). ARCH and GARCH models are used when data display these characteristics.

Let the conditional variance of the returns, $\text{Var}(r_{t|t-1}) = \sigma_{t|t-1}$. In ARCH modeling, a linear regression model of order q is fit to describe the relationship between the current conditional variance and the previous returns.

$r_t = \sigma_{t|t-q}\epsilon_t$

$\sigma^2_{t|t-q} = \omega + \Sigma_{i=1:q}\alpha_i r^2_{t-i}$

such that $\epsilon_t \sim (0,1)$ and $\epsilon_t \perp r_{t-j}$ for j = 1,2,...

The conditional variance is not observable, and so with a linear transformation, the current squared return can be transformed to be a linear combination of previous squared returns and a random error such that

mark, how do I know what model to fit??? not sure from plots... case where both acf of raw and squared etc shows sig implies arma and arch?

```
Error in garchFit(r.price = ~arma(0, 1) + garch(1, 1), data = oil_sub, :  Multivariate data inputs require
lhs for the formula.

Error in summary(g121):  object 'g121' not found

Error in AIC(g121):  object 'g121' not found
```

```
 ***** ESTIMATION WITH ANALYTICAL GRADIENT *****


     I     INITIAL X(I)        D(I)

     1     5.305196e+00     1.000e+00
     2     5.000000e-02     1.000e+00
     3     5.000000e-02     1.000e+00

    IT   NF      F         RELDF    PRELDF    RELDX   STPPAR   D*STEP   NPRELDF
     0    1  1.088e+04
     1    3  1.076e+04  1.08e-02  2.35e-02  9.4e-03  2.6e+04  1.0e-01  3.00e+02
     2    5  1.075e+04  4.60e-04  4.37e-04  7.3e-04  5.7e+00  1.0e-02  6.42e+00
     3    7  1.074e+04  7.62e-04  7.58e-04  1.4e-03  2.0e+00  2.0e-02  7.40e-01
     4    8  1.073e+04  9.41e-04  9.33e-04  2.7e-03  2.7e+00  4.0e-02  5.49e-01
     5   11  1.073e+04  1.21e-05  1.21e-05  5.1e-05  6.7e+01  8.0e-04  6.19e-01
     6   13  1.073e+04  2.36e-05  2.36e-05  1.0e-04  9.3e+00  1.6e-03  6.28e-01
     7   15  1.073e+04  4.52e-05  4.52e-05  2.1e-04  5.3e+00  3.2e-03  6.29e-01
     8   17  1.073e+04  8.74e-06  8.74e-06  4.5e-05  9.4e+01  6.4e-04  6.33e-01
     9   19  1.073e+04  1.74e-06  1.74e-06  9.1e-06  4.8e+02  1.3e-04  6.27e-01
    10   21  1.073e+04  3.46e-06  3.46e-06  1.8e-05  6.1e+01  2.6e-04  6.25e-01
    11   23  1.073e+04  6.91e-07  6.91e-07  3.7e-06  1.2e+03  5.1e-05  6.26e-01
    12   25  1.073e+04  1.38e-06  1.38e-06  7.3e-06  1.5e+02  1.0e-04  6.25e-01
    13   27  1.073e+04  2.76e-07  2.76e-07  1.5e-06  3.0e+03  2.0e-05  6.25e-01
    14   29  1.073e+04  5.51e-07  5.51e-07  2.9e-06  3.8e+02  4.1e-05  6.25e-01
    15   31  1.073e+04  1.10e-07  1.10e-07  5.9e-07  7.6e+03  8.2e-06  6.25e-01
    16   33  1.073e+04  2.20e-07  2.20e-07  1.2e-06  9.5e+02  1.6e-05  6.25e-01
    17   35  1.073e+04  4.41e-08  4.41e-08  2.4e-07  1.9e+04  3.3e-06  6.25e-01
    18   37  1.073e+04  8.81e-09  8.81e-09  4.7e-08  9.5e+04  6.6e-07  6.25e-01
    19   39  1.073e+04  1.76e-08  1.76e-08  9.4e-08  1.2e+04  1.3e-06  6.25e-01
```

```
    20   42  1.073e+04  3.52e-10  3.52e-10  1.9e-09  2.4e+06  2.6e-08  6.25e-01
    21   44  1.073e+04  7.05e-11  7.05e-11  3.8e-10  2.0e+00  5.2e-09 -1.03e-02
    22   46  1.073e+04  1.41e-10  1.41e-10  7.5e-10  1.5e+06  1.0e-08  6.25e-01
    23   48  1.073e+04  2.82e-11  2.82e-11  1.5e-10  2.0e+00  2.1e-09 -1.03e-02
    24   50  1.073e+04  5.64e-11  5.64e-11  3.0e-10  2.0e+00  4.2e-09 -1.03e-02
    25   52  1.073e+04  1.13e-11  1.13e-11  6.0e-11  2.0e+00  8.4e-10 -1.03e-02
    26   55  1.073e+04  9.02e-11  9.02e-11  4.8e-10  2.0e+00  6.7e-09 -1.03e-02
    27   58  1.073e+04  1.80e-12  1.80e-12  9.7e-12  2.0e+00  1.3e-10 -1.03e-02
    28   60  1.073e+04  3.61e-12  3.61e-12  1.9e-11  2.0e+00  2.7e-10 -1.03e-02
    29   62  1.073e+04  7.22e-13  7.22e-13  3.9e-12  2.0e+00  5.4e-11 -1.03e-02
    30   64  1.073e+04  1.45e-12  1.44e-12  7.7e-12  2.0e+00  1.1e-10 -1.03e-02
    31   66  1.073e+04  2.91e-13  2.89e-13  1.5e-12  2.0e+00  2.1e-11 -1.03e-02
    32   68  1.073e+04  5.73e-13  5.78e-13  3.1e-12  2.0e+00  4.3e-11 -1.03e-02
    33   70  1.073e+04  1.16e-12  1.16e-12  6.2e-12  2.0e+00  8.6e-11 -1.03e-02
    34   73  1.073e+04  1.93e-14  2.31e-14  1.2e-13  2.0e+00  1.7e-12 -1.03e-02
    35   75  1.073e+04  4.78e-14  4.62e-14  2.5e-13  2.0e+00  3.4e-12 -1.03e-02
    36   77  1.073e+04  1.03e-14  9.24e-15  4.9e-14  2.0e+00  6.9e-13 -1.03e-02
    37   79  1.073e+04  1.64e-14  1.85e-14  9.9e-14  2.0e+00  1.4e-12 -1.03e-02
    38   81  1.073e+04  1.69e-15  3.70e-15  2.0e-14  2.0e+00  2.7e-13 -1.03e-02
    39   83  1.073e+04  6.95e-15  7.39e-15  4.0e-14  2.0e+00  5.5e-13 -1.03e-02
    40   85  1.073e+04  2.20e-15  1.48e-15  7.9e-15  2.0e+00  1.1e-13 -1.03e-02
    41   87  1.073e+04  2.54e-15  2.96e-15  1.6e-14  2.0e+00  2.2e-13 -1.03e-02
    42   89  1.073e+04 -9.32e+05  5.91e-16  3.2e-15  2.0e+00  4.4e-14 -1.03e-02

 ***** FALSE CONVERGENCE *****

 FUNCTION     1.073348e+04   RELDX        3.198e-15
 FUNC. EVALS      89         GRAD. EVALS      42
 PRELDF       5.914e-16      NPRELDF     -1.029e-02

     I      FINAL X(I)        D(I)          G(I)

     1    5.276331e+00     1.000e+00     1.096e+02
     2    2.053924e-01     1.000e+00    -8.577e+01
     3    9.315376e-15     1.000e+00     3.817e+01

Call:
garch(x = oil_sub$r.price, order = c(1, 1))

Model:
GARCH(1,1)

Residuals:
     Min       1Q   Median       3Q      Max
-6.47732 -0.48301 -0.01414  0.45051  7.42118

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 5.276e+00   1.093e-01    48.28   <2e-16
a1 2.054e-01   7.679e-03    26.75   <2e-16
b1 9.315e-15   1.086e-02     0.00        1

Diagnostic Tests:
Jarque Bera Test
```

```
data:  Residuals
X-squared = 10268, df = 2, p-value < 2.2e-16


Box-Ljung test

data:  Squared.Residuals
X-squared = 2.3063, df = 1, p-value = 0.1288

 ***** ESTIMATION WITH ANALYTICAL GRADIENT *****


     I     INITIAL X(I)        D(I)

     1     3.242064e+00     1.000e+00
     2     5.000000e-02     1.000e+00
     3     5.000000e-02     1.000e+00
     4     5.000000e-02     1.000e+00
     5     5.000000e-02     1.000e+00
     6     5.000000e-02     1.000e+00
     7     5.000000e-02     1.000e+00
     8     5.000000e-02     1.000e+00
     9     5.000000e-02     1.000e+00
    10     5.000000e-02     1.000e+00

    IT   NF      F         RELDF    PRELDF    RELDX   STPPAR   D*STEP   NPRELDF
     0    1  1.017e+04
     1    4  1.017e+04  8.38e-04  9.00e-04  9.1e-04  9.2e+04  1.0e-02  4.12e+01
     2    6  1.015e+04  1.45e-03  1.43e-03  2.1e-03  2.3e+00  2.0e-02  5.42e+01
     3    8  1.015e+04  2.71e-04  2.71e-04  5.0e-04  6.2e+01  4.0e-03  3.27e+01
     4   11  1.013e+04  1.98e-03  1.97e-03  4.0e-03  2.6e+00  3.2e-02  1.66e+01
     5   14  1.013e+04  3.71e-05  3.71e-05  8.5e-05  4.2e+02  6.4e-04  1.76e+01
     6   16  1.013e+04  7.40e-06  7.40e-06  1.7e-05  2.1e+03  1.3e-04  9.36e+00
     7   18  1.013e+04  1.48e-05  1.48e-05  3.4e-05  2.7e+02  2.6e-04  9.27e+00
     8   20  1.013e+04  2.96e-06  2.96e-06  6.8e-06  5.3e+03  5.1e-05  9.26e+00
     9   22  1.013e+04  5.91e-06  5.91e-06  1.4e-05  6.7e+02  1.0e-04  9.23e+00
    10   24  1.013e+04  1.18e-06  1.18e-06  2.7e-06  1.3e+04  2.0e-05  9.22e+00
    11   26  1.013e+04  2.36e-06  2.36e-06  5.4e-06  1.7e+03  4.1e-05  9.21e+00
    12   28  1.013e+04  4.73e-06  4.73e-06  1.1e-05  8.3e+02  8.2e-05  9.21e+00
    13   30  1.013e+04  9.46e-07  9.46e-07  2.2e-06  1.7e+04  1.6e-05  9.20e+00
    14   32  1.013e+04  1.89e-07  1.89e-07  4.3e-07  8.3e+04  3.3e-06  9.19e+00
    15   34  1.013e+04  3.78e-07  3.78e-07  8.7e-07  1.0e+04  6.6e-06  9.19e+00
    16   36  1.013e+04  7.56e-07  7.56e-07  1.7e-06  5.2e+03  1.3e-05  9.19e+00
    17   40  1.013e+04  1.51e-09  1.51e-09  3.5e-09  1.0e+07  2.6e-08  9.19e+00
    18   42  1.013e+04  3.03e-09  3.03e-09  6.9e-09  1.3e+06  5.2e-08  9.19e+00
    19   44  1.013e+04  6.05e-09  6.05e-09  1.4e-08  6.5e+05  1.0e-07  9.19e+00
    20   46  1.013e+04  1.21e-09  1.21e-09  2.8e-09  1.3e+07  2.1e-08  9.19e+00
    21   48  1.013e+04  2.42e-10  2.42e-10  5.6e-10  6.5e+07  4.2e-09  9.19e+00
    22   50  1.013e+04  4.84e-11  4.84e-11  1.1e-10  2.0e+00  8.4e-10 -3.87e-02
    23   52  1.013e+04  9.68e-11  9.68e-11  2.2e-10  2.0e+00  1.7e-09 -3.87e-02
    24   54  1.013e+04  1.94e-11  1.94e-11  4.4e-11  2.0e+00  3.4e-10 -3.87e-02
    25   56  1.013e+04  3.87e-11  3.87e-11  8.9e-11  2.0e+00  6.7e-10 -3.87e-02
    26   58  1.013e+04  7.74e-12  7.74e-12  1.8e-11  2.0e+00  1.3e-10 -3.87e-02
    27   60  1.013e+04  1.55e-11  1.55e-11  3.6e-11  2.0e+00  2.7e-10 -3.87e-02
    28   62  1.013e+04  3.10e-11  3.10e-11  7.1e-11  2.0e+00  5.4e-10 -3.87e-02
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   29   65  1.013e+04  6.22e-13  6.20e-13  1.4e-12  2.0e+00  1.1e-11 -3.87e-02
   30   67  1.013e+04  1.24e-12  1.24e-12  2.8e-12  2.0e+00  2.1e-11 -3.87e-02
   31   69  1.013e+04  2.49e-13  2.48e-13  5.7e-13  2.0e+00  4.3e-12 -3.87e-02
   32   71  1.013e+04  4.90e-13  4.96e-13  1.1e-12  2.0e+00  8.6e-12 -3.87e-02
   33   73  1.013e+04  9.88e-14  9.91e-14  2.3e-13  2.0e+00  1.7e-12 -3.87e-02
   34   75  1.013e+04  1.95e-13  1.98e-13  4.6e-13  2.0e+00  3.4e-12 -3.87e-02
   35   77  1.013e+04  4.36e-14  3.97e-14  9.1e-14  2.0e+00  6.9e-13 -3.87e-02
   36   79  1.013e+04  7.92e-14  7.93e-14  1.8e-13  2.0e+00  1.4e-12 -3.87e-02
   37   81  1.013e+04  1.92e-14  1.59e-14  3.6e-14  2.0e+00  2.7e-13 -3.87e-02
   38   83  1.013e+04  3.59e-15  3.17e-15  7.3e-15  2.0e+00  5.5e-14 -3.87e-02
   39   84  1.013e+04  3.41e-15  6.34e-15  1.5e-14  2.0e+00  1.1e-13 -3.86e-02
   40   86  1.013e+04  1.62e-15  1.27e-15  2.9e-15  2.0e+00  2.2e-14 -3.87e-02
   41   87  1.013e+04  1.08e-15  2.54e-15  5.8e-15  2.0e+00  4.4e-14 -3.88e-02
   42   88  1.013e+04 -9.87e+05  5.08e-15  1.2e-14  2.0e+00  8.8e-14 -3.85e-02

 ***** FALSE CONVERGENCE *****

 FUNCTION     1.012730e+04   RELDX        1.165e-14
 FUNC. EVALS      88         GRAD. EVALS      42
 PRELDF       5.076e-15      NPRELDF     -3.852e-02

     I      FINAL X(I)        D(I)          G(I)

     1    3.225657e+00     1.000e+00     1.710e+02
     2    7.878954e-02     1.000e+00    -1.382e+02
     3    6.831927e-02     1.000e+00    -1.307e+02
     4    6.869440e-02     1.000e+00    -1.242e+02
     5    4.939386e-02     1.000e+00    -5.839e+00
     6    5.697816e-02     1.000e+00    -7.961e+01
     7    4.564836e-02     1.000e+00     1.373e+01
     8    5.165476e-02     1.000e+00    -3.737e+01
     9    4.243142e-02     1.000e+00     5.702e+01
    10    7.134306e-14     1.000e+00     4.995e+02

Call:
garch(x = oil_sub$r.price, order = c(1, 8))

Model:
GARCH(1,8)

Residuals:
     Min       1Q   Median       3Q      Max
-5.47299 -0.53218 -0.01612  0.49840  7.14169

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 3.226e+00   1.693e-01   19.050  < 2e-16
a1 7.879e-02   7.508e-03   10.493  < 2e-16
a2 6.832e-02   8.938e-03    7.644 2.11e-14
a3 6.869e-02   8.305e-03    8.272 2.22e-16
a4 4.939e-02   8.359e-03    5.909 3.44e-09
a5 5.698e-02   1.041e-02    5.476 4.36e-08
a6 4.565e-02   9.318e-03    4.899 9.63e-07
a7 5.165e-02   1.063e-02    4.860 1.17e-06
a8 4.243e-02   1.032e-02    4.111 3.94e-05
```

```
b1 7.134e-14   4.744e-02    0.000        1

Diagnostic Tests:
Jarque Bera Test

data:  Residuals
X-squared = 4242, df = 2, p-value < 2.2e-16


Box-Ljung test

data:  Squared.Residuals
X-squared = 21.566, df = 1, p-value = 3.418e-06

 ***** ESTIMATION WITH ANALYTICAL GRADIENT *****


     I     INITIAL X(I)        D(I)

     1     1.178932e+00     1.000e+00
     2     5.000000e-02     1.000e+00
     3     5.000000e-02     1.000e+00
     4     5.000000e-02     1.000e+00
     5     5.000000e-02     1.000e+00
     6     5.000000e-02     1.000e+00
     7     5.000000e-02     1.000e+00
     8     5.000000e-02     1.000e+00
     9     5.000000e-02     1.000e+00
    10     5.000000e-02     1.000e+00
    11     5.000000e-02     1.000e+00
    12     5.000000e-02     1.000e+00
    13     5.000000e-02     1.000e+00
    14     5.000000e-02     1.000e+00
    15     5.000000e-02     1.000e+00
    16     5.000000e-02     1.000e+00
    17     5.000000e-02     1.000e+00

    IT   NF      F         RELDF    PRELDF    RELDX   STPPAR   D*STEP   NPRELDF
     0    1  9.897e+03
     1    4  9.883e+03  1.45e-03  3.23e-03  2.8e-03  9.2e+04  1.9e-02  1.48e+02
     2    5  9.872e+03  1.04e-03  1.35e-03  4.5e-03  2.1e+00  1.9e-02  7.78e+01
     3    6  9.852e+03  2.03e-03  3.24e-03  6.1e-03  2.0e+00  3.7e-02  4.56e+01
     4    7  9.837e+03  1.55e-03  2.54e-03  7.2e-03  2.0e+00  3.7e-02  1.03e+01
     5    8  9.824e+03  1.34e-03  1.57e-03  7.9e-03  2.0e+00  3.7e-02  4.22e+00
     6   10  9.822e+03  1.40e-04  1.46e-04  6.3e-04  3.4e+00  3.7e-03  3.11e+00
     7   12  9.820e+03  2.23e-04  2.27e-04  1.4e-03  3.0e+00  7.5e-03  3.02e+00
     8   14  9.820e+03  4.59e-05  4.68e-05  3.1e-04  7.0e+01  1.5e-03  3.21e+00
     9   16  9.819e+03  8.83e-05  8.84e-05  6.3e-04  7.2e+00  3.0e-03  4.00e+00
    10   18  9.819e+03  1.75e-05  1.75e-05  1.3e-04  8.1e+02  6.0e-04  4.23e+00
    11   20  9.818e+03  3.48e-05  3.48e-05  2.5e-04  3.8e+01  1.2e-03  5.37e+00
    12   22  9.818e+03  6.93e-06  6.93e-06  5.1e-05  7.7e+02  2.4e-04  5.31e+00
    13   25  9.818e+03  5.51e-05  5.51e-05  4.1e-04  2.5e+01  1.9e-03  5.21e+00
    14   28  9.818e+03  1.10e-06  1.10e-06  8.2e-06  5.0e+03  3.8e-05  5.18e+00
    15   30  9.818e+03  2.19e-06  2.19e-06  1.6e-05  6.3e+02  7.7e-05  5.02e+00
    16   33  9.818e+03  4.39e-08  4.39e-08  3.3e-07  1.3e+05  1.5e-06  5.02e+00
```

```
  17   36  9.818e+03  3.51e-07  3.51e-07  2.6e-06  4.0e+03  1.2e-05  5.01e+00
  18   39  9.818e+03  7.02e-09  7.02e-09  5.2e-08  7.9e+05  2.4e-07  5.01e+00
  19   41  9.818e+03  1.40e-08  1.40e-08  1.0e-07  9.9e+04  4.9e-07  5.01e+00
  20   43  9.818e+03  2.81e-09  2.81e-09  2.1e-08  2.0e+06  9.8e-08  5.01e+00
  21   45  9.818e+03  5.61e-09  5.61e-09  4.2e-08  2.5e+05  2.0e-07  5.01e+00
  22   47  9.818e+03  1.12e-09  1.12e-09  8.4e-09  5.0e+06  3.9e-08  5.01e+00
  23   49  9.818e+03  2.25e-09  2.25e-09  1.7e-08  6.2e+05  7.8e-08  5.01e+00
  24   51  9.818e+03  4.49e-10  4.49e-10  3.4e-09  1.2e+07  1.6e-08  5.01e+00
  25   53  9.818e+03  8.98e-10  8.98e-10  6.7e-09  1.6e+06  3.1e-08  5.01e+00
  26   55  9.818e+03  1.80e-09  1.80e-09  1.3e-08  7.8e+05  6.3e-08  5.01e+00
  27   57  9.818e+03  3.59e-10  3.59e-10  2.7e-09  1.6e+07  1.3e-08  5.01e+00
  28   59  9.818e+03  7.18e-11  7.18e-11  5.4e-10  2.0e+00  2.5e-09 -2.28e-02
  29   61  9.818e+03  1.44e-10  1.44e-10  1.1e-09  9.7e+06  5.0e-09  5.01e+00
  30   63  9.818e+03  2.87e-11  2.87e-11  2.1e-10  2.0e+00  1.0e-09 -2.28e-02
  31   65  9.818e+03  5.75e-11  5.75e-11  4.3e-10  2.0e+00  2.0e-09 -2.28e-02
  32   67  9.818e+03  1.15e-10  1.15e-10  8.6e-10  1.2e+07  4.0e-09  5.01e+00
  33   69  9.818e+03  2.30e-11  2.30e-11  1.7e-10  2.0e+00  8.0e-10 -2.28e-02
  34   71  9.818e+03  4.60e-12  4.60e-12  3.4e-11  2.0e+00  1.6e-10 -2.28e-02
  35   73  9.818e+03  9.20e-12  9.20e-12  6.9e-11  2.0e+00  3.2e-10 -2.28e-02
  36   75  9.818e+03  1.84e-12  1.84e-12  1.4e-11  2.0e+00  6.4e-11 -2.28e-02
  37   77  9.818e+03  3.68e-12  3.68e-12  2.8e-11  2.0e+00  1.3e-10 -2.28e-02
  38   80  9.818e+03  7.58e-14  7.36e-14  5.5e-13  2.0e+00  2.6e-12 -2.28e-02
  39   82  9.818e+03  1.42e-13  1.47e-13  1.1e-12  2.0e+00  5.1e-12 -2.28e-02
  40   84  9.818e+03  2.83e-14  2.94e-14  2.2e-13  2.0e+00  1.0e-12 -2.28e-02
  41   86  9.818e+03  6.50e-14  5.89e-14  4.4e-13  2.0e+00  2.1e-12 -2.28e-02
  42   88  9.818e+03  8.34e-15  1.18e-14  8.8e-14  2.0e+00  4.1e-13 -2.28e-02
  43   90  9.818e+03  2.35e-14  2.35e-14  1.8e-13  2.0e+00  8.2e-13 -2.28e-02
  44   92  9.818e+03  5.19e-15  4.71e-15  3.5e-14  2.0e+00  1.6e-13 -2.28e-02
  45   95  9.818e+03  3.76e-14  3.51e-14  2.6e-13  2.0e+00  1.2e-12 -2.28e-02
  46   98  9.818e+03  3.71e-16  7.01e-16  5.2e-15  2.0e+00  2.4e-14 -2.28e-02
  47  101  9.818e+03  4.63e-15  5.61e-15  4.2e-14  2.0e+00  2.0e-13 -2.29e-02
  48  103  9.818e+03 -1.02e+06  1.12e-15  8.4e-15  2.0e+00  3.9e-14 -2.28e-02

***** FALSE CONVERGENCE *****

FUNCTION     9.817638e+03   RELDX        8.376e-15
FUNC. EVALS     103         GRAD. EVALS      48
PRELDF       1.122e-15      NPRELDF     -2.278e-02

    I      FINAL X(I)        D(I)          G(I)

    1    1.126602e+00     1.000e+00    1.358e+02
    2    9.194932e-02     1.000e+00   -6.467e+01
    3    9.744145e-02     1.000e+00   -6.552e+01
    4    8.835981e-02     1.000e+00   -5.801e+01
    5    5.715135e-02     1.000e+00   -2.390e+01
    6    7.125255e-02     1.000e+00   -3.683e+01
    7    6.474147e-02     1.000e+00   -3.250e+01
    8    6.898199e-02     1.000e+00   -2.912e+01
    9    4.944499e-02     1.000e+00    1.839e+00
   10    8.086948e-15     1.000e+00    1.104e+02
   11    5.031069e-03     1.000e+00    9.252e+01
   12    5.140441e-03     1.000e+00    8.962e+01
   13    1.453598e-02     1.000e+00    6.639e+01
   14    2.787489e-02     1.000e+00    2.668e+01
```

```
    15    4.116315e-02     1.000e+00    -1.257e+01
    16    5.528729e-02     1.000e+00    -5.938e+01
    17    6.665506e-02     1.000e+00    -8.616e+01

Call:
garch(x = oil_sub$r.price, order = c(8, 8))

Model:
GARCH(8,8)

Residuals:
     Min       1Q   Median       3Q      Max
-5.60679 -0.58820 -0.01769  0.54076  7.49171

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 1.127e+00   3.699e-01    3.046 0.002323
a1 9.195e-02   8.384e-03   10.967  < 2e-16
a2 9.744e-02   5.635e-02    1.729 0.083754
a3 8.836e-02   2.786e-02    3.172 0.001515
a4 5.715e-02   3.718e-02    1.537 0.124303
a5 7.125e-02   1.602e-02    4.449 8.63e-06
a6 6.474e-02   4.502e-02    1.438 0.150432
a7 6.898e-02   2.049e-02    3.367 0.000759
a8 4.944e-02   3.632e-02    1.361 0.173426
b1 8.087e-15   6.159e-01    0.000 1.000000
b2 5.031e-03   5.462e-01    0.009 0.992651
b3 5.140e-03   4.096e-01    0.013 0.989987
b4 1.454e-02   2.793e-01    0.052 0.958493
b5 2.787e-02   2.614e-01    0.107 0.915076
b6 4.116e-02   2.875e-01    0.143 0.886146
b7 5.529e-02   2.443e-01    0.226 0.820960
b8 6.666e-02   1.465e-01    0.455 0.649023

Diagnostic Tests:
Jarque Bera Test

data:  Residuals
X-squared = 2483.2, df = 2, p-value < 2.2e-16


Box-Ljung test

data:  Squared.Residuals
X-squared = 3.5628, df = 1, p-value = 0.05909

 ***** ESTIMATION WITH ANALYTICAL GRADIENT *****


     I     INITIAL X(I)        D(I)

     1     2.357865e+00     1.000e+00
     2     5.000000e-02     1.000e+00
     3     5.000000e-02     1.000e+00
     4     5.000000e-02     1.000e+00
```

```
    5     5.000000e-02     1.000e+00
    6     5.000000e-02     1.000e+00
    7     5.000000e-02     1.000e+00
    8     5.000000e-02     1.000e+00
    9     5.000000e-02     1.000e+00
   10     5.000000e-02     1.000e+00
   11     5.000000e-02     1.000e+00
   12     5.000000e-02     1.000e+00
   13     5.000000e-02     1.000e+00

   IT   NF      F         RELDF    PRELDF    RELDX   STPPAR   D*STEP   NPRELDF
    0    1  1.008e+04
    1    3  1.002e+04  5.86e-03  1.32e-02  9.4e-03  1.3e+04  1.0e-01  8.83e+01
    2    4  1.002e+04  4.71e-04  9.88e-03  8.8e-03  2.0e+00  1.0e-01  1.26e+02
    3    6  1.001e+04  8.56e-04  8.51e-04  4.5e-04  1.1e+01  5.0e-03  2.59e+01
    4    8  1.001e+04  1.62e-04  1.62e-04  9.2e-05  5.2e+01  1.0e-03  2.67e+00
    5   10  1.001e+04  3.14e-04  3.14e-04  1.8e-04  7.3e+00  2.0e-03  2.90e+00
    6   12  1.001e+04  6.13e-05  6.13e-05  3.7e-05  1.2e+02  4.0e-04  3.02e+00
    7   14  1.001e+04  1.22e-05  1.22e-05  7.4e-06  6.0e+02  8.0e-05  3.11e+00
    8   17  1.000e+04  9.68e-05  9.68e-05  6.0e-05  2.0e+01  6.4e-04  3.13e+00
    9   20  1.000e+04  1.92e-06  1.92e-06  1.2e-06  3.7e+03  1.3e-05  3.16e+00
   10   22  1.000e+04  3.85e-07  3.85e-07  2.4e-07  1.8e+04  2.6e-06  3.19e+00
   11   24  1.000e+04  7.69e-07  7.69e-07  4.8e-07  2.3e+03  5.1e-06  3.19e+00
   12   26  1.000e+04  1.54e-07  1.54e-07  9.5e-08  4.6e+04  1.0e-06  3.19e+00
   13   28  1.000e+04  3.08e-07  3.08e-07  1.9e-07  5.7e+03  2.0e-06  3.19e+00
   14   30  1.000e+04  6.15e-07  6.15e-07  3.8e-07  2.9e+03  4.1e-06  3.19e+00
   15   33  1.000e+04  1.23e-08  1.23e-08  7.6e-09  5.7e+05  8.2e-08  3.19e+00
   16   35  1.000e+04  2.46e-08  2.46e-08  1.5e-08  7.1e+04  1.6e-07  3.19e+00
   17   37  1.000e+04  4.92e-09  4.92e-09  3.1e-09  1.4e+06  3.3e-08  3.19e+00
   18   40  1.000e+04  3.94e-08  3.94e-08  2.4e-08  4.5e+04  2.6e-07  3.19e+00
   19   43  1.000e+04  7.87e-10  7.87e-10  4.9e-10  8.9e+06  5.2e-09  3.19e+00
   20   45  1.000e+04  1.57e-09  1.57e-09  9.8e-10  1.1e+06  1.0e-08  3.19e+00
   21   47  1.000e+04  3.15e-10  3.15e-10  2.0e-10  2.2e+07  2.1e-09  3.19e+00
   22   49  1.000e+04  6.30e-10  6.30e-10  3.9e-10  2.8e+06  4.2e-09  3.19e+00
   23   51  1.000e+04  1.26e-10  1.26e-10  7.8e-11  5.6e+07  8.4e-10  3.19e+00
   24   54  1.000e+04  1.01e-09  1.01e-09  6.3e-10  1.7e+06  6.7e-09  3.19e+00
   25   57  1.000e+04  2.02e-11  2.02e-11  1.3e-11  2.0e+00  1.3e-10 -2.68e-02
   26   59  1.000e+04  4.03e-12  4.03e-12  2.5e-12  2.0e+00  2.7e-11 -2.68e-02
   27   62  1.000e+04  3.23e-11  3.23e-11  2.0e-11  2.0e+00  2.1e-10 -2.68e-02
   28   65  1.000e+04  6.45e-13  6.45e-13  4.0e-13  2.0e+00  4.3e-12 -2.68e-02
   29   67  1.000e+04  1.26e-13  1.29e-13  8.0e-14  2.0e+00  8.6e-13 -2.68e-02
   30   70  1.000e+04  1.04e-12  1.03e-12  6.4e-13  2.0e+00  6.9e-12 -2.68e-02
   31   73  1.000e+04  1.47e-14  2.06e-14  1.3e-14  2.0e+00  1.4e-13 -2.68e-02
   32   75  1.000e+04  4.40e-14  4.13e-14  2.6e-14  2.0e+00  2.7e-13 -2.68e-02
   33   77  1.000e+04  6.91e-15  8.26e-15  5.1e-15  2.0e+00  5.5e-14 -2.68e-02
   34   79  1.000e+04  1.69e-14  1.65e-14  1.0e-14  2.0e+00  1.1e-13 -2.69e-02
   35   80  1.000e+04 -1.00e+06  3.30e-14  2.0e-14  2.0e+00  2.2e-13 -2.68e-02

 ***** FALSE CONVERGENCE *****

 FUNCTION     1.000477e+04   RELDX        2.050e-14
 FUNC. EVALS      80         GRAD. EVALS      35
 PRELDF       3.303e-14      NPRELDF     -2.681e-02

    I     FINAL X(I)        D(I)          G(I)
```

```
     1    2.333268e+00     1.000e+00     1.990e+02
     2    1.235371e-01     1.000e+00     3.143e+02
     3    1.084592e-01     1.000e+00     2.666e+02
     4    1.050709e-01     1.000e+00     2.742e+02
     5    7.332192e-02     1.000e+00     3.287e+02
     6    8.662418e-02     1.000e+00     2.631e+02
     7    7.171106e-02     1.000e+00     2.920e+02
     8    8.038701e-02     1.000e+00     2.916e+02
     9    6.445899e-02     1.000e+00     3.420e+02
    10    2.091598e-14     1.000e+00     6.536e+02
    11    3.855821e-03     1.000e+00     6.143e+02
    12    4.073184e-03     1.000e+00     6.120e+02
    13    9.442327e-03     1.000e+00     5.740e+02

Call:
garch(x = oil_sub$r.price, order = c(4, 8))

Model:
GARCH(4,8)

Residuals:
    Min      1Q  Median      3Q     Max
-5.2610 -0.5336 -0.0162  0.4949  6.9159

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0 2.333e+00   2.791e-01    8.360  < 2e-16
a1 1.235e-01   1.168e-02   10.573  < 2e-16
a2 1.085e-01   3.079e-02    3.522 0.000428
a3 1.051e-01   1.817e-02    5.784 7.32e-09
a4 7.332e-02   2.051e-02    3.575 0.000351
a5 8.662e-02   1.495e-02    5.796 6.80e-09
a6 7.171e-02   1.888e-02    3.798 0.000146
a7 8.039e-02   1.480e-02    5.433 5.55e-08
a8 6.446e-02   1.789e-02    3.602 0.000315
b1 2.092e-14   2.269e-01    0.000 1.000000
b2 3.856e-03   1.997e-01    0.019 0.984595
b3 4.073e-03   1.525e-01    0.027 0.978685
b4 9.442e-03   6.522e-02    0.145 0.884881

Diagnostic Tests:
Jarque Bera Test

data:  Residuals
X-squared = 3203.8, df = 2, p-value < 2.2e-16


Box-Ljung test

data:  Squared.Residuals
X-squared = 3.4965, df = 1, p-value = 0.0615

Series Initialization:
 ARMA Model:                arma
 Formula Mean:              ~ arma(0, 0)
```

```
 GARCH Model:                garch
 Formula Variance:           ~ garch(1, 1)
 ARMA Order:                 0 0
 Max ARMA Order:             0
 GARCH Order:                1 1
 Max GARCH Order:            1
 Maximum Order:              1
 Conditional Dist:           norm
 h.start:                    2
 llh.start:                  1
 Length of Series:           1974
 Recursion Init:             mci
 Series Scale:               0.4702445

Parameter Initialization:
 Initial Parameters:          $params
 Limits of Transformations:   $U, $V
 Which Parameters are Fixed?  $includes
 Parameter Matrix:
                     U           V      params includes
    mu     -0.34932441   0.3493244 -0.03493244     TRUE
    omega   0.00000100 100.0000000  0.10000000     TRUE
    alpha1  0.00000001   1.0000000  0.10000000     TRUE
    gamma1 -0.99999999   1.0000000  0.10000000    FALSE
    beta1   0.00000001   1.0000000  0.80000000     TRUE
    delta   0.00000000   2.0000000  2.00000000    FALSE
    skew    0.10000000  10.0000000  1.00000000    FALSE
    shape   1.00000000  10.0000000  4.00000000    FALSE
 Index List of Parameters to be Optimized:
    mu  omega alpha1  beta1
     1      2      3      5
 Persistence:                  0.9


--- START OF TRACE ---
Selected Algorithm: nlminb

R coded nlminb Solver:

  0:     2622.6409: -0.0349324 0.100000 0.100000 0.800000
  1:     2614.8796: -0.0349308 0.0787306 0.102589 0.788660
  2:     2605.2292: -0.0349281 0.0782926 0.125313 0.797093
  3:     2601.7838: -0.0349245 0.0592478 0.132983 0.791935
  4:     2597.6133: -0.0349147 0.0565826 0.151013 0.802700
  5:     2596.9479: -0.0349018 0.0485511 0.152721 0.802721
  6:     2596.8346: -0.0348064 0.0461847 0.155068 0.809720
  7:     2596.7205: -0.0346199 0.0496574 0.154115 0.804615
  8:     2596.7121: -0.0346191 0.0493448 0.153972 0.804432
  9:     2596.7018: -0.0344951 0.0478286 0.152286 0.808039
 10:     2596.6933: -0.0343078 0.0474530 0.151002 0.808511
 11:     2596.6732: -0.0341149 0.0478411 0.151367 0.808472
 12:     2596.6028: -0.0319323 0.0494289 0.159871 0.800208
 13:     2596.1556: -0.0230451 0.0493166 0.155621 0.803196
 14:     2595.9991: -0.0141576 0.0480967 0.152900 0.806811
 15:     2595.9971: -0.0131126 0.0490616 0.153252 0.805505
```

```
 16:     2595.9961: -0.0130855 0.0487019 0.153196 0.805839
 17:     2595.9960: -0.0131875 0.0486342 0.153107 0.806049
 18:     2595.9960: -0.0131655 0.0486669 0.153135 0.805971
 19:     2595.9960: -0.0131640 0.0486655 0.153134 0.805974

Final Estimate of the Negative LLH:
 LLH:  1106.608    norm LLH:  0.5605916
         mu        omega       alpha1        beta1
-0.006190314  0.010761384  0.153134059  0.805973748

R-optimhess Difference Approximated Hessian Matrix:
                mu         omega       alpha1         beta1
mu     -14019.91568      510.4853     276.5549      31.11225
omega     510.48532 -1459798.8567 -118938.2379 -197810.71357
alpha1    276.55489  -118938.2379  -18058.9949  -22143.21565
beta1      31.11225  -197810.7136  -22143.2156  -32044.79727
attr(,"time")
Time difference of 0.03400707 secs

--- END OF TRACE ---


Time to Estimate Parameters:
 Time difference of 0.15361 secs

Title:
 GARCH Modelling

Call:
 garchFit(formula = oil_sub$r.price ~ garch(1, 1))

Mean and Variance Equation:
 data ~ garch(1, 1)
<environment: 0x000000001d01a4b8>
 [data = dem2gbp]

Conditional Distribution:
 norm

Coefficient(s):
       mu       omega      alpha1       beta1
-0.0061903   0.0107614   0.1531341   0.8059737

Std. Errors:
 based on Hessian

Error Analysis:
        Estimate  Std. Error  t value Pr(>|t|)
mu     -0.006190    0.008462   -0.732 0.464448
omega   0.010761    0.002838    3.793 0.000149
alpha1  0.153134    0.026422    5.796  6.8e-09
beta1   0.805974    0.033381   24.144  < 2e-16

Log Likelihood:
 -1106.608    normalized:  -0.5605916
```

```
Description:
 Sun Nov 27 19:30:51 2016 by user: Andrea Mack


Standardised Residuals Tests:
                                Statistic p-Value
 Jarque-Bera Test   R    Chi^2  1059.851  0
 Shapiro-Wilk Test  R    W      0.9622848 0
 Ljung-Box Test     R    Q(10)  10.12141  0.4299066
 Ljung-Box Test     R    Q(15)  17.04349  0.3162711
 Ljung-Box Test     R    Q(20)  19.29764  0.5025619
 Ljung-Box Test     R^2  Q(10)  9.062556  0.5261773
 Ljung-Box Test     R^2  Q(15)  16.07769  0.3769072
 Ljung-Box Test     R^2  Q(20)  17.50715  0.6198388
 LM Arch Test       R    TR^2   9.771217  0.6360237

Information Criterion Statistics:
     AIC      BIC      SIC     HQIC
1.125236 1.136559 1.125228 1.129396
```

```
Error in data.frame(c(g8.aic, g121.aic, g11.aic, lm1.aic)):  object 'g121.aic' not found

Error in colnames(aic_all) <- "Model AIC":  object 'aic_all' not found

Error in rownames(aic_all) <- c("GARCH(8,1)", "GARCH(12,1)", "GARCH(1,1)", :  object 'aic_all' not found

Error in xtable(aic_all):  object 'aic_all' not found
```

The best fit model in terms of AIC was the GARCH(8,1) model. Normality and independence of squared residuals was tested for this model. CC estimate the long term variance as $\frac{\hat{\omega}}{1-\hat{\alpha}-\hat{\beta}}$. Below is a summary of the long term variances from all GARCH models considered, along with the sample long run variance in returns. All estimates are very close to that observed. *why would they be or not be?*

Note that garch uses a Quasi-Newton optimizer to find the ML estimates, for which AIC does not apply (cc 301).

```
Error in coef(g121):  object 'g121' not found

Error in coef(g121):  object 'g121' not found

Error in data.frame(c(g8_var, g121_var, g11_var, r.obs_var)):  object 'g121_var' not found

Error in colnames(var_all) <- "Long Run Variance Esitmates of Returns":  object 'var_all' not found

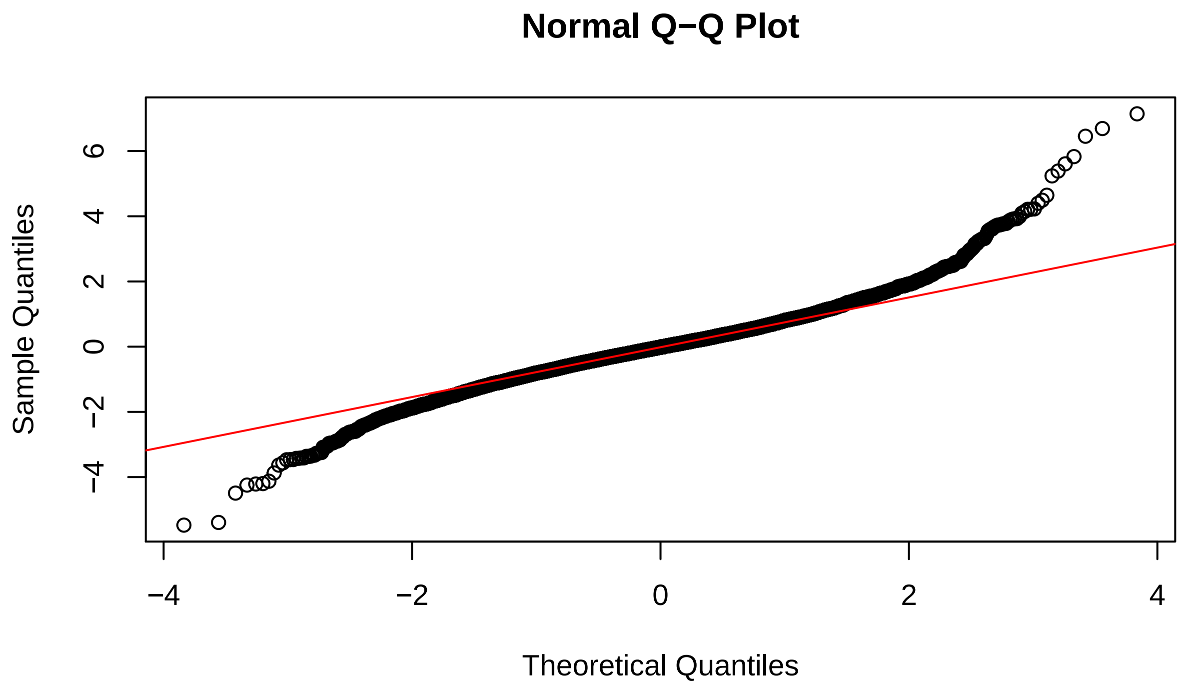
Error in rownames(var_all) <- c("GARCH(8,1)", "GARCH(12,1)", "GARCH(1,1)", :  object 'var_all' not found

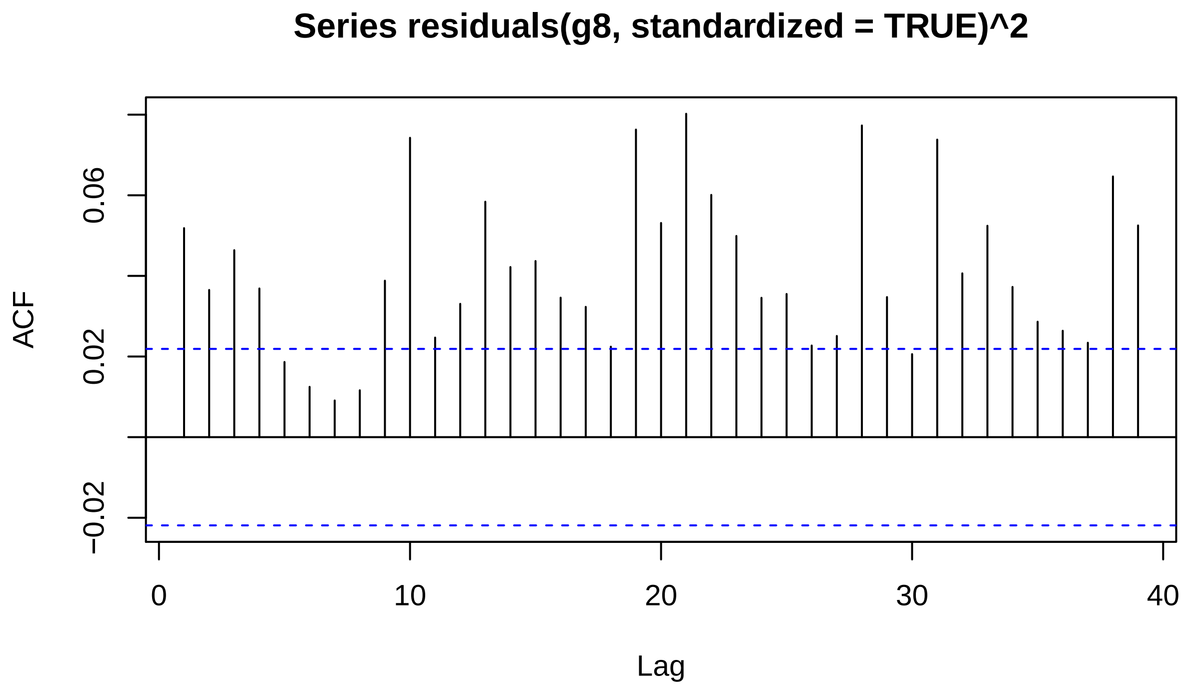
Error in xtable(var_all):  object 'var_all' not found
```

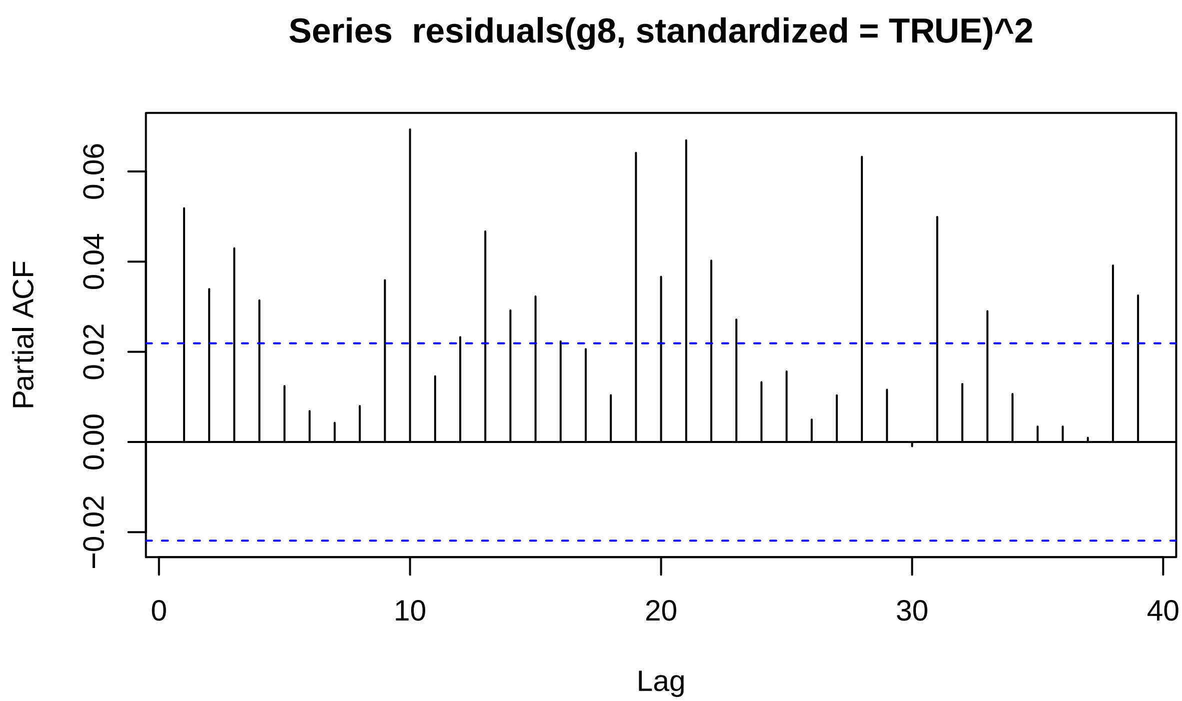
Assessing Model Assumptions

The standardized errors are assumed to be independently and identically distributed.

CC Jarque-Bera test assesses normality, but Mark says not to use.







The assumptions look terrible.

Predictions of 2016

I have no idea what this is predicting

```
Call:
garch(x = oil_sub$r.price, order = c(1, 8))

Model:
GARCH(1,8)

Residuals:
     Min       1Q   Median       3Q      Max 
-5.47299 -0.53218 -0.01612  0.49840  7.14169 

Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)    
a0 3.226e+00   1.693e-01   19.050  < 2e-16
a1 7.879e-02   7.508e-03   10.493  < 2e-16
a2 6.832e-02   8.938e-03    7.644 2.11e-14
a3 6.869e-02   8.305e-03    8.272 2.22e-16
a4 4.939e-02   8.359e-03    5.909 3.44e-09
a5 5.698e-02   1.041e-02    5.476 4.36e-08
a6 4.565e-02   9.318e-03    4.899 9.63e-07
a7 5.165e-02   1.063e-02    4.860 1.17e-06
a8 4.243e-02   1.032e-02    4.111 3.94e-05
b1 7.134e-14   4.744e-02    0.000        1

Diagnostic Tests:
Jarque Bera Test

data:  Residuals
X-squared = 4242, df = 2, p-value < 2.2e-16


Box-Ljung test

data:  Squared.Residuals
X-squared = 21.566, df = 1, p-value = 3.418e-06
             [,1]       [,2]
   [1,]        NA         NA
   [2,]        NA         NA
   [3,]        NA         NA
   [4,]        NA         NA
   [5,]        NA         NA
   [6,]        NA         NA
   [7,]        NA         NA
   [8,]        NA         NA
   [9,]  4.271917  -4.271917
  [10,]  4.066764  -4.066764
  [11,]  4.190794  -4.190794
  [12,]  4.033812  -4.033812
  [13,]  3.880478  -3.880478
  [14,]  4.298400  -4.298400
  [15,]  3.746053  -3.746053
```

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[16,]  3.973167  -3.973167
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[19,]  3.359735  -3.359735
[20,]  3.487148  -3.487148
[21,]  3.705716  -3.705716
[22,]  4.066394  -4.066394
[23,]  4.764809  -4.764809
[24,]  4.809178  -4.809178
[25,]  4.703759  -4.703759
[26,]  4.733662  -4.733662
[27,]  4.620974  -4.620974
[28,]  4.444997  -4.444997
[29,]  4.232361  -4.232361
[30,]  4.030817  -4.030817
[31,]  3.228235  -3.228235
[32,]  2.929063  -2.929063
[33,]  3.141201  -3.141201
[34,]  2.914264  -2.914264
[35,]  2.812991  -2.812991
[36,]  2.739752  -2.739752
[37,]  2.797905  -2.797905
[38,]  2.602617  -2.602617
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[2063,]  2.389427  -2.389427
[2064,]  2.359595  -2.359595
[2065,]  2.347496  -2.347496
[2066,]  2.491657  -2.491657
[2067,]  2.442670  -2.442670
[2068,]  2.437128  -2.437128
[2069,]  2.327623  -2.327623
[2070,]  2.219029  -2.219029
[2071,]  2.126385  -2.126385
[2072,]  2.417753  -2.417753
[2073,]  2.483087  -2.483087
[2074,]  2.388640  -2.388640
[2075,]  2.308187  -2.308187
[2076,]  2.290771  -2.290771
[2077,]  2.455977  -2.455977
[2078,]  2.365633  -2.365633
[2079,]  2.396825  -2.396825
[2080,]  2.164450  -2.164450
[2081,]  2.248280  -2.248280
[2082,]  2.413369  -2.413369
[2083,]  2.445191  -2.445191
[2084,]  2.377707  -2.377707
[2085,]  2.238709  -2.238709
[2086,]  2.215125  -2.215125
[2087,]  2.306824  -2.306824
[2088,]  2.343400  -2.343400
[2089,]  2.332158  -2.332158
[2090,]  2.165928  -2.165928
[2091,]  2.472118  -2.472118
[2092,]  2.568163  -2.568163
[2093,]  2.593153  -2.593153
[2094,]  2.524096  -2.524096
[2095,]  2.654133  -2.654133
[2096,]  2.610697  -2.610697
[2097,]  2.646034  -2.646034
[2098,]  2.564521  -2.564521
[2099,]  2.385579  -2.385579
[2100,]  2.309928  -2.309928
[2101,]  2.277089  -2.277089
[2102,]  2.263343  -2.263343
[2103,]  2.240857  -2.240857
[2104,]  2.181772  -2.181772
[2105,]  2.168962  -2.168962
[2106,]  2.147788  -2.147788
[2107,]  2.171895  -2.171895
[2108,]  2.211529  -2.211529
[2109,]  2.199203  -2.199203
[2110,]  2.197125  -2.197125
[2111,]  2.078354  -2.078354
[2112,]  2.073012  -2.073012
[2113,]  2.046439  -2.046439
```

Still to do: 1) use comp code and apply to estimate var and pot 2) find other previous estimates and compare 3) discuss other garch model extensions and limitations

Extreme Value Theory and VaR

Often, of interest is modeling the extremes of the distribution of returns in a financial time series to inform potential risk. Often the exceedance of a threshold is used to model large returns (or losses) because it is shown to be more efficient than modeling the maxima (Charpentier, 258). Assuming the distribution of the returns, x_i are independent and identically distributed with an unknown distribution F, Charpentier discusses the limiting ditribution of the x_i's as converging in distribution to G under certain constraints with η the extreme value index, the peak over threshold (POT) method introduced by (Charpentier,) based in results from the extreme value theory theorem says that, "when one selects a threshold high enough, the distribution of the values exceeding the threshold coverges in deistribution to the generalized Pareto distribution:

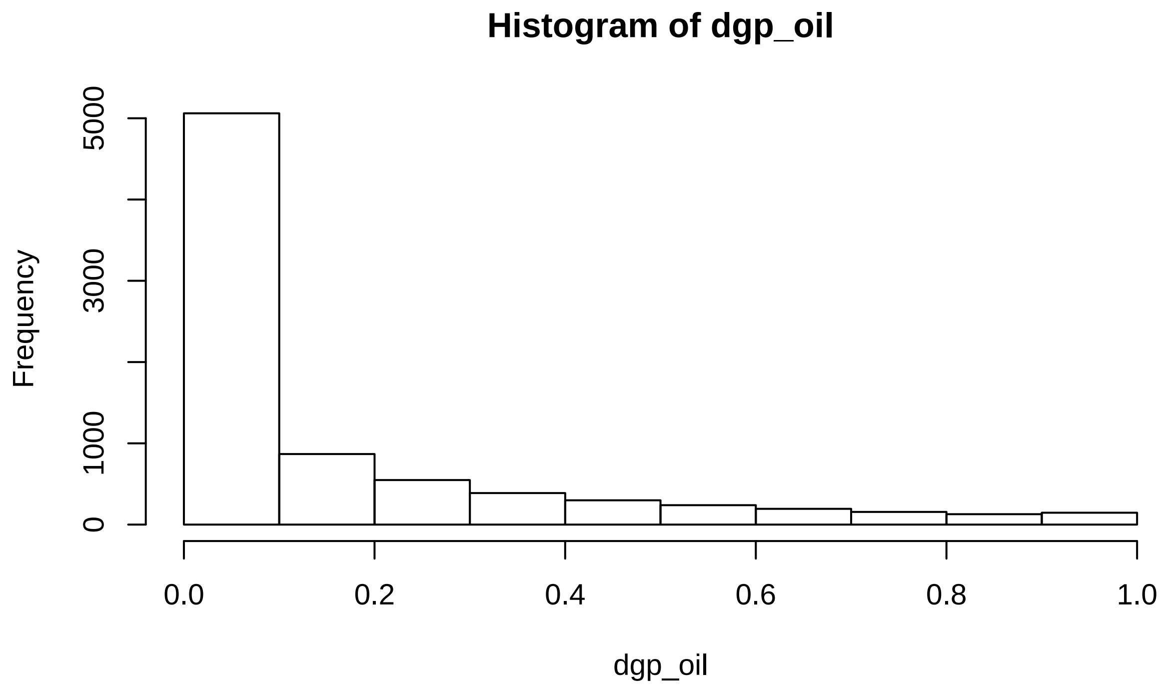
$$g_{\eta,\beta}(x) = \begin{cases} 1 \dfrac{}{\beta(1+\eta x/\beta)^{-\frac{1}{\eta}-1}} \text{ if } \eta \neq 0 \\ \frac{1}{\beta}exp(\frac{-x}{\beta}) \text{ if } \eta = 0 \end{cases}$$

for $\eta < 0$; x ≤ 0, $0 \geq x \geq -\beta/\eta$

Let Mn = the maximum of the distribution of returns

$G_\eta(x) = exp[-(1 + (\eta)x)]$

Value at Risk (VaR) is the value that one might lose with a set probablity α. Extreme value theory is related to modeling the tail of a distribution.



`https://www.eia.gov/workingpapers/pdf/factors_influencing_oil_prices.pdf`

suggests that the cgarch model fits oil price data better than the garch model

account for long run price volatilities more

`https://www.r-bloggers.com/a-practical-introduction-to-garch-modeling/`

limitation may occur if markets change over time and combining all the markets into one data set

use the t distribution becaue of the fat tails

box-ljung test is not robust to extreme data, but the test is robust -¿ test whether autocorrelation is accounted for using a test on the ranks

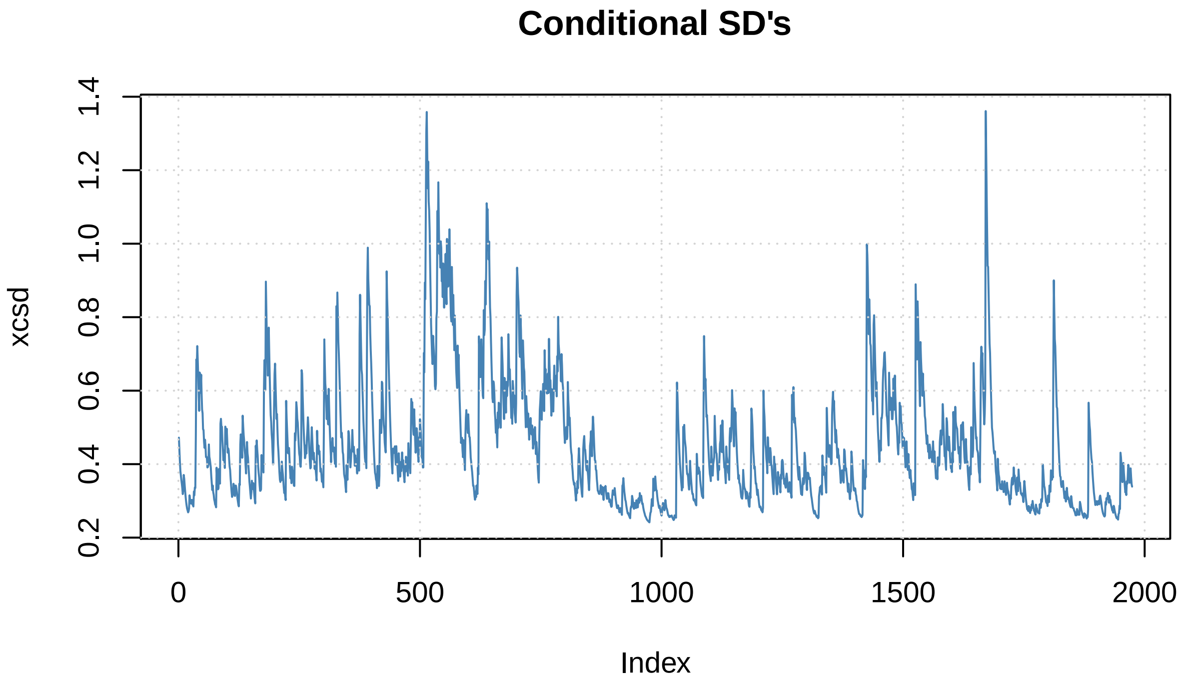
persistence – sum of first two output terms in garch model

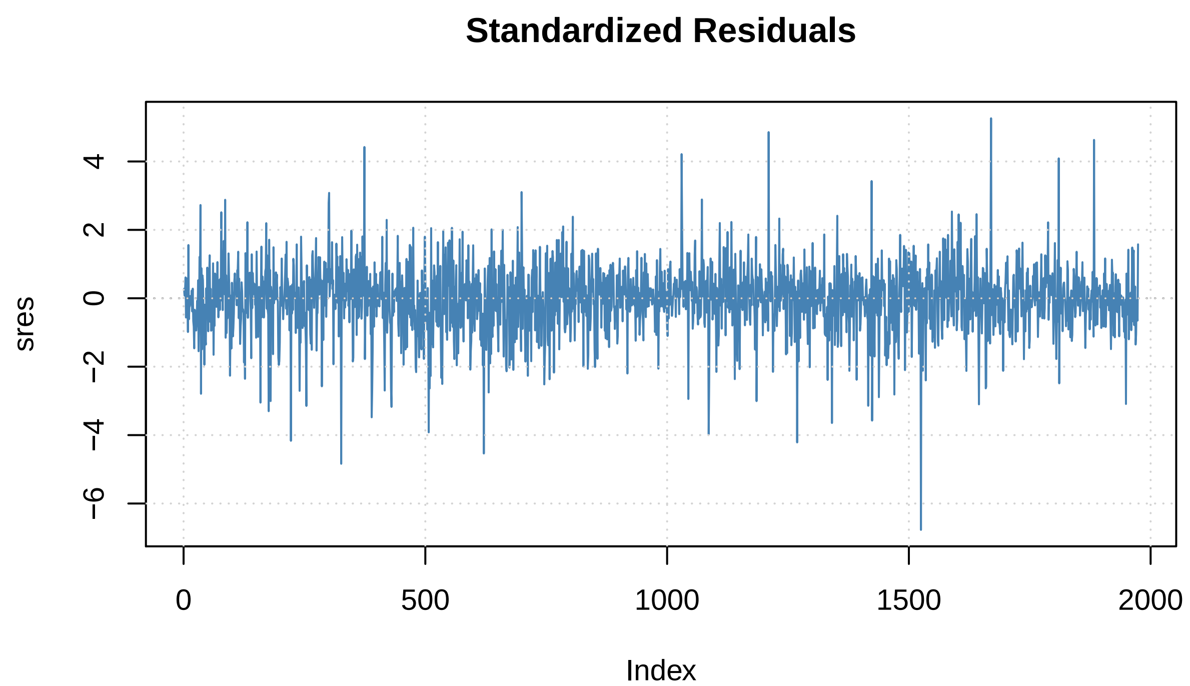
CC use the garch() function from the $_{packagetofitGARCHmodels.Thatfunctionislimitedinthatitdoesnotallowfittingan ARMAandGA}$

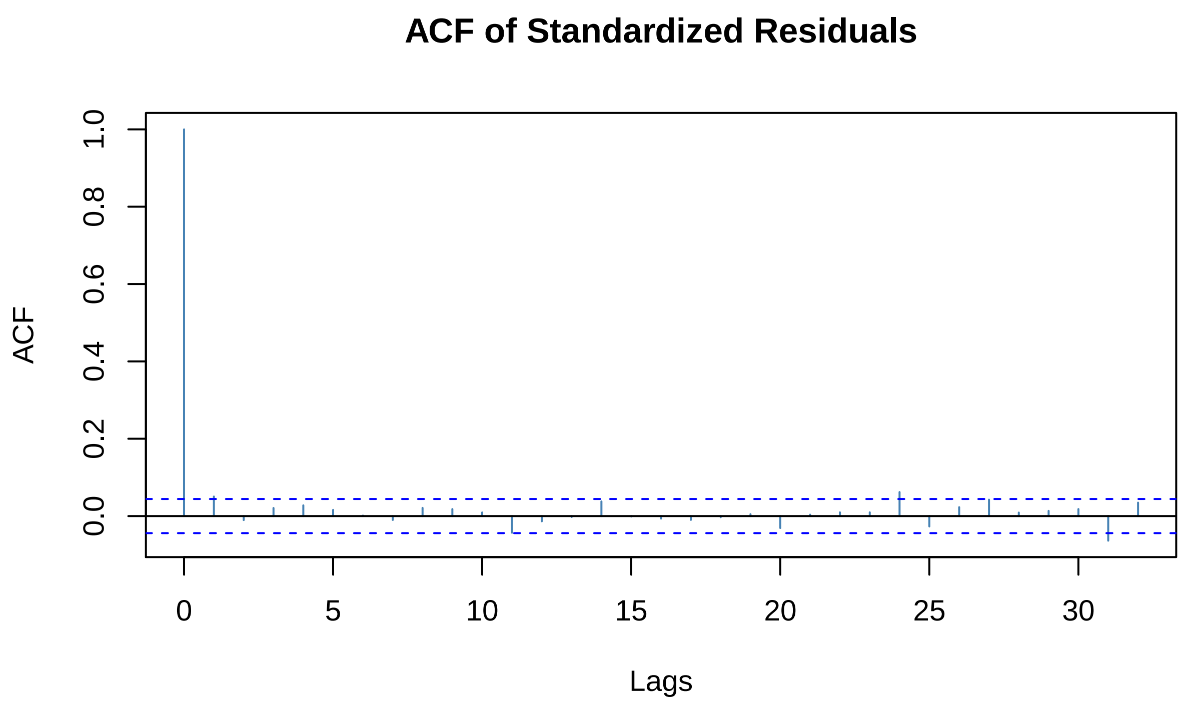
how do I get aic when I specify this way

```
Error in eval(expr, envir, enclos):  could not find function "ugarchspec"
```

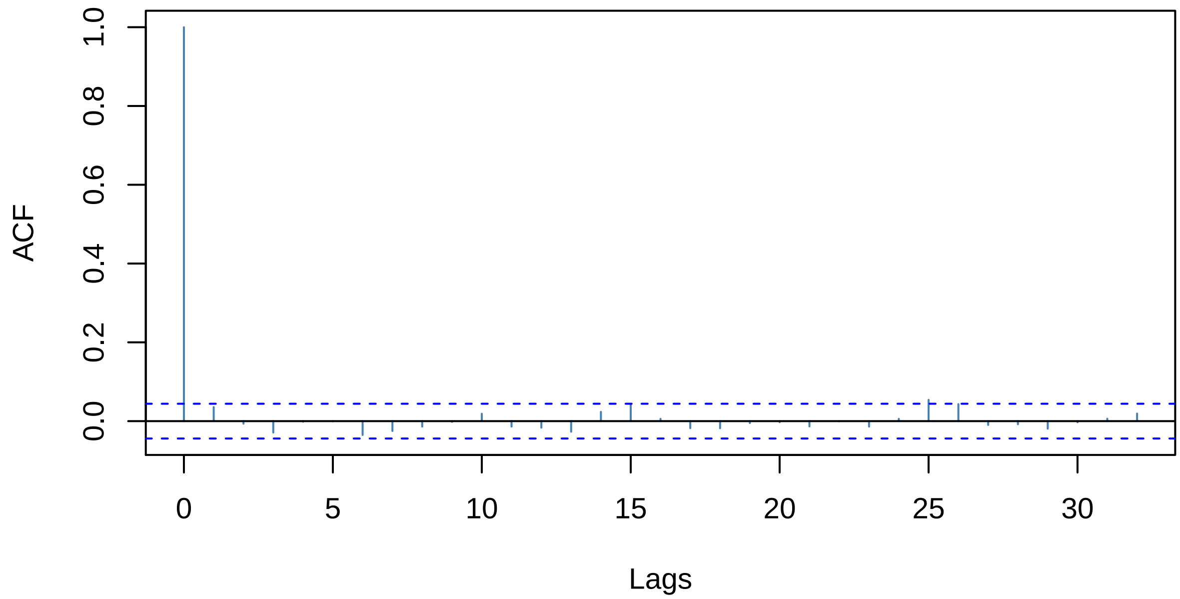
```
Error in eval(expr, envir, enclos):  could not find function "ugarchfit"
```




Standardized Residuals
sres
4
2
0
−2
−4
−6
0
500
1000
1500
2000
Index


ACF of Standardized Residuals
ACF
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Lags

ACF of Squared Standardized Residuals




```
Error in eval(expr, envir, enclos):  could not find function "ugarchspec"

Error in eval(expr, envir, enclos):  could not find function "ugarchfit"

Error in plot(oil_garch1122, which = 8):  object 'oil_garch1122' not found

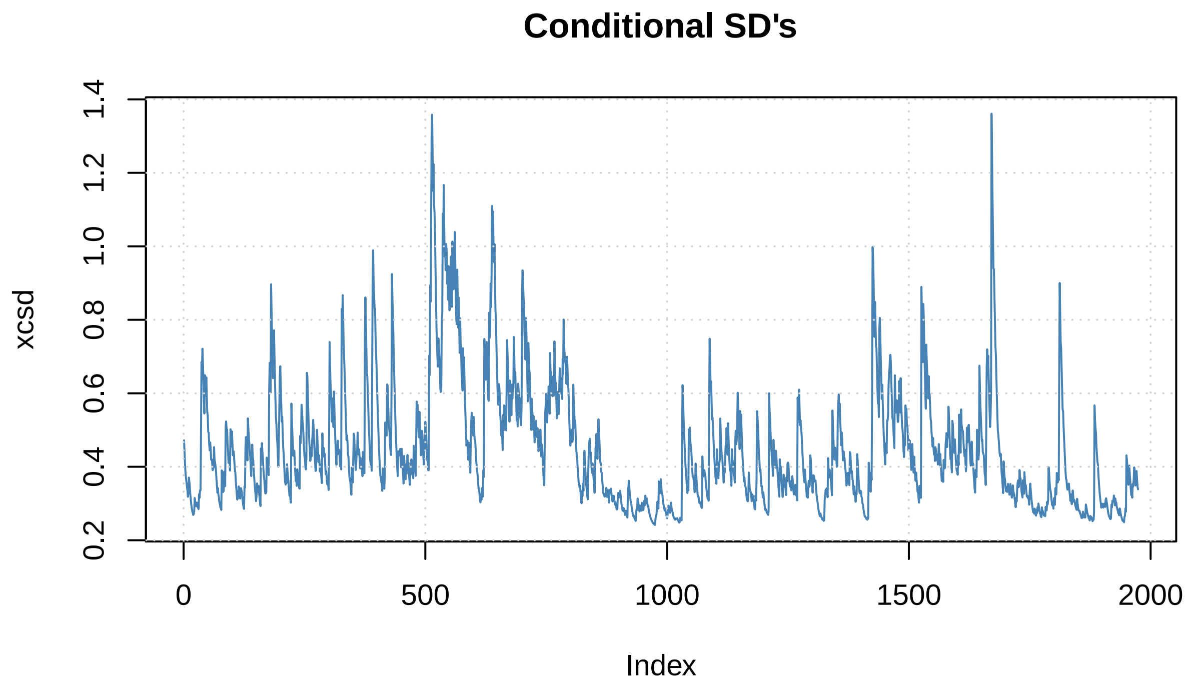
Error in plot(oil_garch1122, which = 9):  object 'oil_garch1122' not found

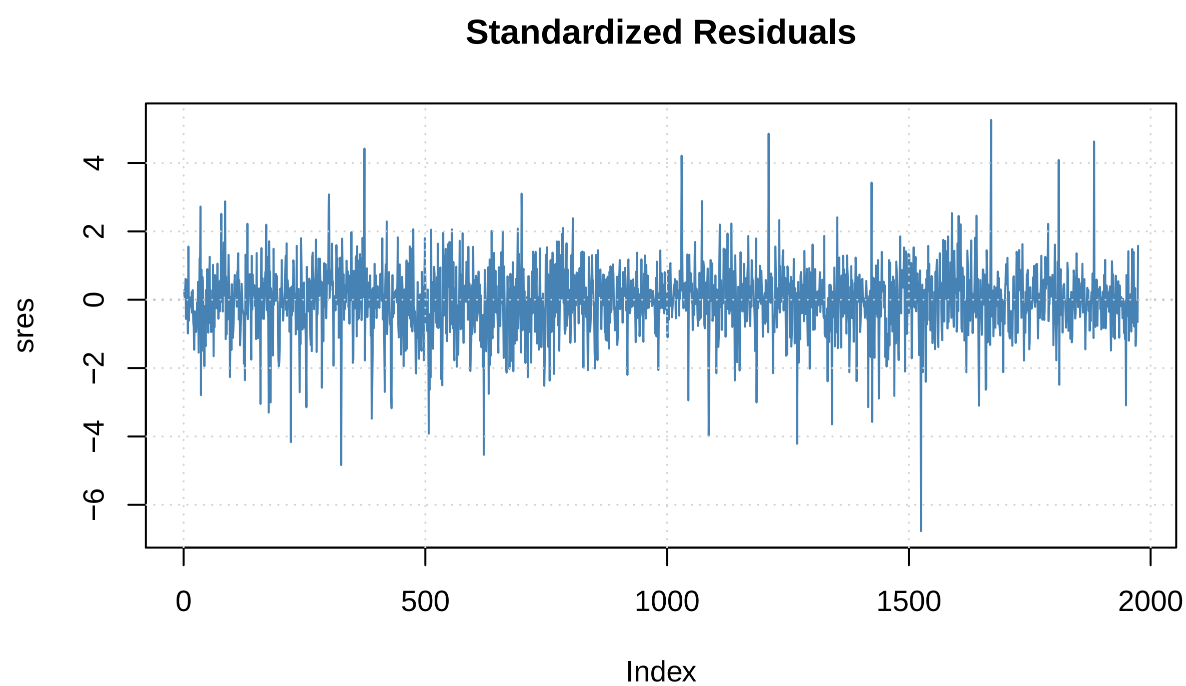
Error in plot(oil_garch1122, which = 10):  object 'oil_garch1122' not found

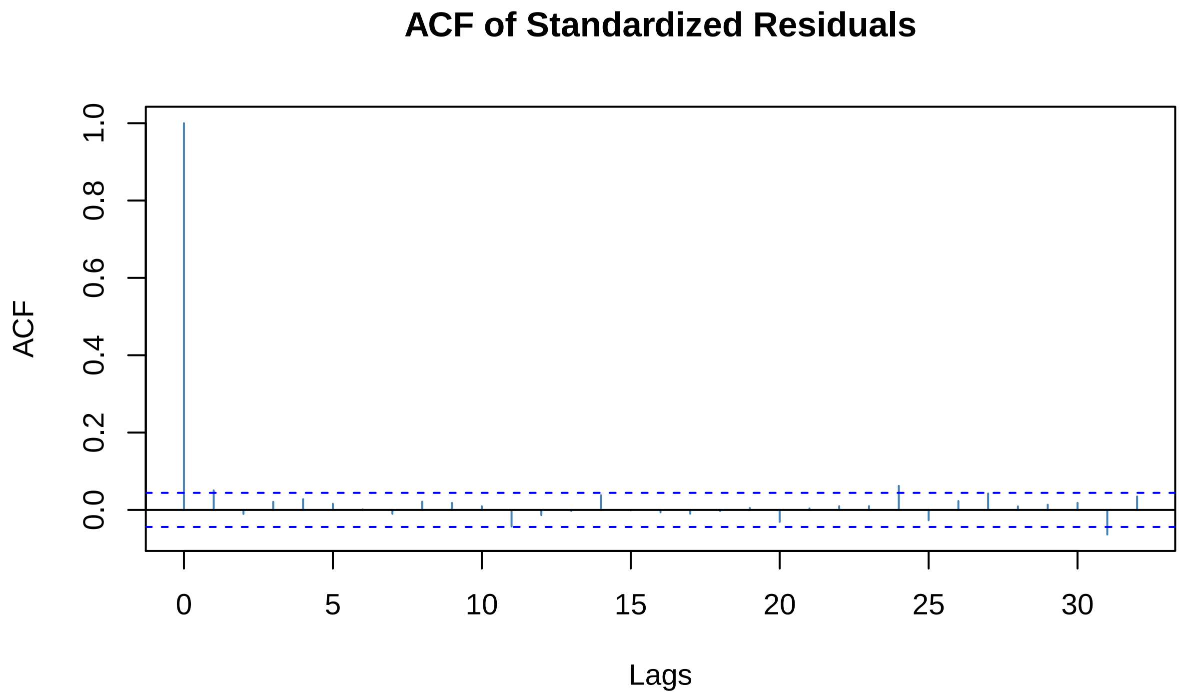
Error in plot(oil_garch1122, which = 11):  object 'oil_garch1122' not found

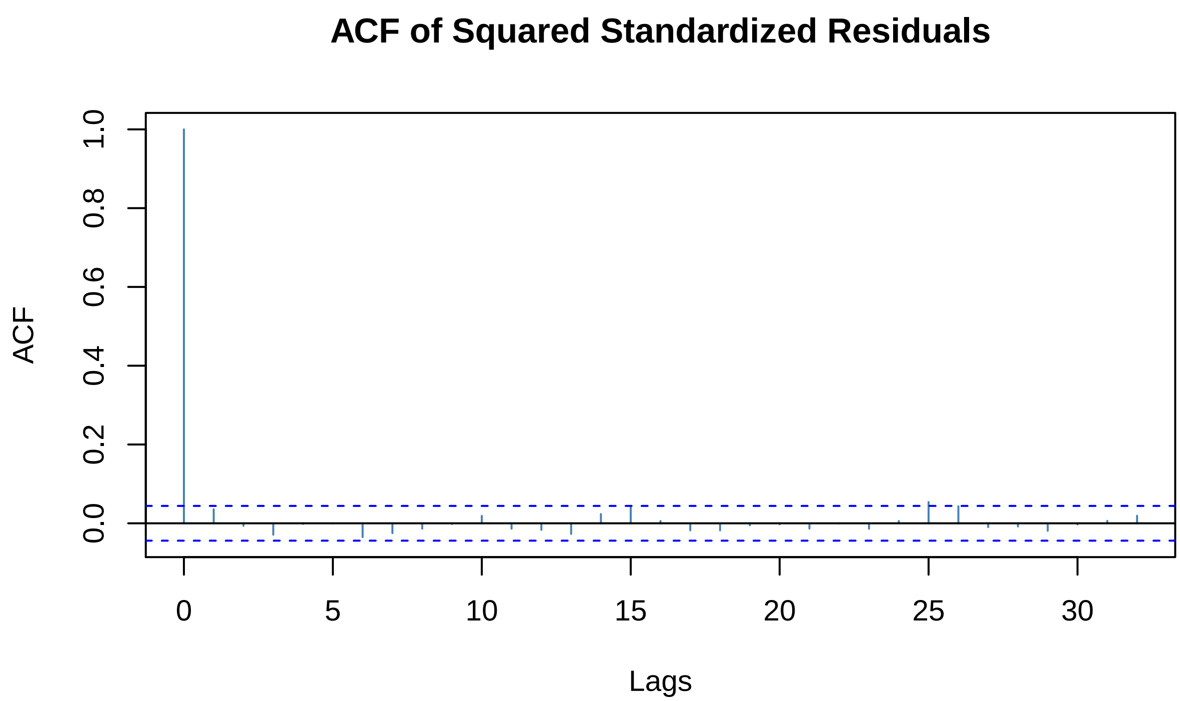
Error in eval(expr, envir, enclos):  could not find function "ugarchspec"

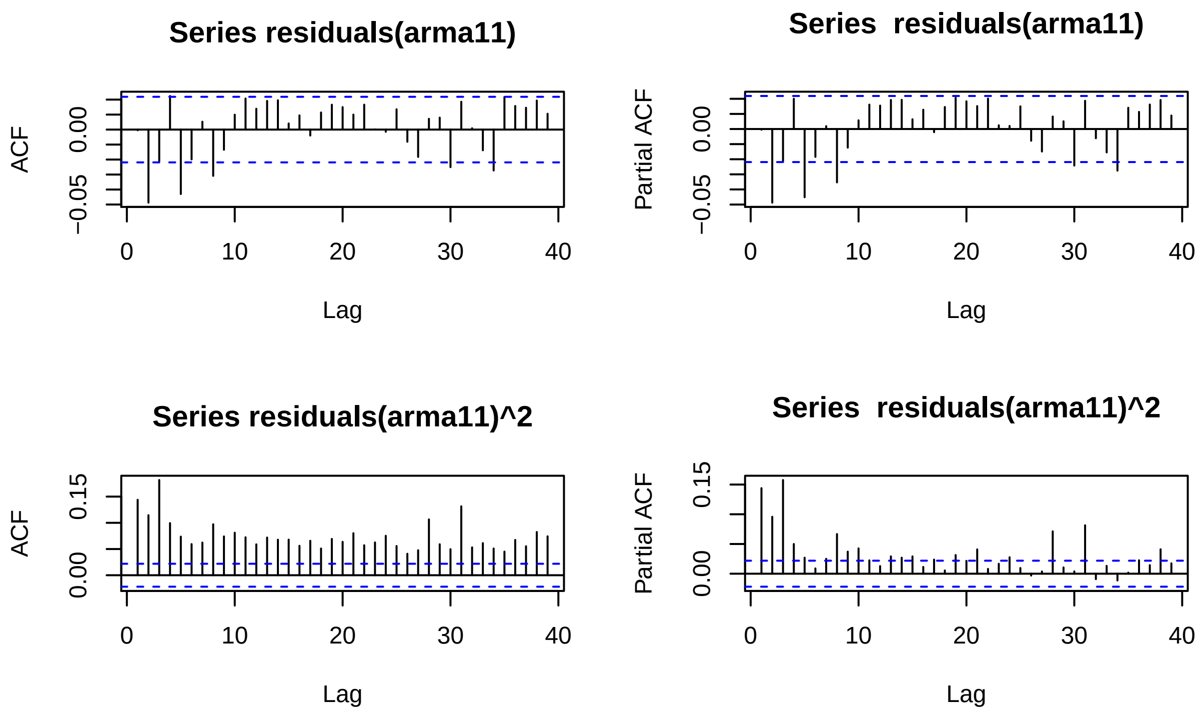
Error in eval(expr, envir, enclos):  could not find function "ugarchfit"
```


Conditional SD's
xcsd
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
500
1000
1500
2000
Index


Standardized Residuals
sres
−6
−4
−2
0
2
4
0
500
1000
1500
2000
Index


ACF of Standardized Residuals
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
Lags


ACF of Squared Standardized Residuals
ACF
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
Lags




```
Error in residuals(oil_garch1111):  object 'oil_garch1111' not found

Error in residuals(oil_garch1111):  object 'oil_garch1111' not found
```

ask mark how to choose which model to use, if specifying right, and what more to do with this... actuarial code...?