Outline II

- Volatility analysis with G@RCH models
  - First generation univariate G@RCH
    - ARCH, GARCH
    - Diagnostics
    - Forecasting
    - Forecast Evaluation
  - Second generation univariate G@RCH
    - GARCH-in-mean
    - EGARCH
    - GJR GARCH
    - Leverage effects and volatility smiles

Outline III
Long-Memory GARCH

- APARCH
- FIGARCH
  - FIGARCH- BBM
  - FIGARCH-Chung
  - FIEGARCH,
- Davidson’s HYGARCH
- VaR

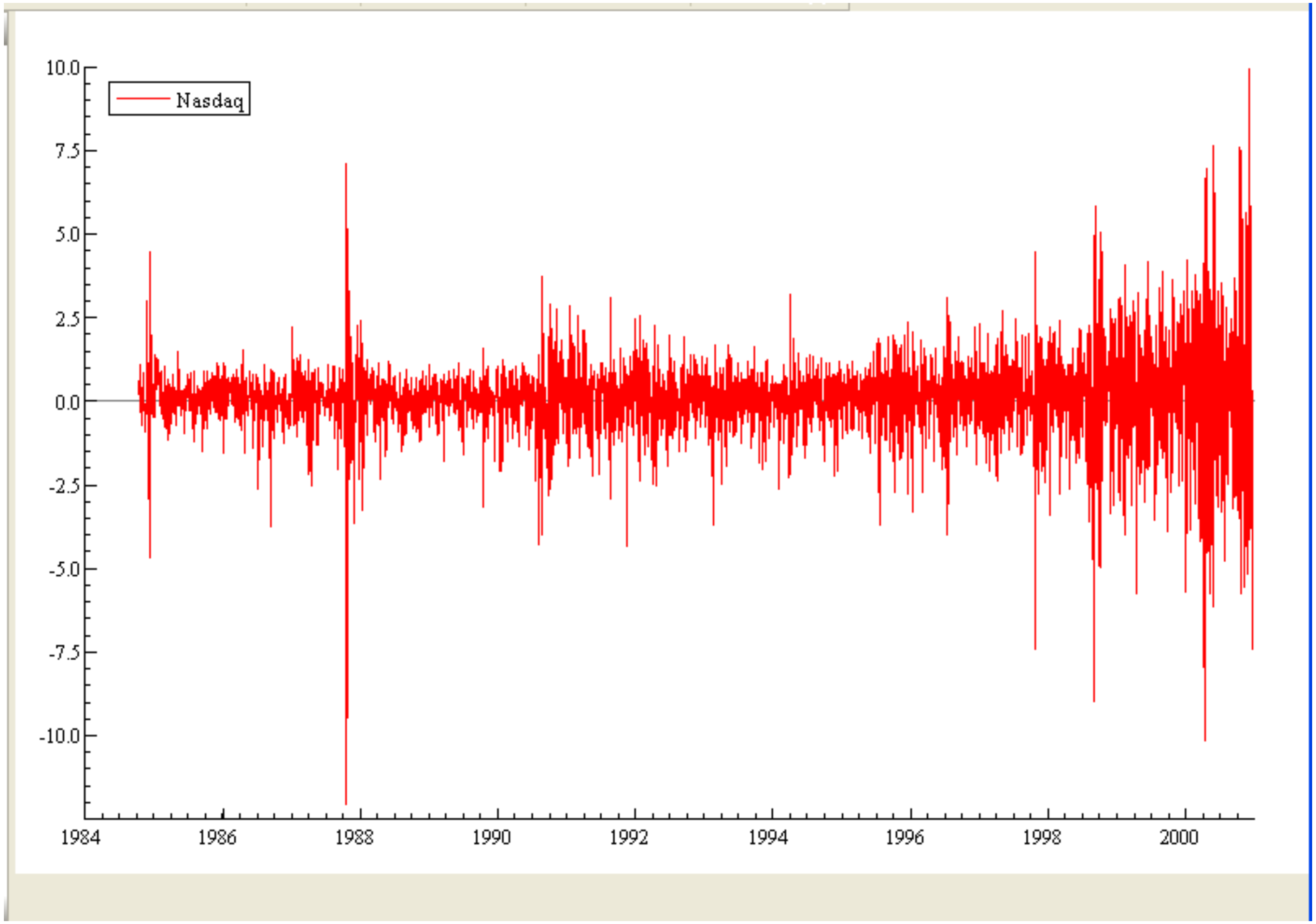
Outline IV
Multivariate GARCH

- Multivariate G@RCH
  - BEKK models
  - Factor garch: OGARCH, GOGARCH
  - Dynamic correlations: CCC, DCC
- Simulations

Risk Analysis with G@RCH

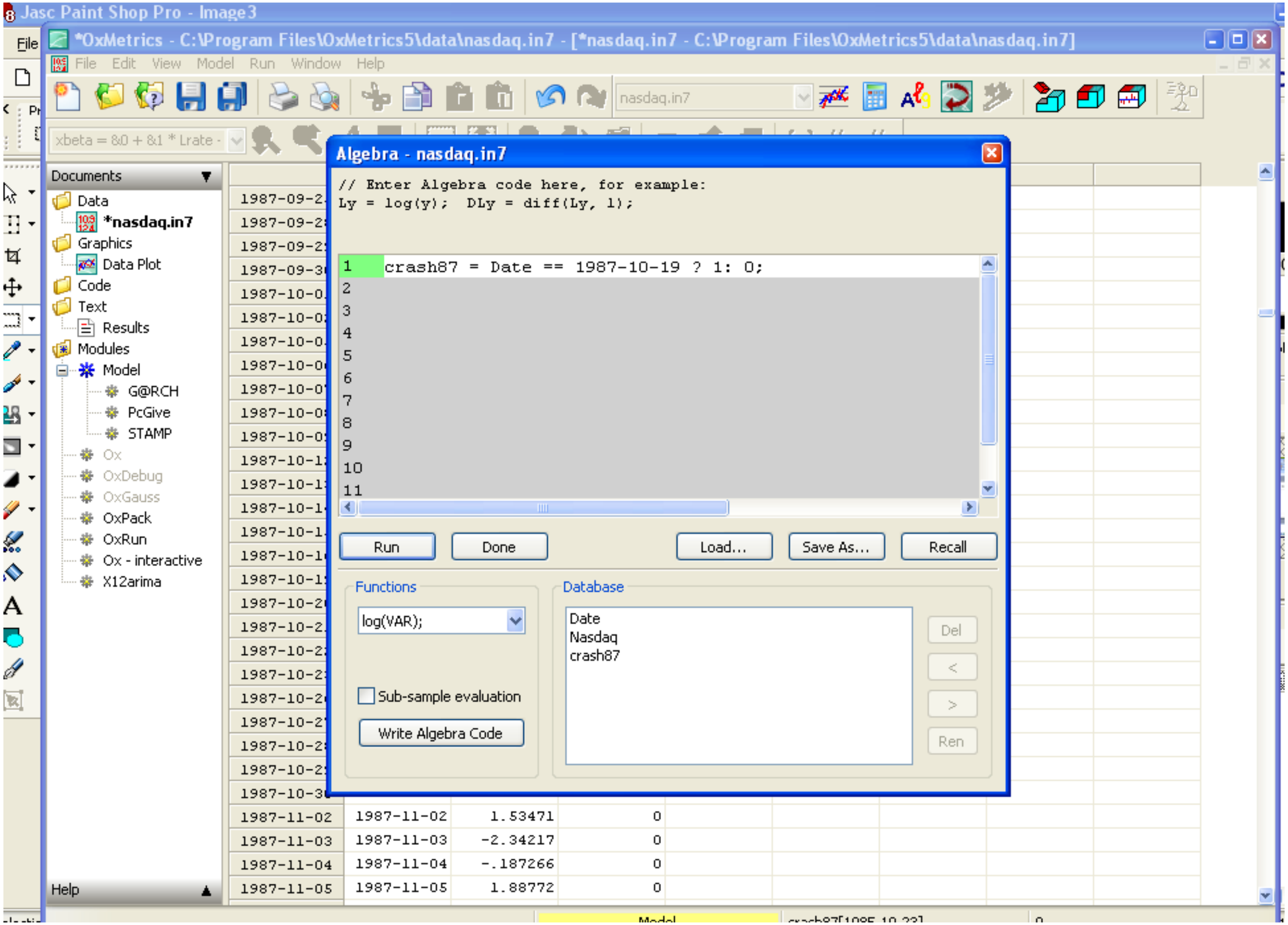
- We analyze volatility of indicators and assets with G@RCH.
- What is new about G@RCH 5?
    - It contains most of the multivariate Garch models
    - One can obtain the Ox Code for the menu model just run
    - One can model outliers and predictors in the mean and variance models
    - Estimation models has been improved. Simulated annealing option included.
    - Simulation of models is now possible
    - Functions to detect high frequency jumps have been included.

Load and Examine Nasdaq Returns

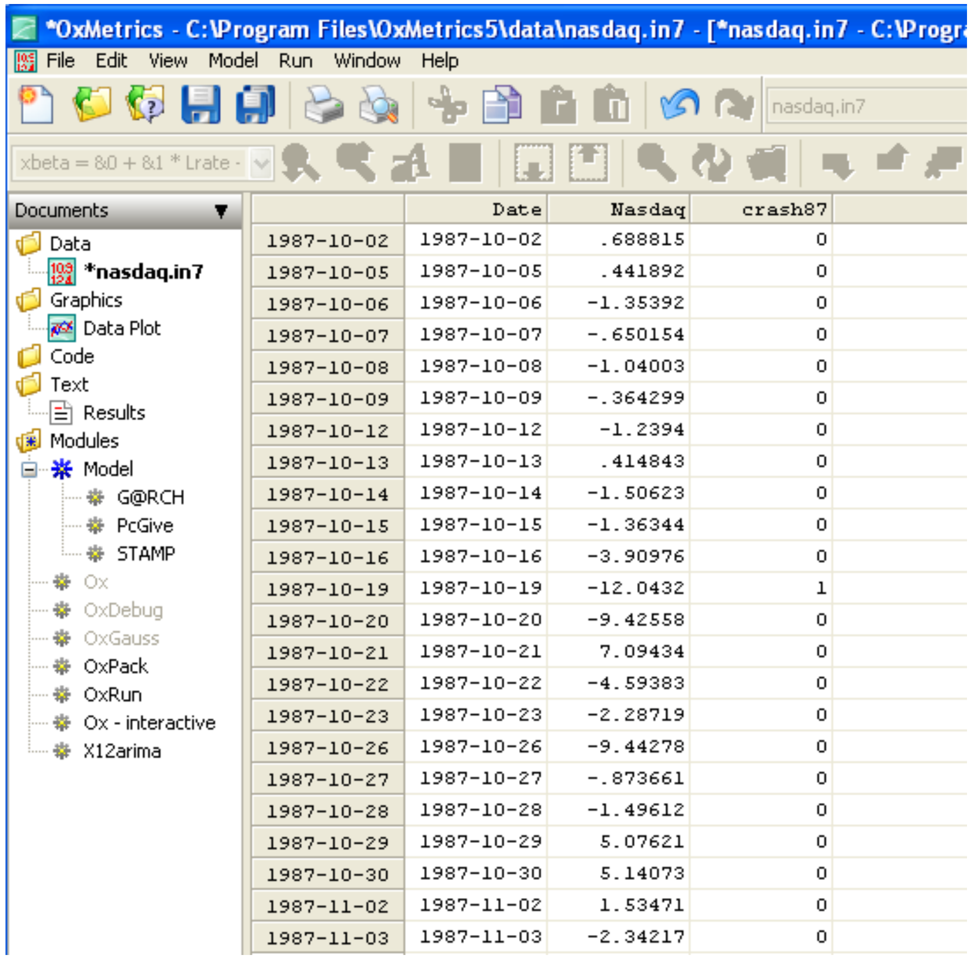


Notice the 1987 crash. We construct a dummy variable for Oct 19, 1987

We want record of all variable constructions so I do this with the algebra code

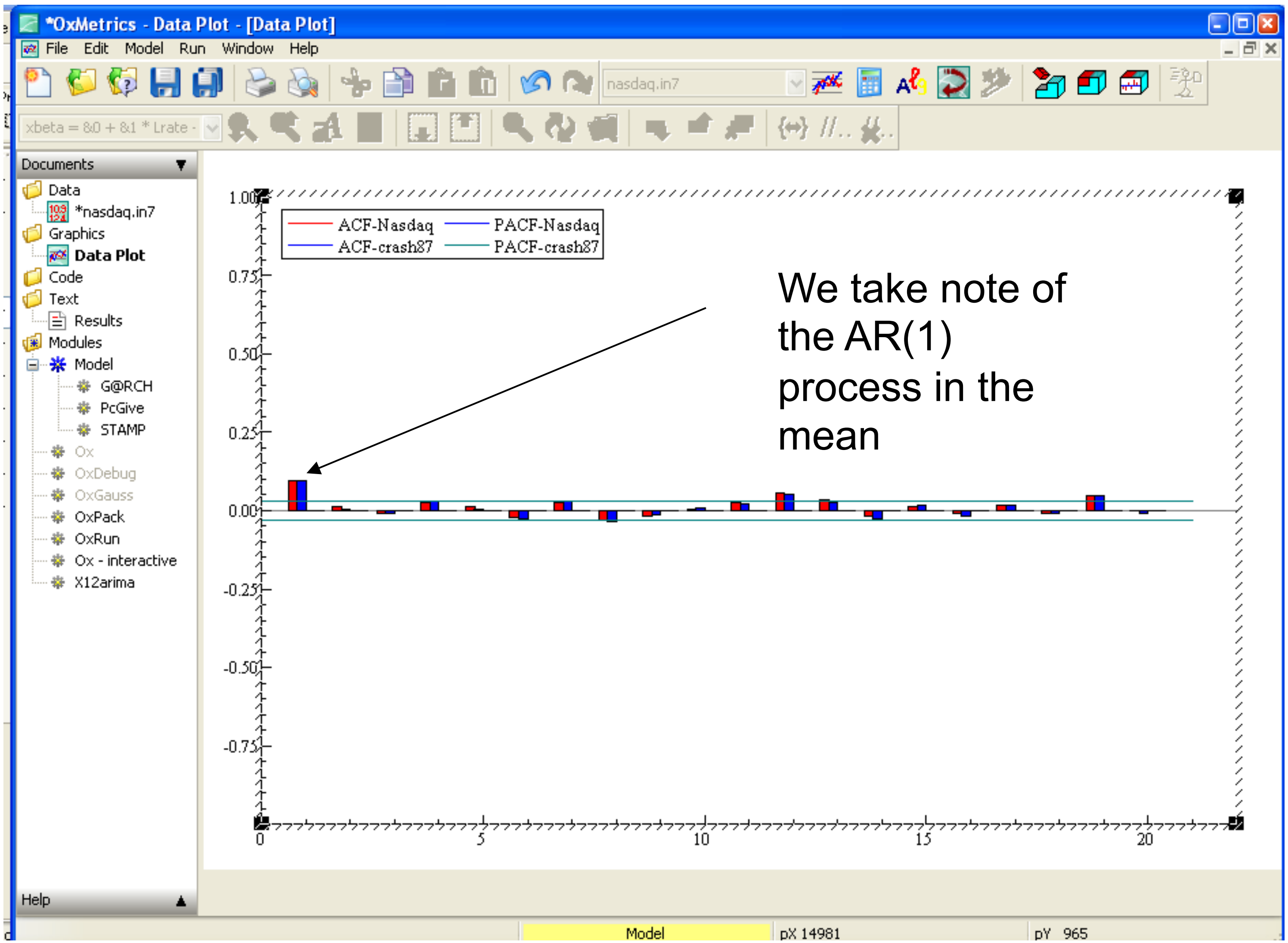


This constructs our dummy variable

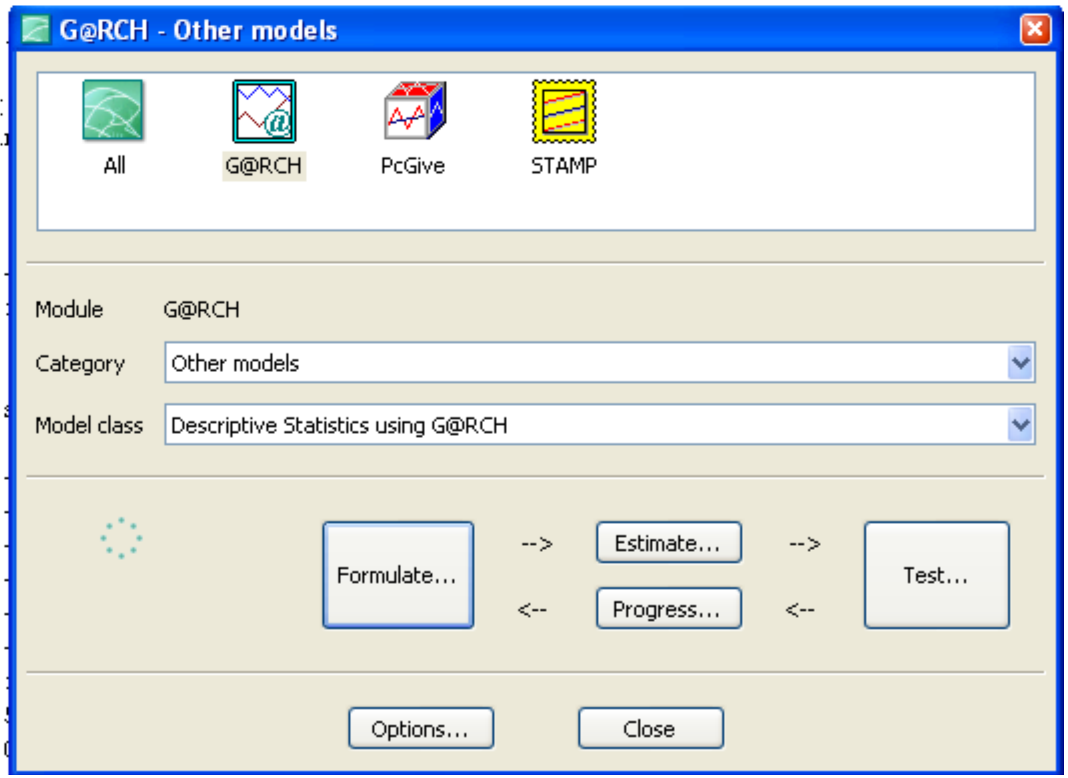


	Date	Nasdaq	crash87
1987-10-02	1987-10-02	.688815	0
1987-10-05	1987-10-05	.441892	0
1987-10-06	1987-10-06	-1.35392	0
1987-10-07	1987-10-07	-.650154	0
1987-10-08	1987-10-08	-1.04003	0
1987-10-09	1987-10-09	-.364299	0
1987-10-12	1987-10-12	-1.2394	0
1987-10-13	1987-10-13	.414843	0
1987-10-14	1987-10-14	-1.50623	0
1987-10-15	1987-10-15	-1.36344	0
1987-10-16	1987-10-16	-3.90976	0
1987-10-19	1987-10-19	-12.0432	1
1987-10-20	1987-10-20	-9.42558	0
1987-10-21	1987-10-21	7.09434	0
1987-10-22	1987-10-22	-4.59383	0
1987-10-23	1987-10-23	-2.28719	0
1987-10-26	1987-10-26	-9.44278	0
1987-10-27	1987-10-27	-.873661	0
1987-10-28	1987-10-28	-1.49612	0
1987-10-29	1987-10-29	5.07621	0
1987-10-30	1987-10-30	5.14073	0
1987-11-02	1987-11-02	1.53471	0
1987-11-03	1987-11-03	-2.34217	0

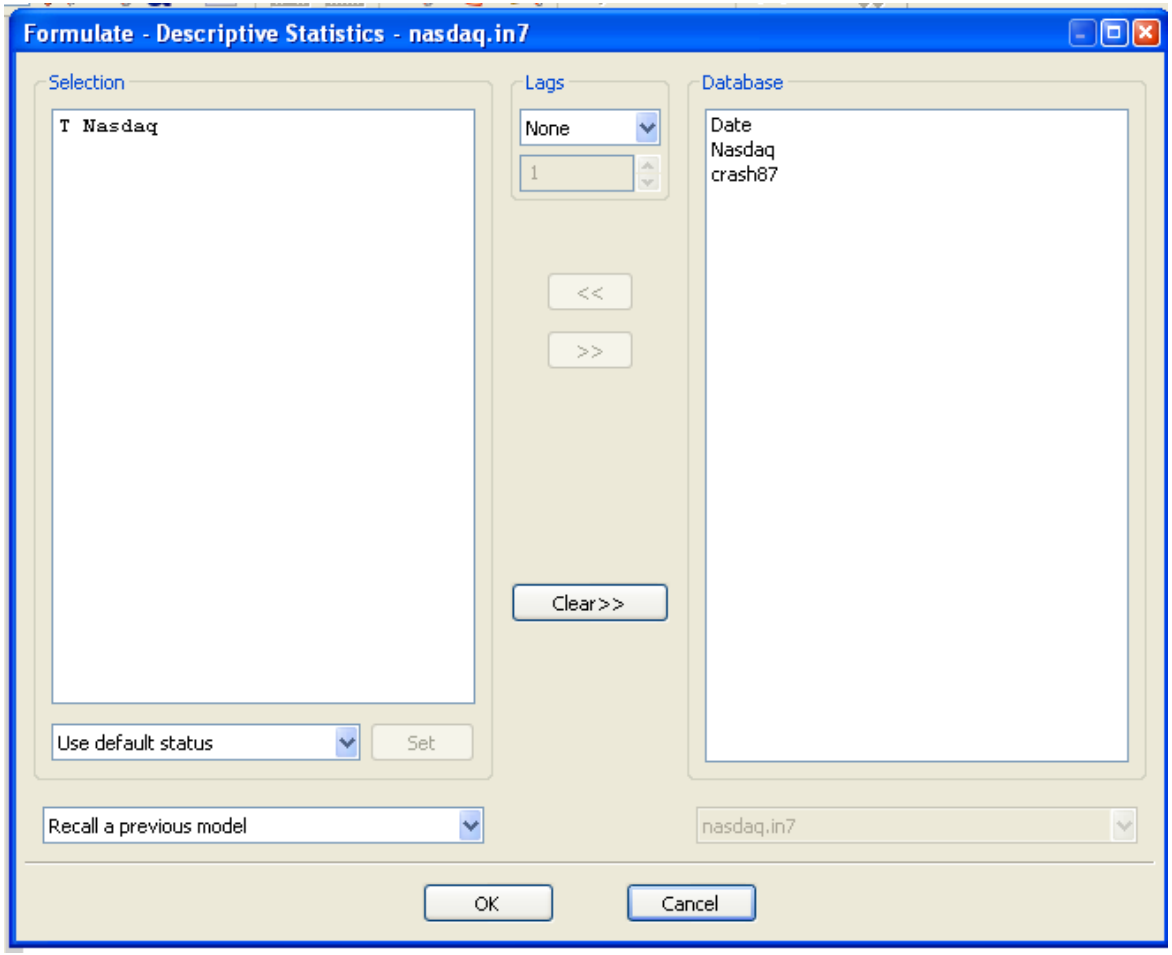
Correlograms reveal an AR(1) and possibly some seasonality



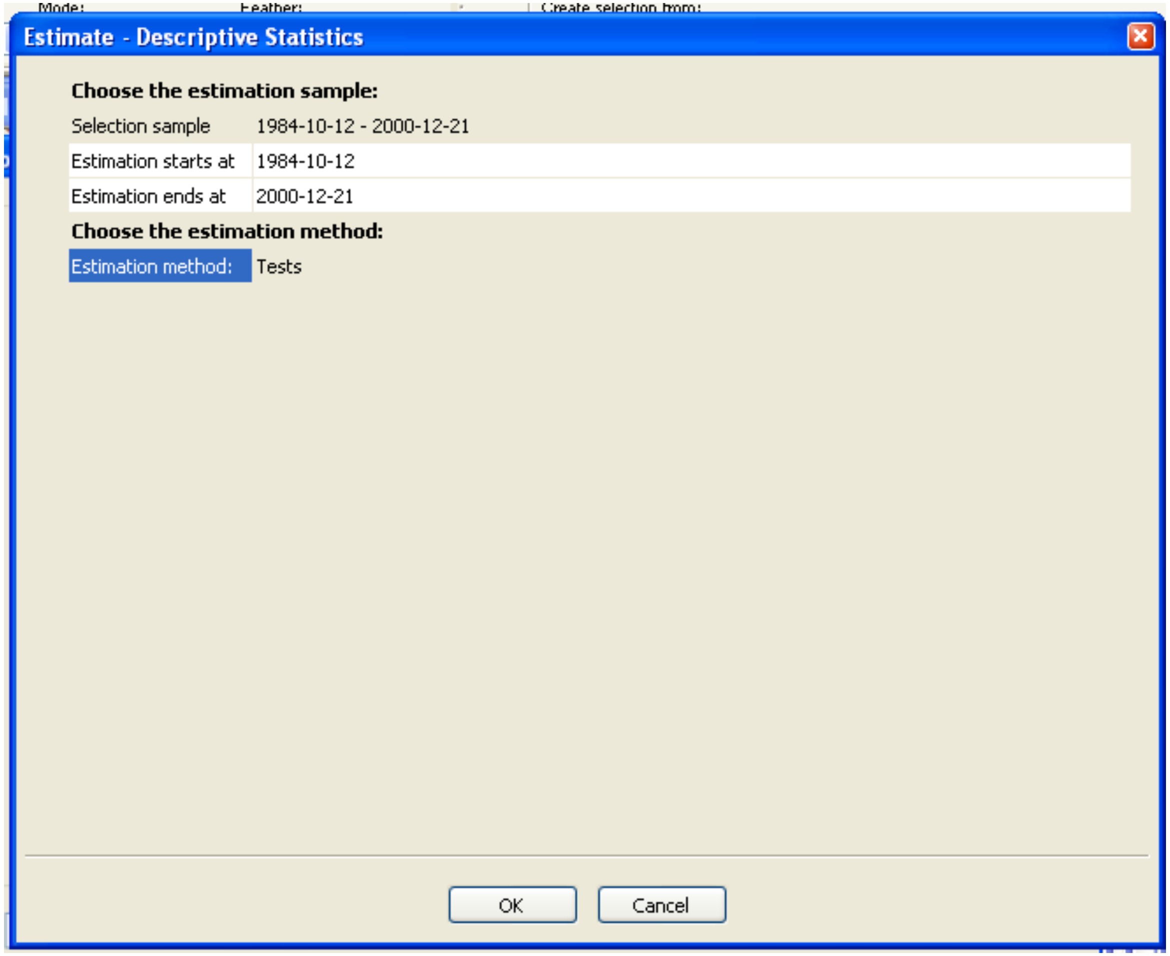
Basic Pre-Model Analysis



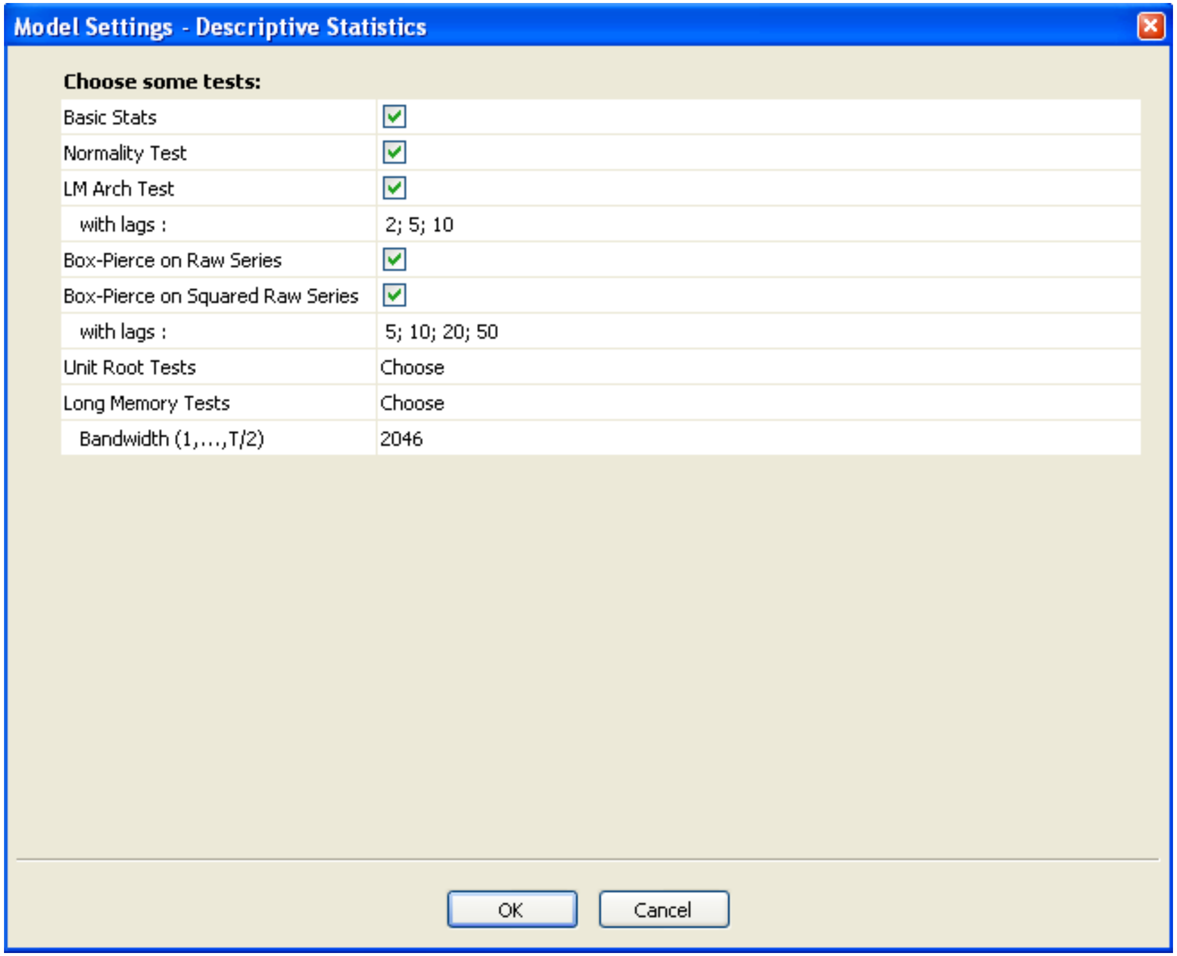
Select the variable



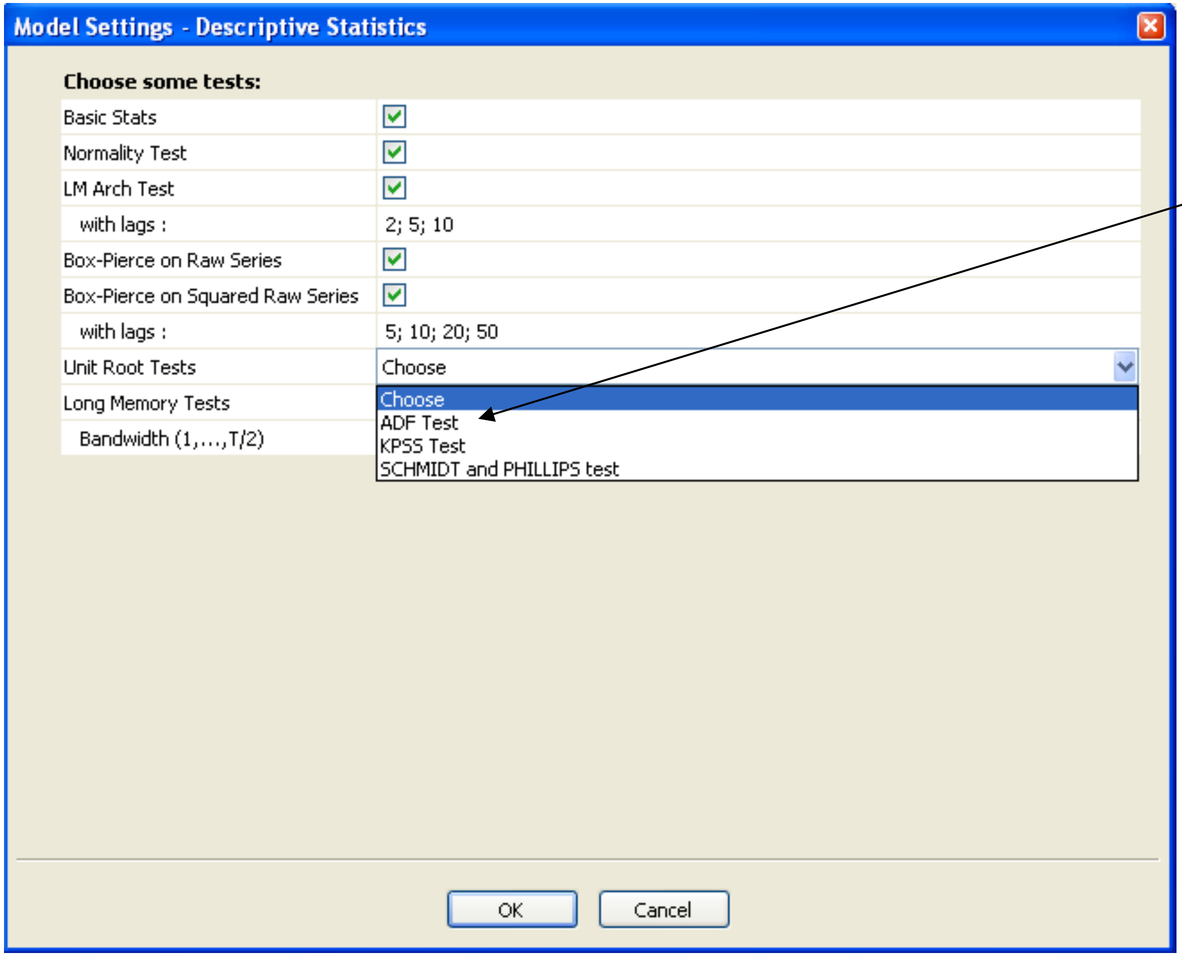
Define the sample



Specify the preliminary tests

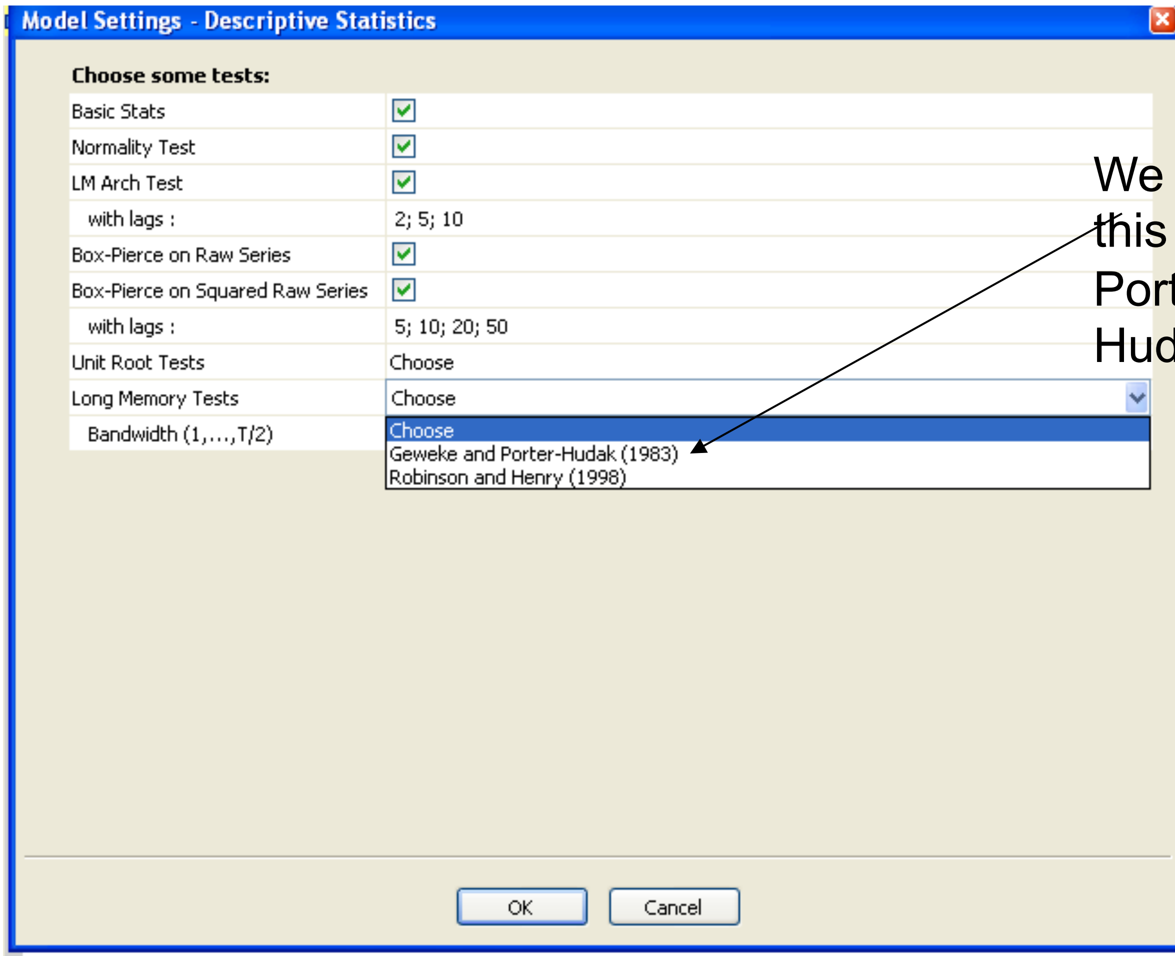


Choose the Stationarity tests



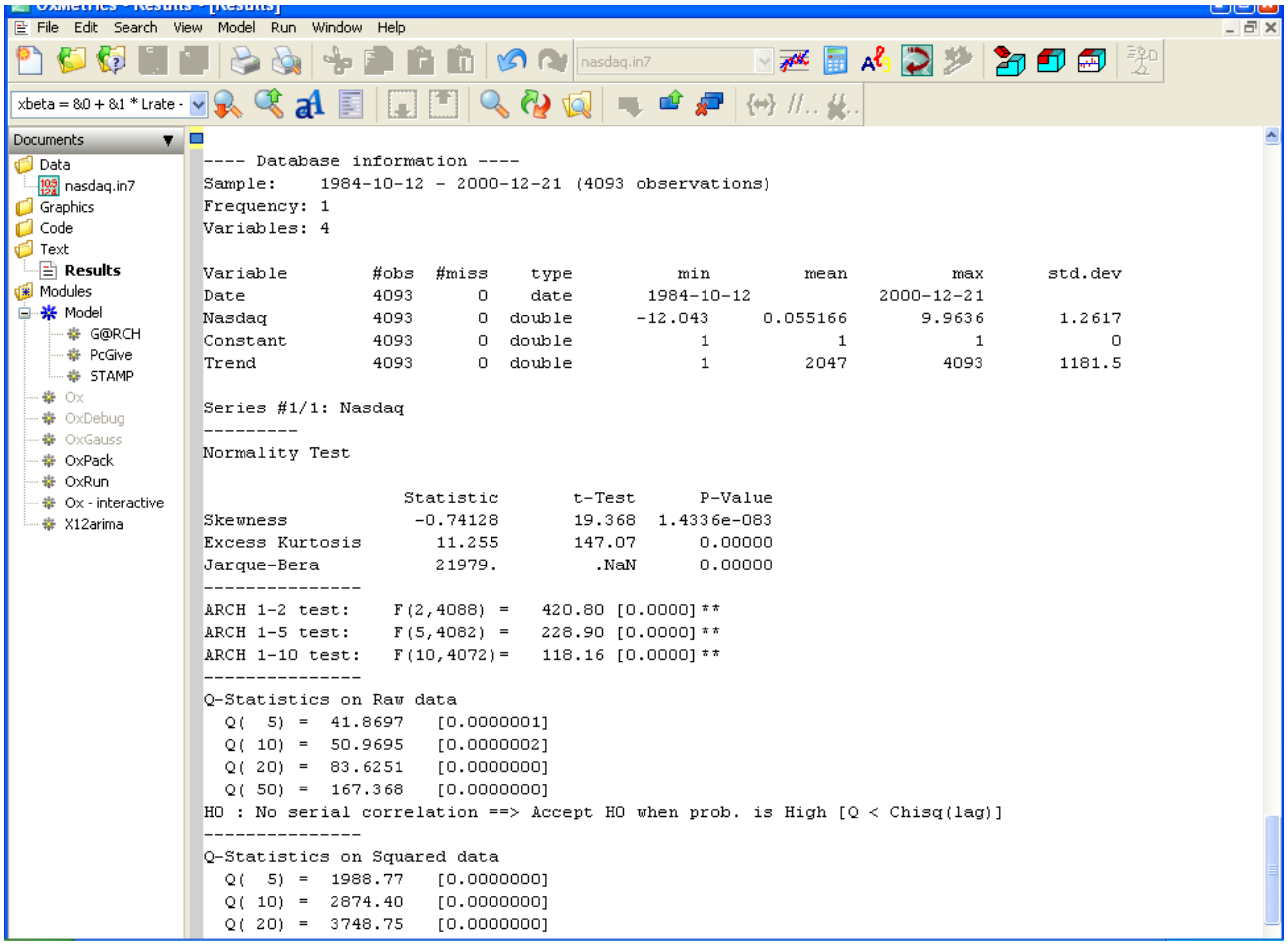
We select ADF test

Choose the Long-Memory Test

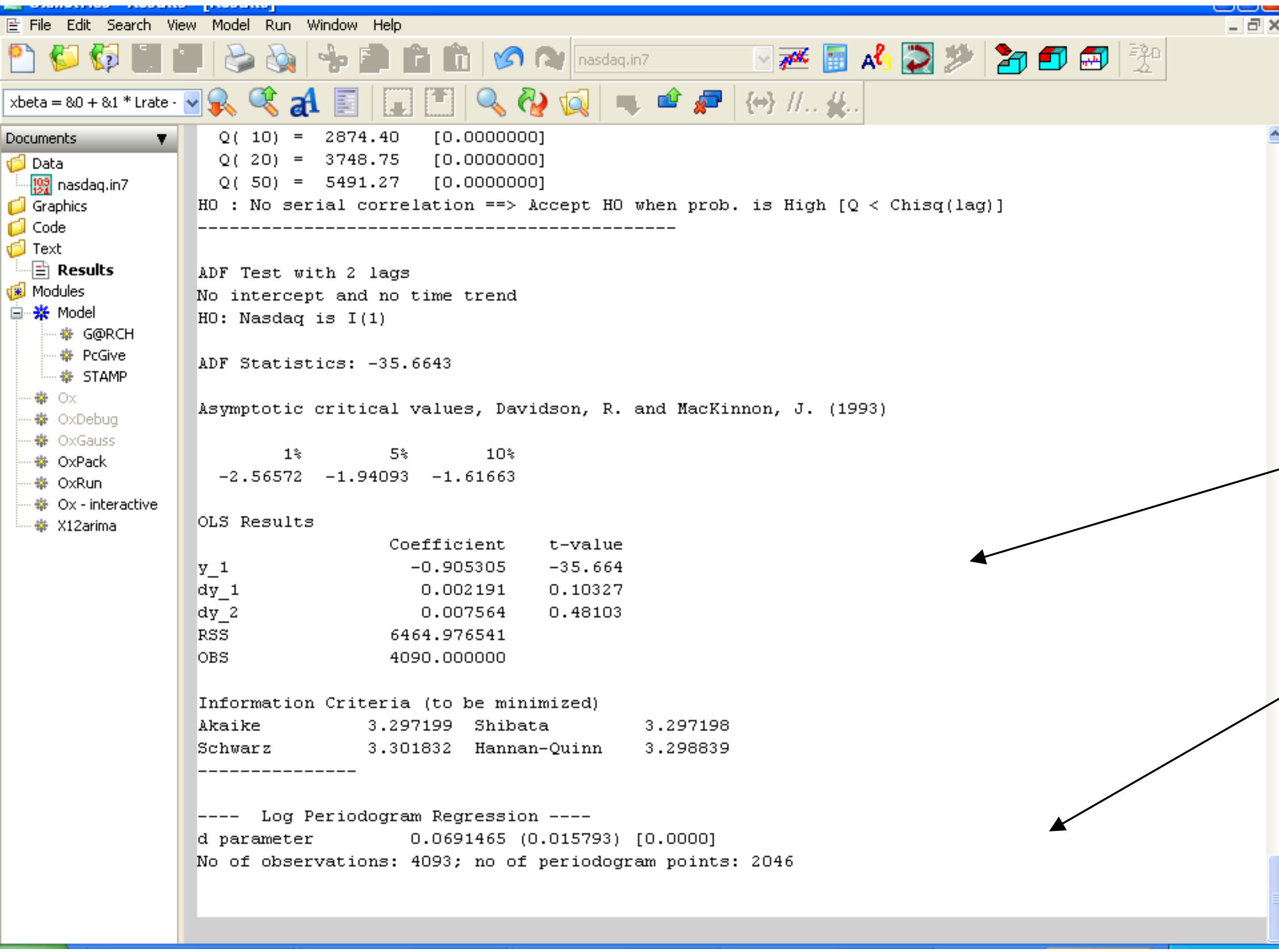


We select this Geweke Porter-Hudak test

Obtain the results



Nonstationarity and Long-Memory Results



$$\Delta y_t = (\beta - 1) y_{t-1} + e_t$$

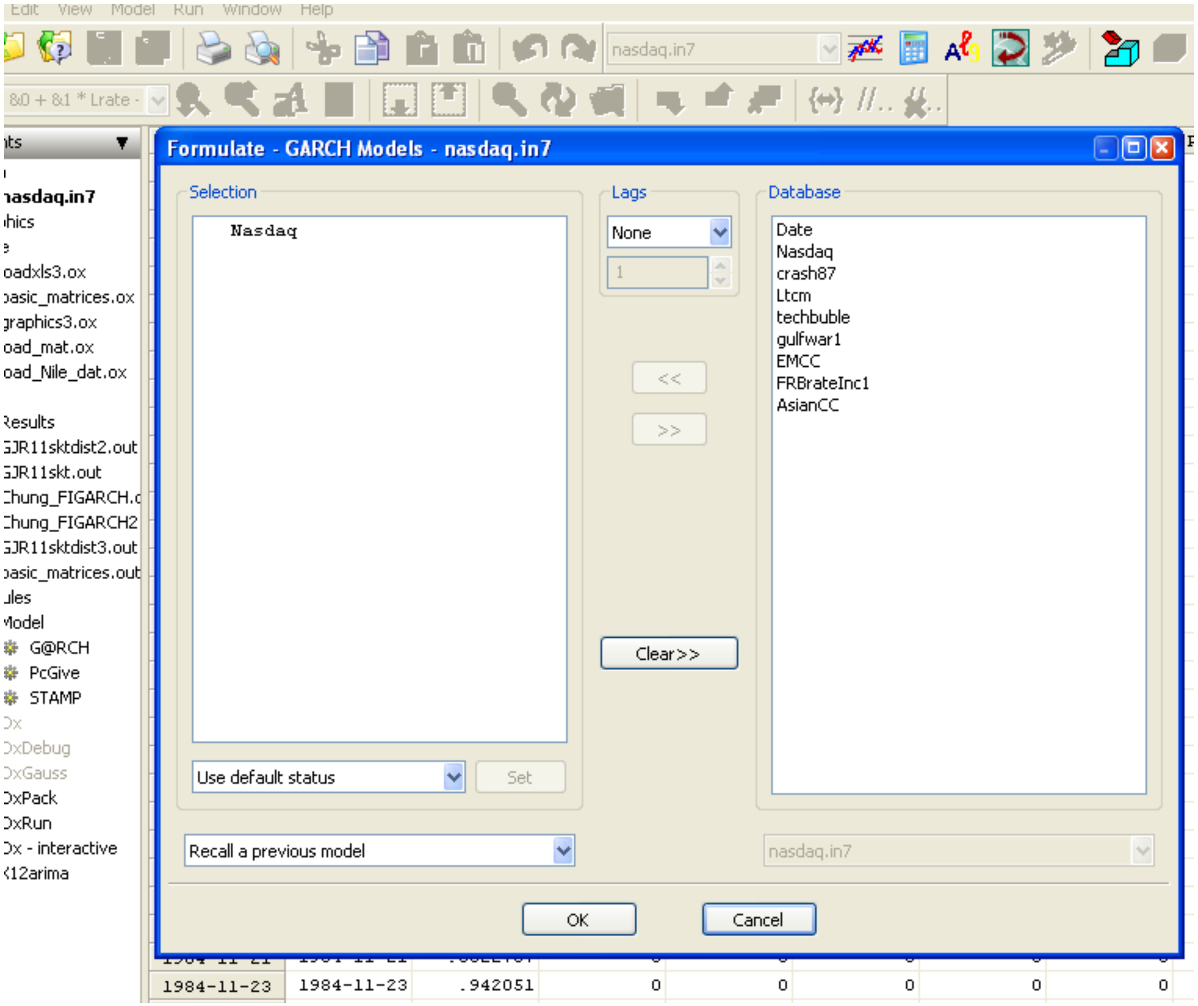
Nonstationary

Long memory parameter is weak—should be .2 to .5 for persistence.

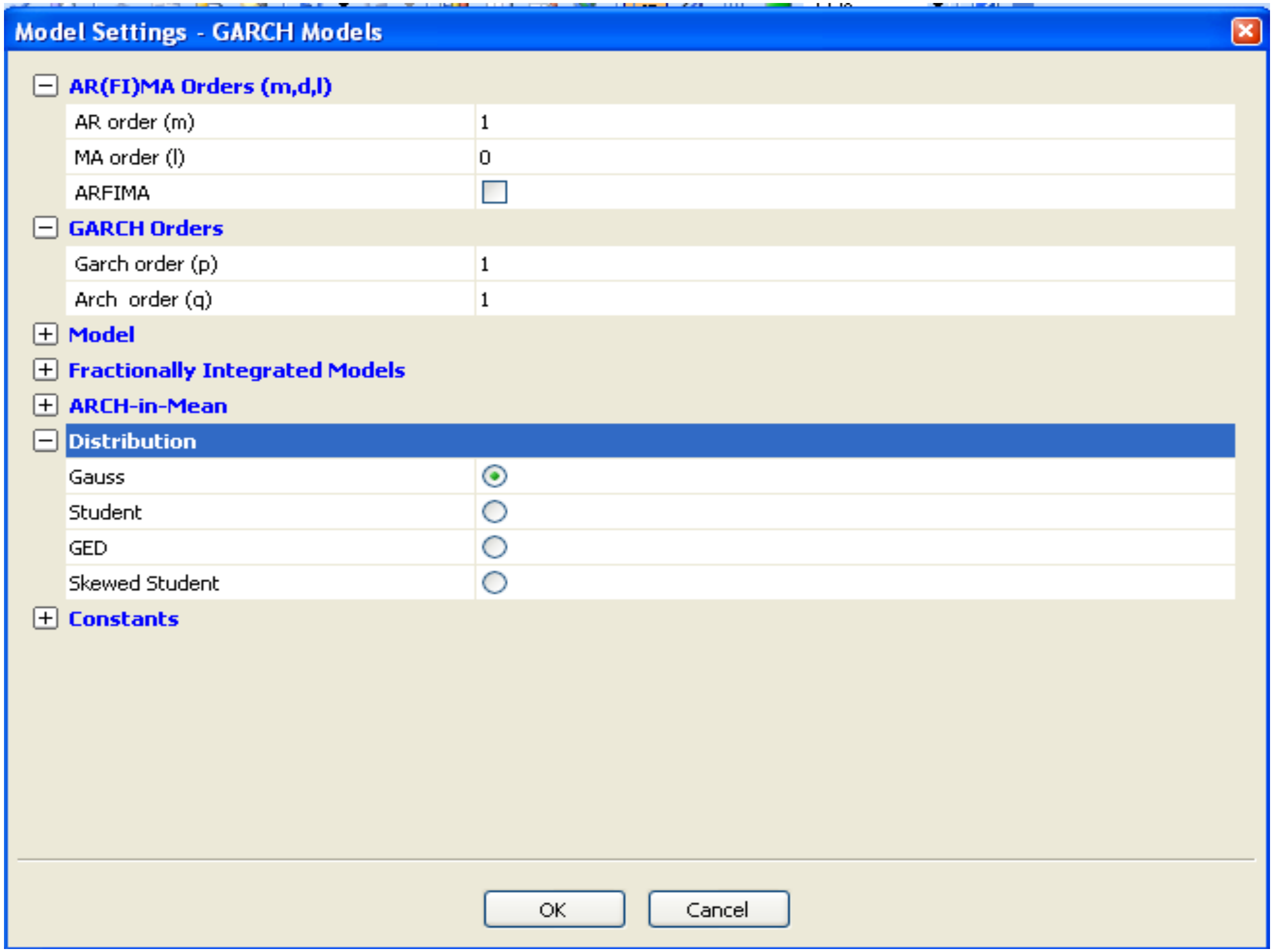
Pre-Model Analysis

- The Jarque-Bera tests suggests nonnormality--- we should probably try a t distribution
- The ARCH tests suggest ARCH effects
- The Portmanteau tests suggest autocorrelation
- The Nasdaq returns are nonstationary and there is long memory

Variable Selection



Baseline model parameter selection

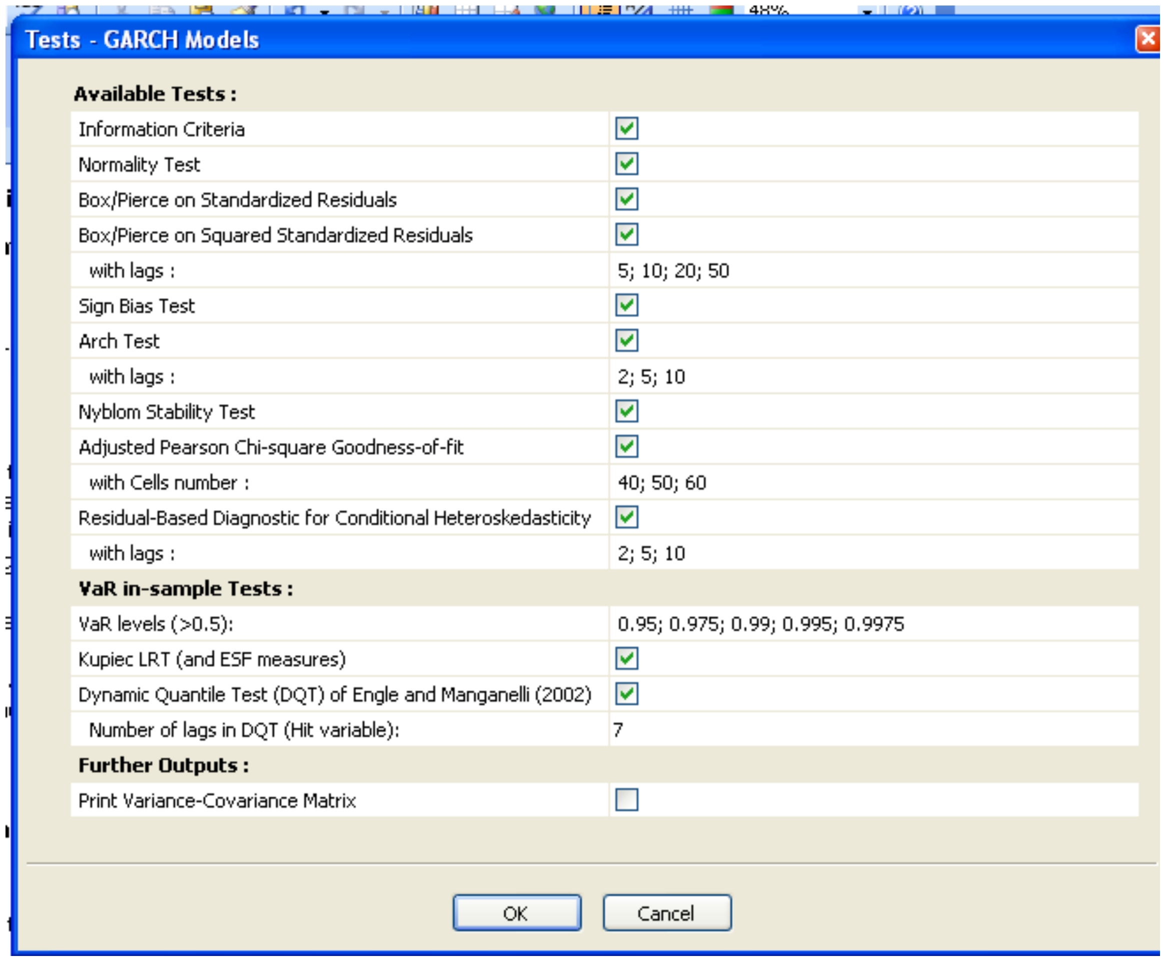


AR(1) GARCH(1,1) normal distribution is our baseliine model

GARCH(1,1) model output

```
 ******************************
 ** G@RCH( 1) SPECIFICATIONS **
 ******************************
Dependent variable : Nasdaq
Mean Equation : ARMA (1, 0) model.
No regressor in the conditional mean
Variance Equation : GARCH (1, 1) model.
No regressor in the conditional variance
Normal distribution.

Strong convergence using numerical derivatives
Log-likelihood = -5395.14
Please wait : Computing the Std Errors ...

 Robust Standard Errors (Sandwich formula)
                  Coefficient  Std.Error  t-value  t-prob
Cst(M)               0.084113   0.015616    5.386  0.0000
AR(1)                0.193052   0.017187    11.23  0.0000
Cst(V)               0.025299  0.0071185    3.554  0.0004
ARCH(Alpha1)         0.167673   0.029686    5.648  0.0000
GARCH(Beta1)         0.820858   0.028236    29.07  0.0000

No. Observations :      4093  No. Parameters  :         5
Mean (Y)         :   0.05517  Variance (Y)    :   1.59189
Skewness (Y)     :  -0.74128  Kurtosis (Y)    :  14.25531
Log Likelihood   : -5395.144  Alpha[1]+Beta[1]:   0.98853

The sample mean of squared residuals was used to start recursion.
The positivity constraint for the GARCH (1,1) is observed.
This constraint is alpha[L]/[1 - beta(L)] >= 0.
The unconditional variance is 2.2058
The conditions are alpha[0] > 0, alpha[L] + beta[L] < 1 and alpha[i] + beta[i] >= 0.
  => See Doornik & Ooms (2001) for more details.
The condition for existence of the fourth moment of the GARCH is not observed.
The constraint equals 1.03342 and should be < 1.
  => See Ling & McAleer (2001) for details.
```

Selecting Post-Estimation tests



Test Results I

```
  ***********
 ** TESTS **
***********

TESTS :
---------
Information Criteria (to be minimized)
Akaike          2.638722  Shibata         2.638719
Schwarz         2.646439  Hannan-Quinn    2.641454
---------------

Normality Test

                   Statistic       t-Test      P-Value
Skewness            -0.69210       18.083  4.3269e-073
Excess Kurtosis       2.8275       36.947      0.00000
Jarque-Bera           1690.2         .NaN      0.00000
---------------

Q-Statistics on Standardized Residuals
  --> P-values adjusted by 1 degree(s) of freedom
  Q(  5) =  4.93617   [0.2939093]
  Q( 10) =  6.12809   [0.7270328]
  Q( 20) =  20.1258   [0.3870456]
  Q( 50) =  63.5812   [0.0787143]
HO : No serial correlation ==> Accept HO when prob. is High [Q < Chisq(lag)]
---------------

Q-Statistics on Squared Standardized Residuals
  --> P-values adjusted by 2 degree(s) of freedom
  Q(  5) =  3.20892   [0.3605224]
  Q( 10) =  6.56843   [0.5838280]
  Q( 20) =  14.7703   [0.6776756]
  Q( 50) =  44.0824   [0.6340817]
HO : No serial correlation ==> Accept HO when prob. is High [Q < Chisq(lag)]
---------------
```

Test Results II

```
Diagnostic test based on the news impact curve (EGARCH vs. GARCH)
                                       Test   P-value
Sign Bias t-Test                    2.48129   0.01309
Negative Size Bias t-Test           1.20393   0.22862
Positive Size Bias t-Test           1.42296   0.15475
Joint Test for the Three Effects 25.46329   0.00001
---------------
ARCH 1-2 test:    F(2,4086) =   1.2301 [0.2924]
ARCH 1-5 test:    F(5,4080) =  0.62728 [0.6790]
ARCH 1-10 test:   F(10,4070)=  0.63998 [0.7805]
---------------

Joint Statistic of the Nyblom test of stability: 6.34273

Individual Nyblom Statistics:
Cst(M)           0.09948
AR(1)            3.47893
Cst(V)           0.63865
ARCH(Alpha1)     1.25070
GARCH(Beta1)     1.58594

Rem: Asymptotic 1% critical value for individual statistics = 0.75.
     Asymptotic 5% critical value for individual statistics = 0.47.
---------------

Adjusted Pearson Chi-square Goodness-of-fit test

# Cells(g)  Statistic      P-Value(g-1)     P-Value(g-k-1)
    40      176.3672         0.000000         0.000000
    50      210.1884         0.000000         0.000000
    60      219.8317         0.000000         0.000000
Rem.: k = 5 = # estimated parameters
---------------
```

Test Results III

```
Residual-Based Diagnostic for Conditional Heteroskedasticity of Tse (2002)
  RBD( 2) = -6.40705   [1.0000000]
  RBD( 5) = 0.485674   [0.9926385]
  RBD(10) =  4.53051   [0.9202588]
------------------------------------------------
P-values in brackets


In-sample Value-at-Risk Backtesting

Kupiec LR test
--------------
```

- Short positions -

Quantile	Failure rate	Kupiec LRT	P-value	ESF1	ESF2
0.95000	0.96628	25.679	4.0322e-007	2.4334	1.2525
0.97500	0.98534	21.040	4.4975e-006	2.7129	1.2327
0.99000	0.99365	6.3191	0.011945	3.3298	1.2057
0.99500	0.99682	3.1457	0.076125	3.7132	1.2360
0.99750	0.99780	0.15517	0.69364	4.2753	1.2153

- Long positions -

Quantile	Failure rate	Kupiec LRT	P-value	ESF1	ESF2
0.050000	0.058881	6.4458	0.011121	-2.3226	1.4410
0.025000	0.035915	17.662	2.6386e-005	-2.5715	1.3855
0.010000	0.019301	28.117	1.1419e-007	-2.9948	1.3767
0.0050000	0.013926	44.033	3.2289e-011	-3.2095	1.3548
0.0025000	0.0092841	44.368	2.7216e-011	-3.6826	1.3830

Test Results IV

Dynamic Quantile Test of Engle and Manganelli (2002)

\- Short positions -

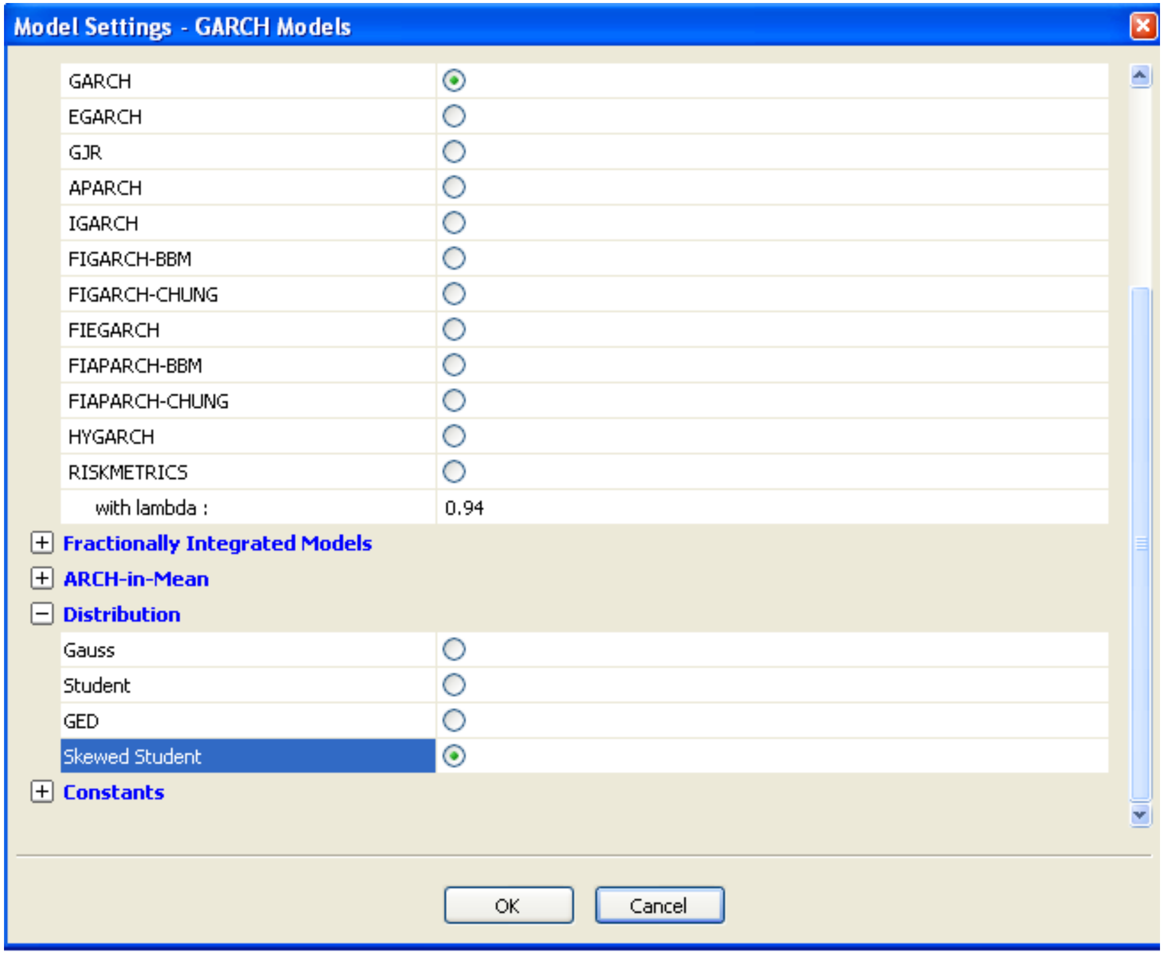
Quantile	Stat.	P-value
0.95000	25.551	0.0012532
0.97500	20.863	0.0075214
0.99000	8.8216	0.35757
0.99500	2.9260	0.93892
0.99750	0.27316	0.99999

\- Long positions -

Quantile	Stat.	P-value
0.050000	13.109	0.10814
0.025000	36.600	1.3629e-005
0.010000	48.500	7.9279e-008
0.0050000	77.972	1.2501e-013
0.0025000	90.662	3.3307e-016

Remark: In the Dynamic Quantile Regression, p=7.

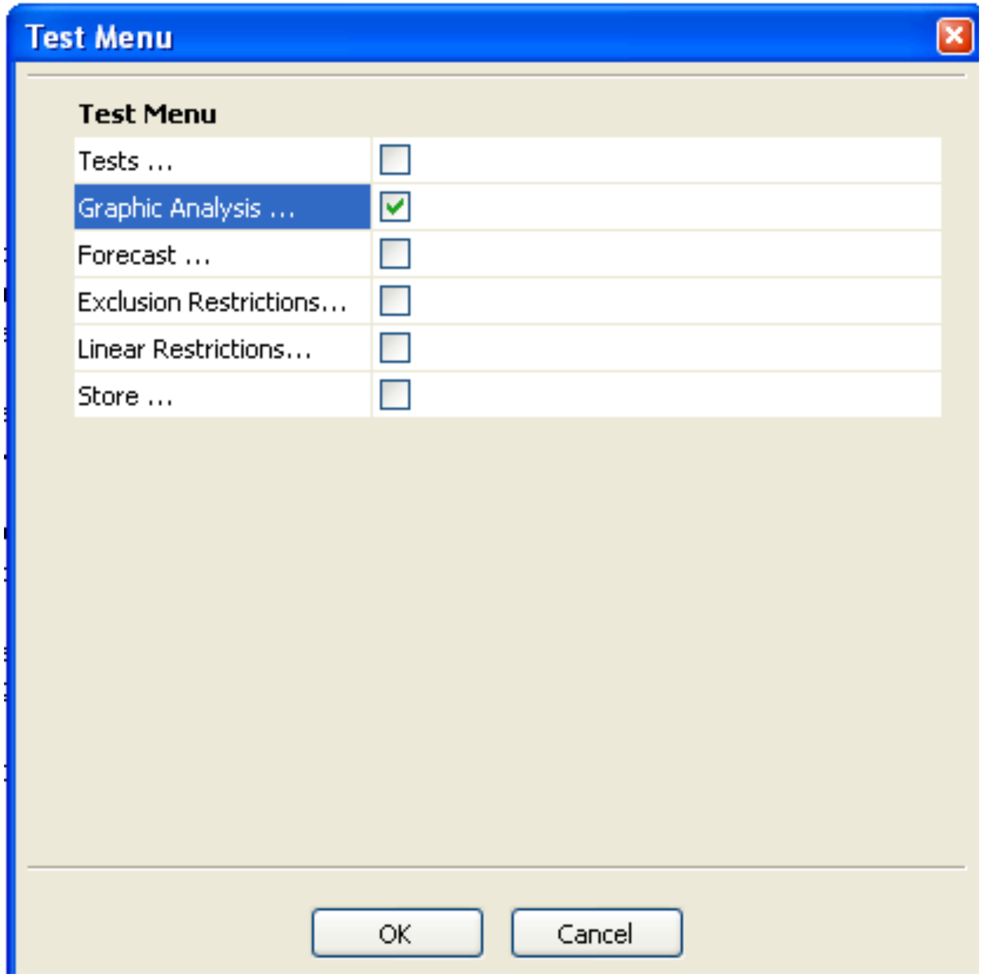
AR(1) GARCH(1,1) sk(t)



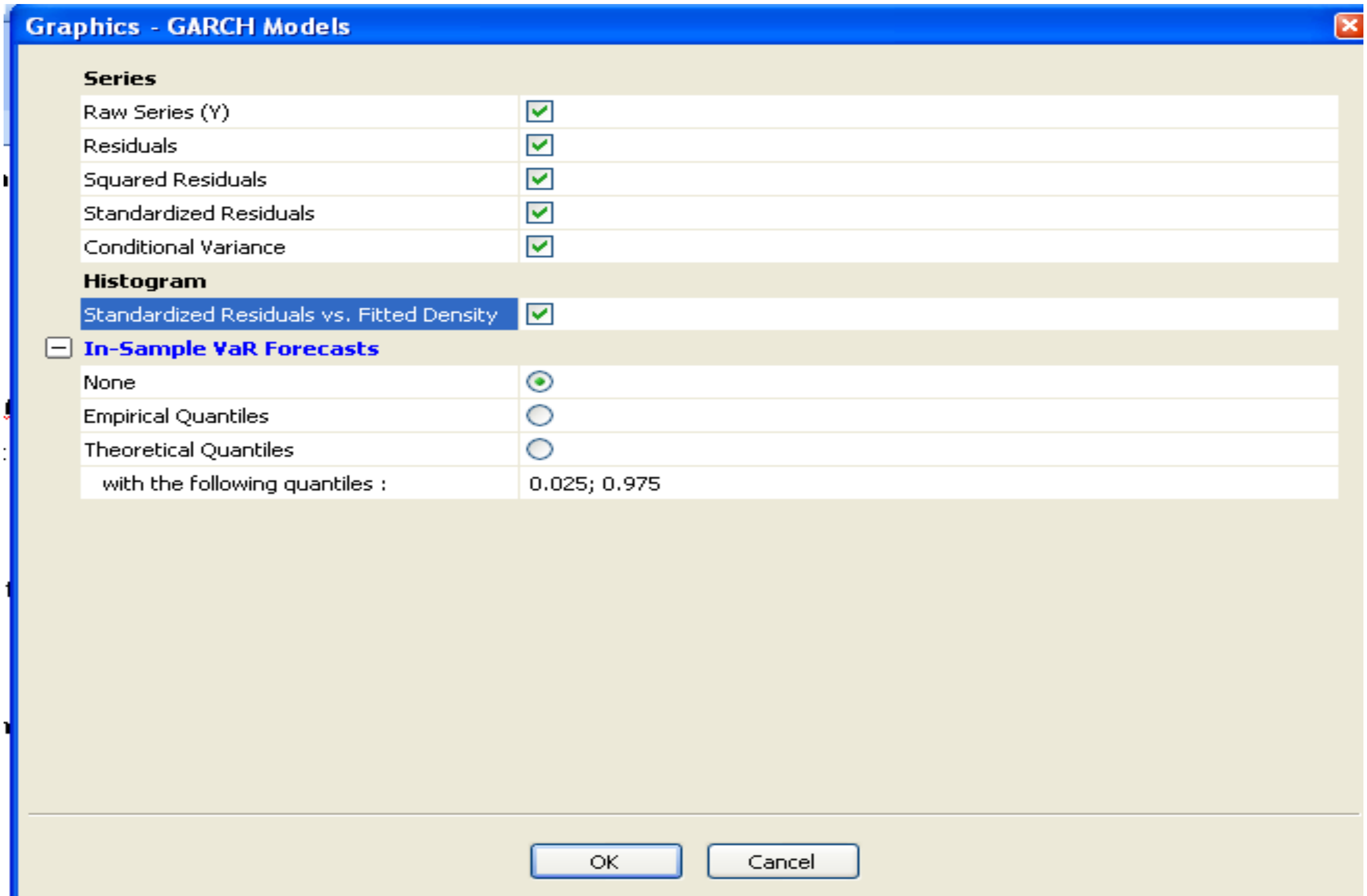
AR(1)-GARCH(1,1) sk(t) output

```
 ******************************
 ** G@RCH( 2) SPECIFICATIONS **
 ******************************
Dependent variable : Nasdaq
Mean Equation : ARMA (1, 0) model.
No regressor in the conditional mean
Variance Equation : GARCH (1, 1) model.
No regressor in the conditional variance
Skewed Student distribution, with 6.36561 degrees of freedom.
and asymmetry coefficient (log xi) -0.176807.

Strong convergence using numerical derivatives
Log-likelihood = -5228.77
Please wait : Computing the Std Errors ...

 Robust Standard Errors (Sandwich formula)
                  Coefficient  Std.Error  t-value  t-prob
Cst(M)               0.074547   0.013749    5.422  0.0000
AR(1)                0.172029   0.015928    10.80  0.0000
Cst(V)               0.013518  0.0041361    3.268  0.0011
ARCH(Alpha1)         0.135317   0.022145    6.111  0.0000
GARCH(Beta1)         0.862093   0.021804    39.54  0.0000
Asymmetry           -0.176807   0.022959   -7.701  0.0000
Tail                 6.365606    0.62455    10.19  0.0000

No. Observations :      4093  No. Parameters   :         7
Mean (Y)         :   0.05517  Variance (Y)     :   1.59189
Skewness (Y)     :  -0.74128  Kurtosis (Y)     :  14.25531
Log Likelihood   : -5228.772  Alpha[1]+Beta[1]:   0.99741

The sample mean of squared residuals was used to start recursion.
The positivity constraint for the GARCH (1,1) is observed.
This constraint is alpha[L]/[1 - beta(L)] >= 0.
The unconditional variance is 5.21841
The conditions are alpha[0] > 0, alpha[L] + beta[L] < 1 and alpha[i] + beta[i] >= 0.
  => See Doornik & Ooms (2001) for more details.
```

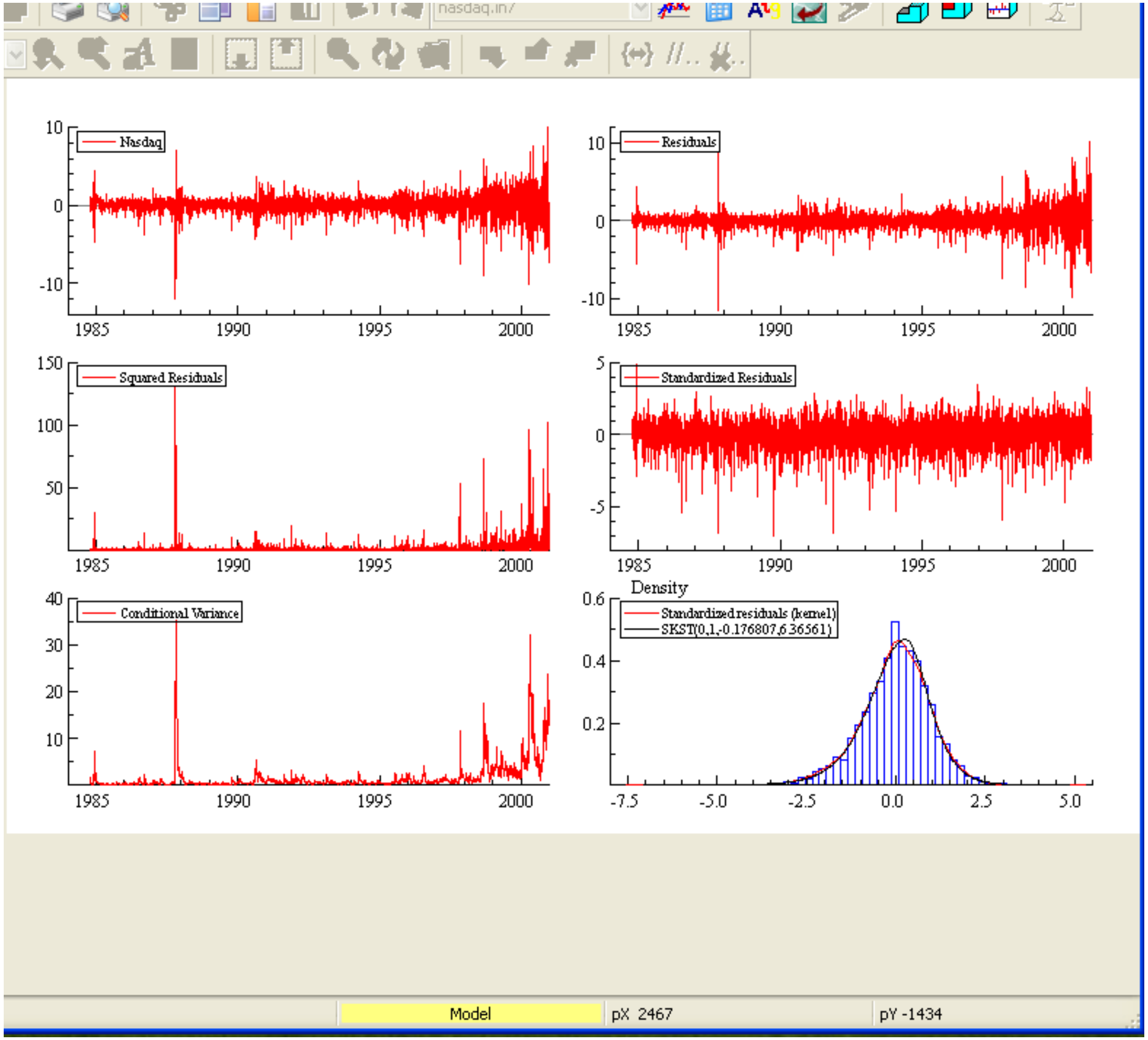
Graphical Analysis



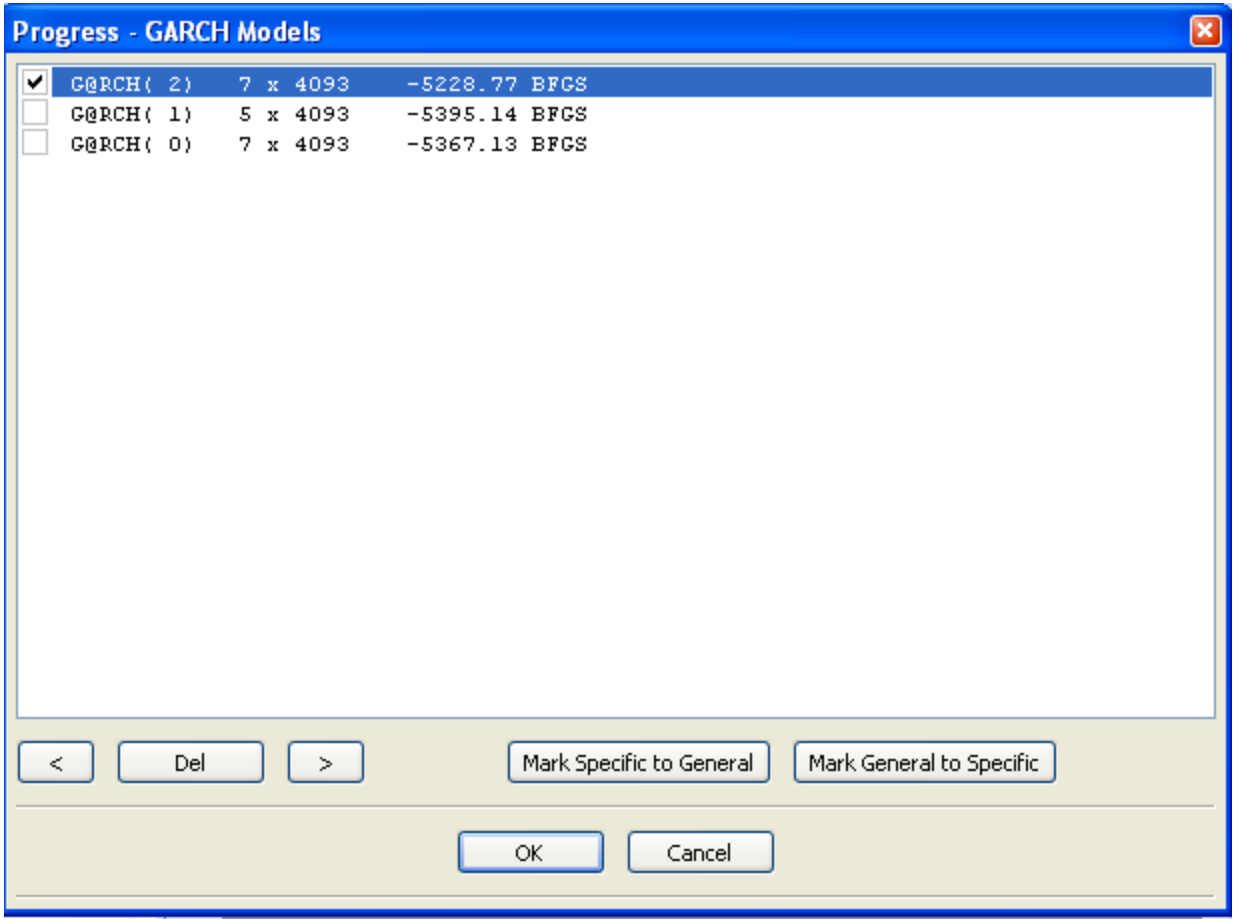
Graph selection



Graphical Output



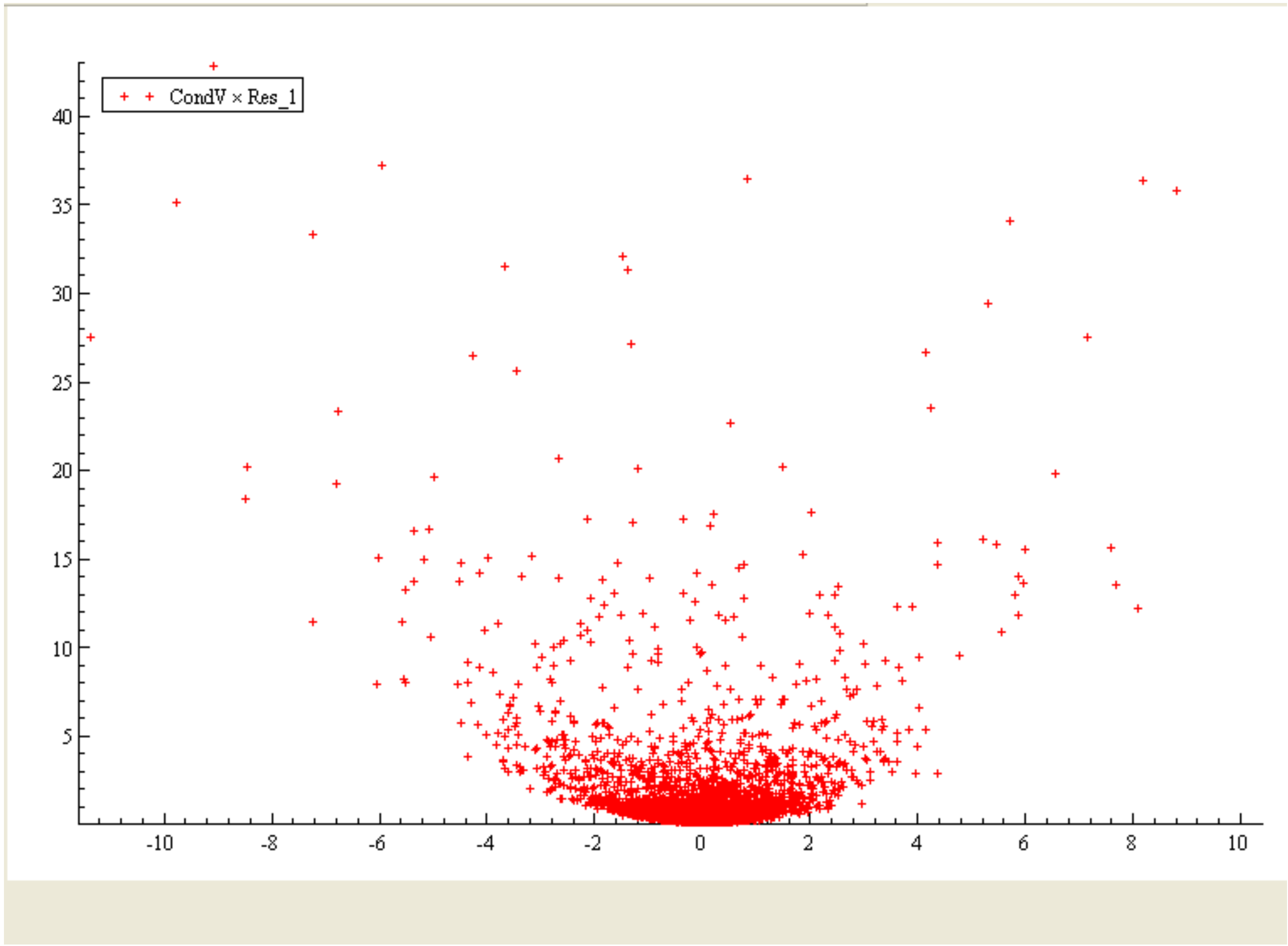
Model Comparison



Simulation of CEV confidence intervals

- Demonstrate Simulation of CEV confidence intervals

Volatility Smile



Asymmetry tests

- Sign bias tests
- Positive
- Negative
- Joint

GJR Asymmetric GARCH(1,1)

```
 ** G@RCH( 3) SPECIFICATIONS **
 ******************************
Dependent variable : Nasdaq
Mean Equation : ARMA (1, 0) model.
No regressor in the conditional mean
Variance Equation : GJR (1, 1) model.
No regressor in the conditional variance
Skewed Student distribution, with 6.54157 degrees of freedom.
and asymmetry coefficient (log xi) -0.17954.

Strong convergence using numerical derivatives
Log-likelihood = -5184.52
Please wait : Computing the Std Errors ...

 Robust Standard Errors (Sandwich formula)
                  Coefficient  Std.Error  t-value  t-prob
Cst(M)               0.062393   0.014353    4.347  0.0000
AR(1)                0.185970   0.016883    11.02  0.0000
Cst(V)               0.017264  0.0052401    3.295  0.0010
ARCH(Alpha1)         0.096650   0.015176    6.369  0.0000
GARCH(Beta1)         0.850005   0.023975    35.45  0.0000
GJR(Gamma1)          0.092444   0.030406    3.040  0.0024
Asymmetry           -0.179540   0.023111   -7.769  0.0000
Tail                 6.541571    0.66287    9.869  0.0000

No. Observations :      4081  No. Parameters  :         8
Mean (Y)         :   0.06050  Variance (Y)    :   1.55316
Skewness (Y)     :  -0.72562  Kurtosis (Y)    :  14.49309
Log Likelihood   : -5184.518

The sample mean of squared residuals was used to start recursion.
The condition for existence of the second moment of the GJR is not observed.
This condition is alpha(1) + beta(1) + k gamma(1) < 1 (with k = 0.588818 with this distributio
In this estimation, this sum equals 1.00109.
The condition for existence of the fourth moment of the GJR is not observed.
The constraint equals 1.12247 (should be < 1).  => See Ling & McAleer (2001) for details.
```

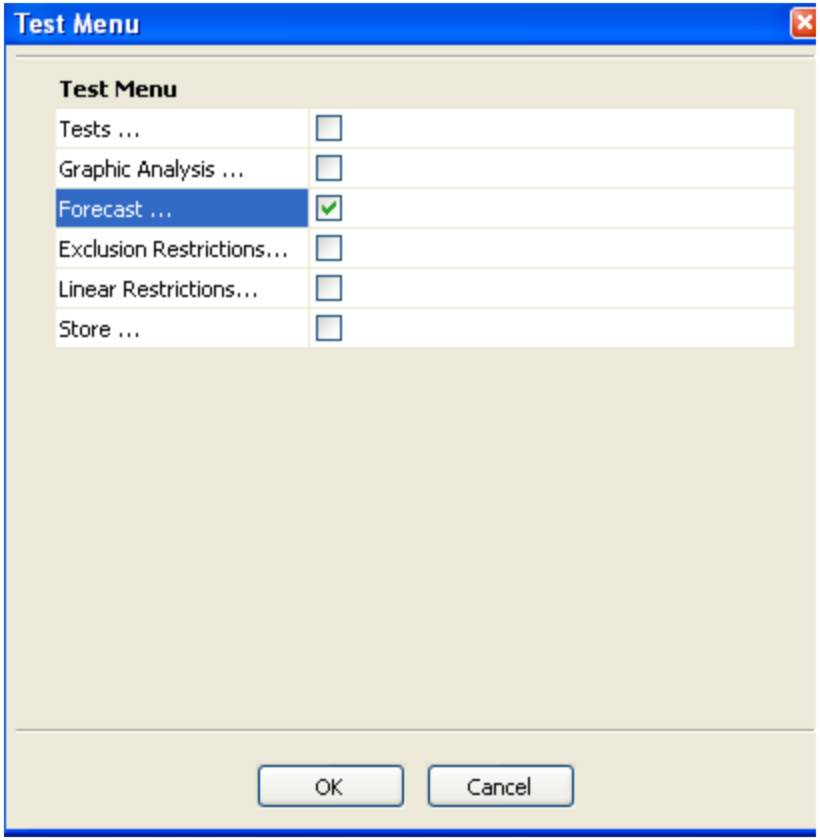
Model Comparison

```
Progress to date
Model              T     p          log-likelihood          SC           HQ          AIC
G@RCH( 0)       4093     7   BFGS       -5367.1337      2.6368       2.6298       2.6260
G@RCH( 1)       4093     5   BFGS       -5395.1442      2.6464       2.6415       2.6387
G@RCH( 2)       4093     7   BFGS       -5228.7723      2.5692       2.5622       2.5584
G@RCH( 3)       4081     8   BFGS       -5184.5175      2.5571<      2.5491<      2.5447<

Tests of model reduction (please ensure models are nested for test validity)
G@RCH( 0) --> G@RCH( 1): Chi^2( 2) =      56.021 [0.0000] **
```

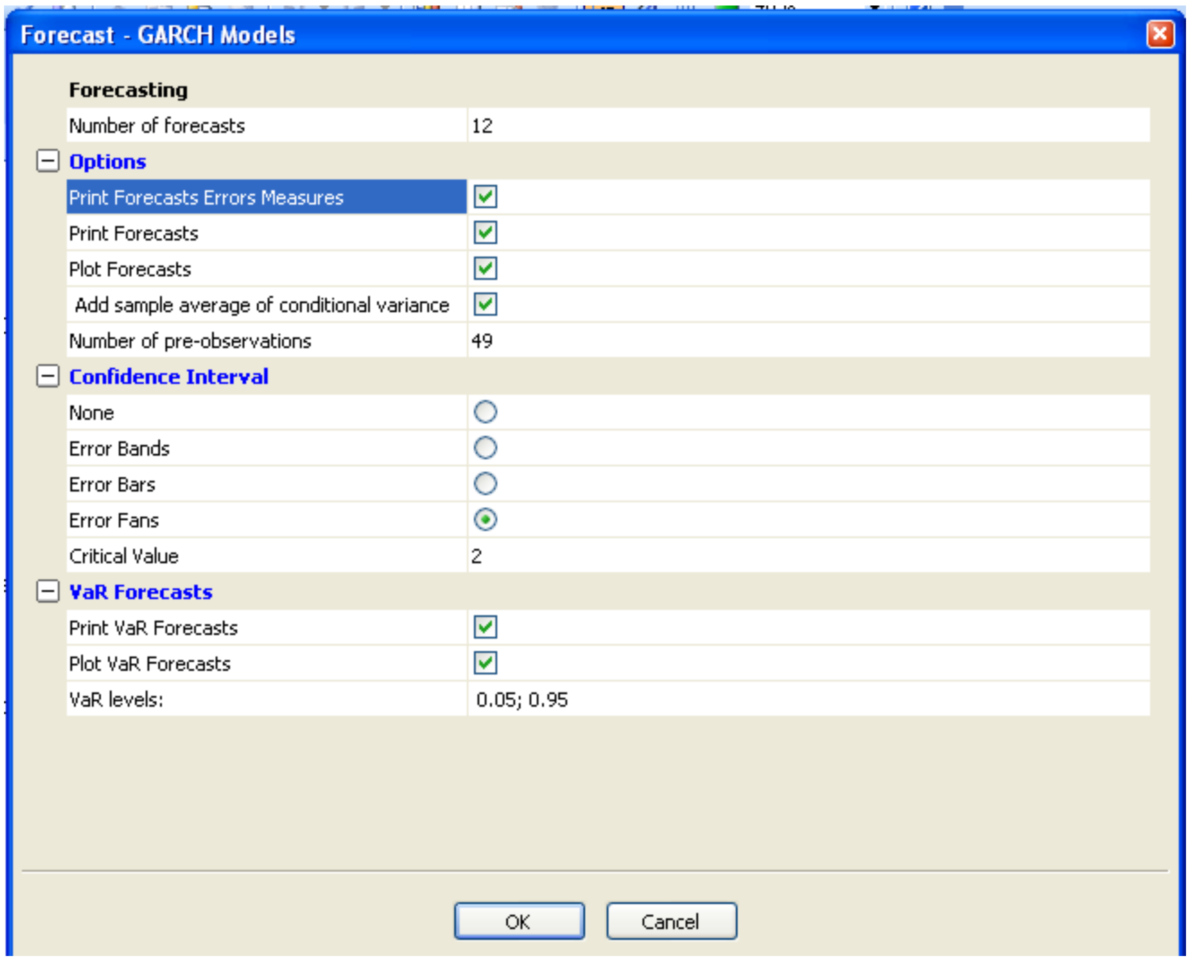
Forecasts

- Conditional mean, with confidence intervals
- Conditional variance
  - Intervals can be simulated
- VaR intervals serve as confidence intervals

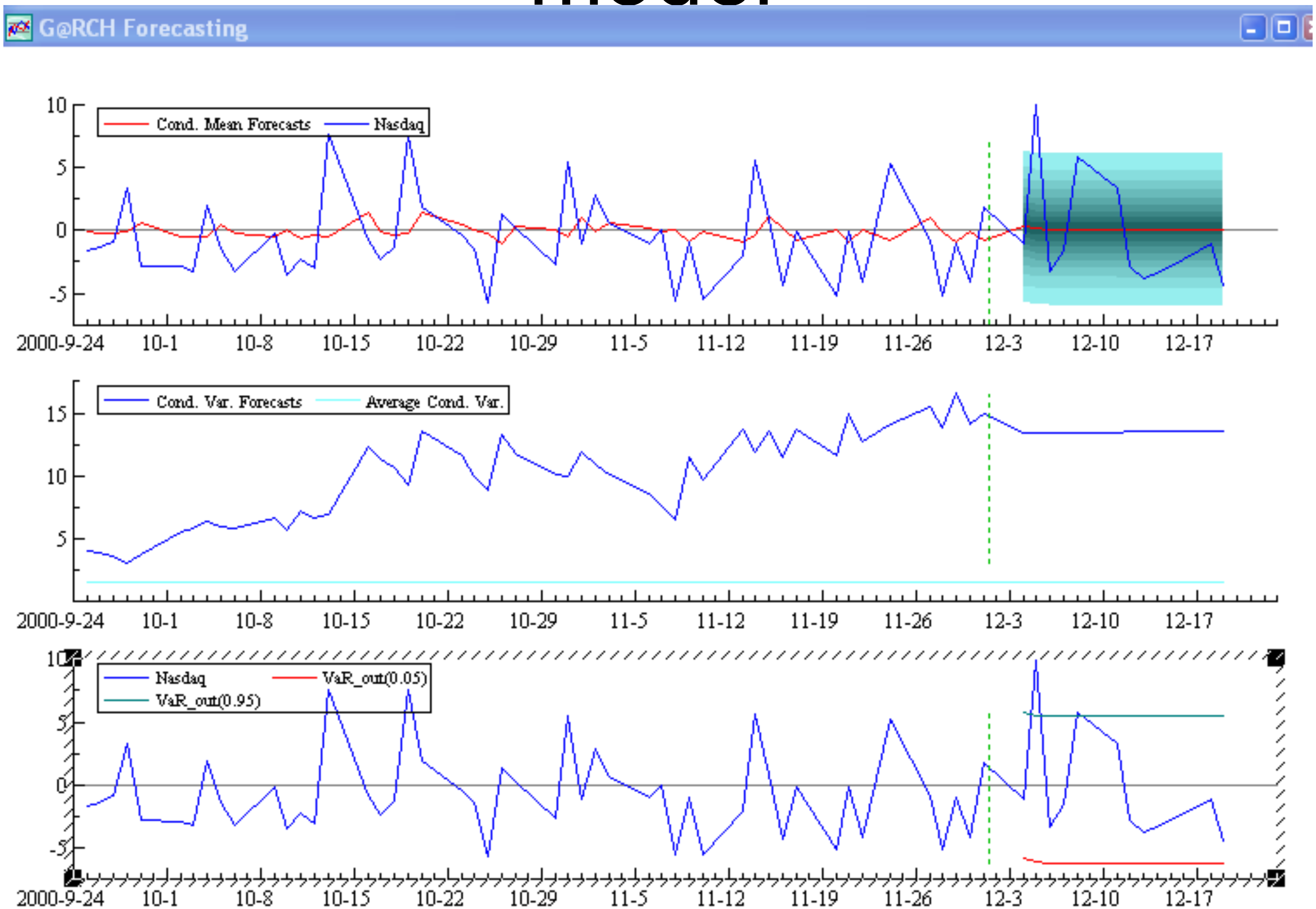
Click on the test icon



Forecast selection



Forecasts graphed from GJR model



Forecasts printed

```
  *******************
 ** VaR FORECASTS **
*******************
Number of Forecasts: 12

Horizon       0.05       0.95
      1     -5.716      8.482
      2     -7.222      6.989
      3     -7.508      6.717
      4     -7.567      6.671
      5     -7.584      6.668
      6     -7.594      6.673
      7     -7.601      6.679
      8     -7.609      6.685
      9     -7.616      6.692
     10     -7.624      6.698
     11     -7.631      6.705
     12     -7.639      6.711
```

Forecast Evaluation

Forecast Evaluation Measures

	Mean	Variance
Mean Squared Error(MSE)	18.41	674
Median Squared Error(MedSE)	10.85	33.91
Mean Error(ME)	-0.5271	4.921
Mean Absolute Error(MAE)	3.664	13.71
Root Mean Squared Error(RMSE)	4.291	25.96
Mean Absolute Percentage Error(MAPE)	.NaN	2.144
Adjusted Mean Absolute Percentage Error(AMAPE)	.NaN	0.3743
Percentage Correct Sign(PCS)	0.25	.NaN
Theil Inequality Coefficient(TIC)	0.9714	0.5777
Logarithmic Loss Function(LL)	.NaN	1.559

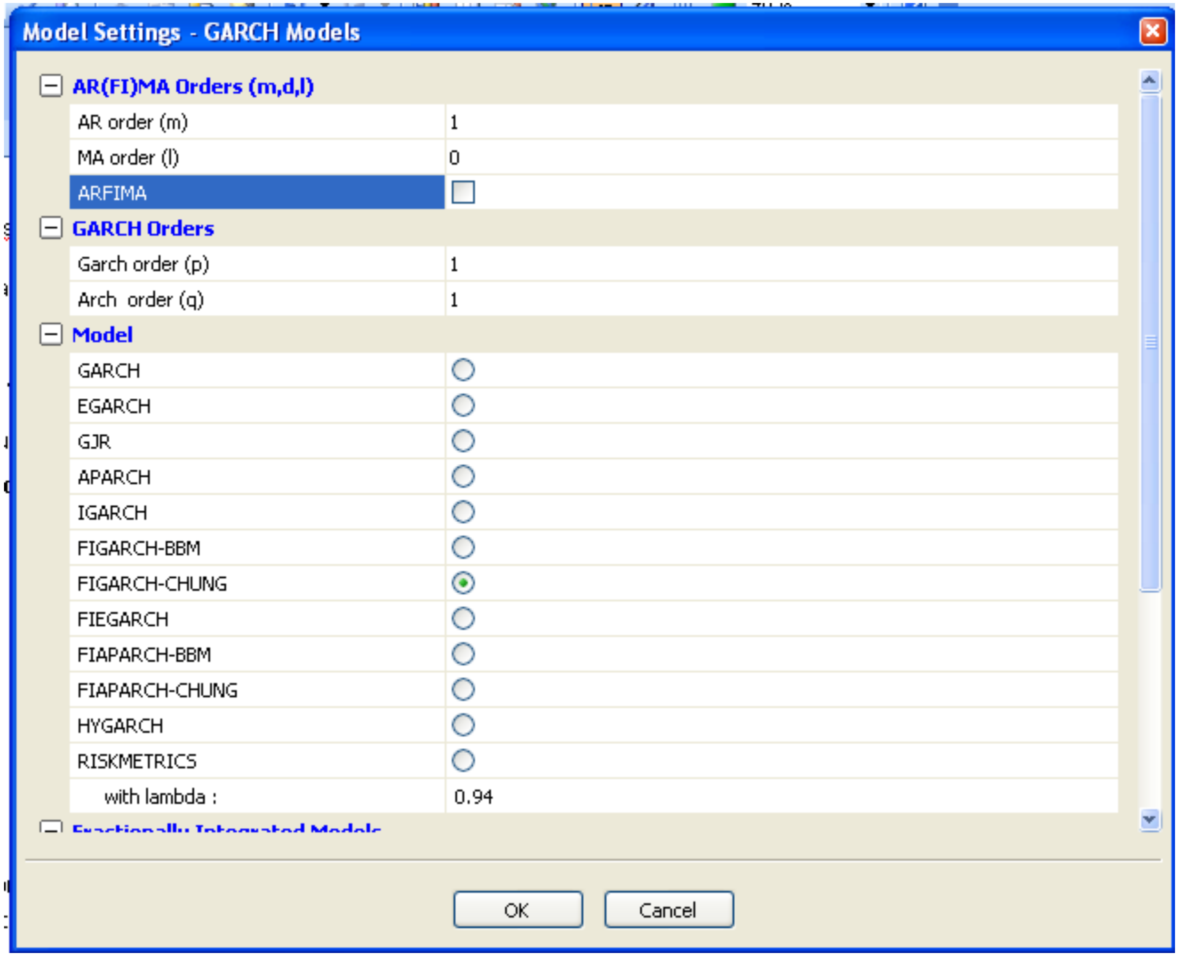
Long Memory Models

- APARCH
- FIGARCH-BBM
- FIGARCH-Chung
- FIAPARCH-BBM
- FIAPARCH-Chung
- FIEGARCH
- Davidson’s Hyperbolic GARCH

Long-Memory Models

- We run the basic descriptives test on it
  - And find that it has long memory with a GPH
  - d = .2885 with p = 0.0000.
  - Therefore we try a long-memory model.
  - A FIGARCH - Chung model

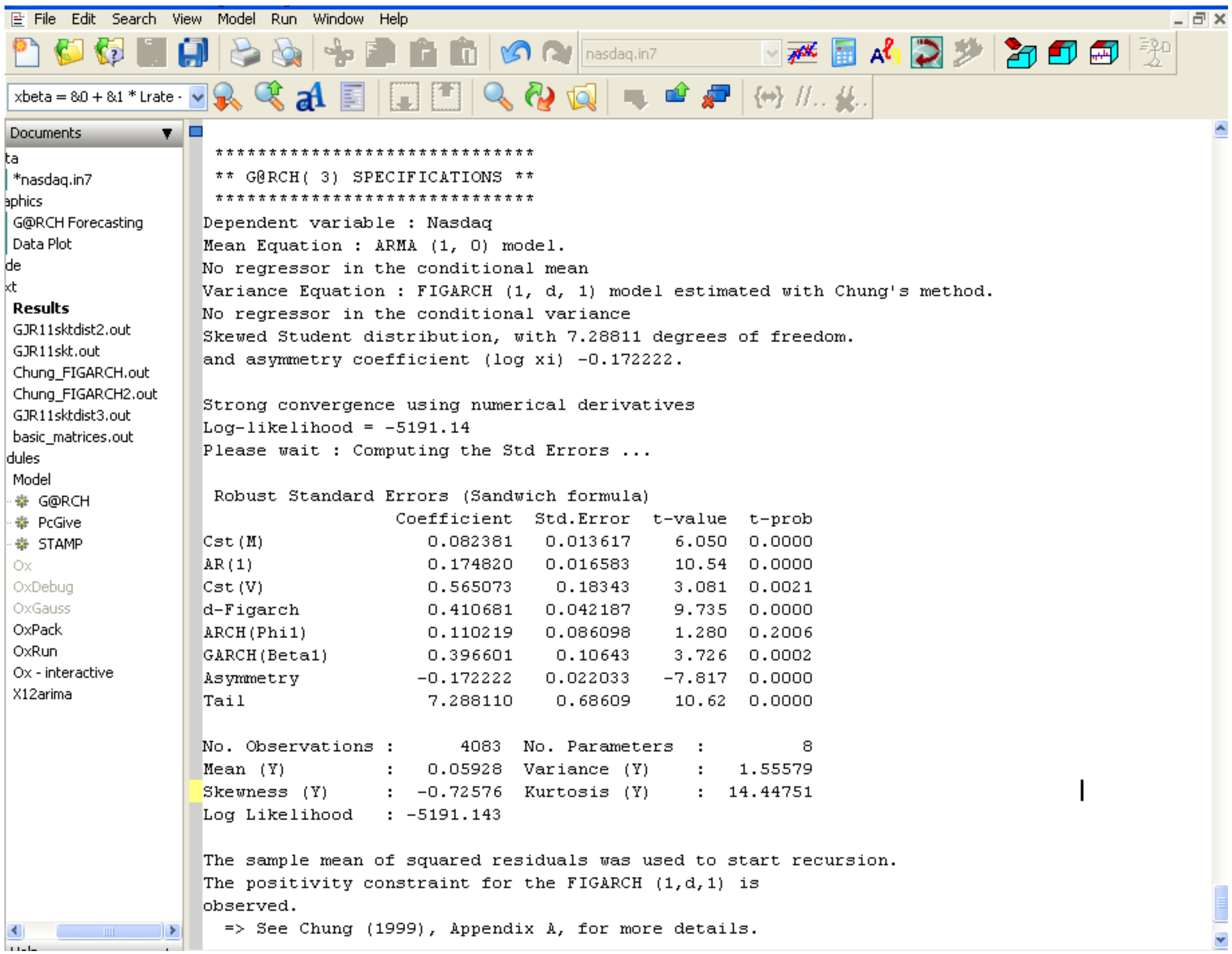
The Long Memory Model Menu



Chung’s Method

```
 ******************************
 ** G@RCH( 5) SPECIFICATIONS **
 ******************************
Dependent variable : Nasdaq
Mean Equation : ARMA (1, 0) model.
No regressor in the conditional mean
Variance Equation : FIGARCH (1, d, 1) model estimated with Chung's method.
No regressor in the conditional variance
Normal distribution.

Strong convergence using numerical derivatives
Log-likelihood = -5385.77
Please wait : Computing the Std Errors ...

 Robust Standard Errors (Sandwich formula)
                  Coefficient  Std.Error  t-value  t-prob
Cst(M)               0.088338   0.016143    5.472  0.0000
AR(1)                0.197900   0.018280    10.83  0.0000
Cst(V)               0.821616    0.27665    2.970  0.0030
d-Figarch            0.358937   0.048296    7.432  0.0000
ARCH(Phi1)           0.045390    0.16180   0.2805  0.7791
GARCH(Beta1)         0.240098    0.18513    1.297  0.1947

No. Observations :       4093  No. Parameters   :         6
Mean (Y)         :    0.05517  Variance (Y)     :   1.59189
Skewness (Y)     :   -0.74128  Kurtosis (Y)     :  14.25531
Log Likelihood   :  -5385.775

The sample mean of squared residuals was used to start recursion.
The positivity constraint for the FIGARCH (1,d,1) is
observed.
  => See Chung (1999), Appendix A, for more details.
```

Chung's Model after some trimming



Multivariate GARCH

- BEKK
  - Diagonal
  - Scalar
- RiskMetrics
- Factor GARCH
  - Carol Alexander’s OGARCH
  - GOGARCH

Conditional Correlation Models

- Bollerslev's Constant Conditional Correlation
- Tse and Tsui(2002) Dynamic Conditional Correlation
- Engle(2002) Dynamic Conditional Correlation

Outlier Modeling

- Mean model outliers
- Variance model outliers
- Cross-model outliers